Delivering improved resilience for Mongolian herding communities using satellite derived services

Case study for the SIBELIUS project in Mongolia supported by the UK Space Agency- International Partnership Programme

eOsphere, November 2021

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Executive summary

The SIBELIUs project has developed and delivered new technology which is providing improved pasture monitoring capabilities in Mongolia to support the country's large and economically significant herding community. Satellite Earth observation provides an efficient means for monitoring environmental parameters, such as pasture, snow and drought, over large regions, which can facilitate improved pasture management decisions and to allow preparations to be made as soon as problems are seen to be developing.

A lone Mongolian herder.

An important feature of the SIBELIUS project is that it has combined its technical solution with a series of initiatives to ensure the benefits from the technology are propagated outwards across the country to create improved resilience for herding communities. For a project being run in the UK but being delivered in a country on another continent, like Mongolia, it is vital to have a good understanding of the political and administrative landscape of a country. In SIBELIUS this background knowledge has been provided by a project team of UK and Mongolian partners, which already had technical experience working in Mongolia and which has many years working with the herding community.

At the heart of the SIBELIUS technical solution is the Mongolian Data Cube, which provides an efficient means for storing and accessing satellite data and derived products. The data archive in the Data Cube goes back to 2009 and is being added to all the time as new satellite data is automatically acquired and processed. The Mongolian Data Cube was developed by the eOsphere team in the UK in close consultation with staff from NAMEM (Mongolia's meteorological institute), where the servers hosting the Data Cube are now located. eOsphere first started working with NAMEM in 2007 when Dominic Flach installed a satellite ground receiving station on the roof of the NAMEM building, which continues to acquire data which feeds into a range of NAMEM's applications, including the SIBELIUS Data Cube. This history of collaboration provided an excellent platform to build the technical solution of the SIBELIUS project.

The wider engagement, which has been an important part of delivering the impacts from the satellite technology, was greatly assisted by Prof Caroline Upton from the University of Leicester and Dr Batbuyan Batjav from the Centre for Nomadic Pastoralism Studies. Both Caroline and Batbuyan have many years of experience working with Mongolia's herding communities and the many institutions and stakeholders who support them. This has helped the project to develop its technical solution in line with the genuine requirements of the herding community, and to ensure their feedback was heard by the UK-based project team.

Project overview

Mongolia, the herding community and dzuds

In Mongolia one of the main problems faced by herders, who, estimates suggest constitute approximately 30% of its population, are extreme weather events known as dzuds, which are highly damaging to Mongolia's economy and devastating for the poorest herders in particular. Dzuds are characterised by extreme winters often following on from dry summers, which adversely affected pasture growth, and prevented livestock from putting on sufficient weight to survive the cold and snow of a Mongolian winter. If drought conditions are followed by a particularly severe winter this can impact tens of thousands of herders, many of whom will lose most of their livestock leaving them in extreme poverty, with associated impacts for the wider economy.

The worst dzud of this century was in 2009-2010, when approximately 20% of the national livestock died. Recent research has shown that this dzud not only impacted on the livestock and the economy, but it also affected the development of children born in the worse dzud affected regions[1].

Dzuds are characterised by dry spring and summer conditions, leading to poor pasture. Followed by harsh winters.

Climate change

The frequency and severity of dzuds are being influenced by climate change, which is causing altered precipitation patterns and more frequent heat waves, leading to increased aridity and drought, reducing the reliability of pasture, and further impacting on herders and their livestock.

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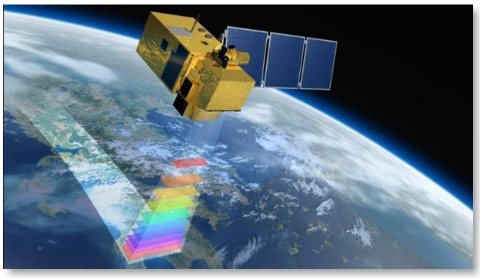
[1] Valeria Groppo, Kati Kraehnert, "Extreme Weather Events and Child Height: Evidence from Mongolia", World Development, Volume 86, 2016.

The changing climate is also leading to more frequent bursts of heavy rain leading to flooding. Before 2000, there were approximately 20 extreme events per year, but since 2000, this number has doubled to 40 events per year[2].

Satellite derived products

Satellite derived products can provide regular information about key parameters such as pasture, snow and drought, which are vital for building resilience for herding communities. The products from the SIBELIUS system can provide complete-country coverage and are provided more frequently and for longer periods of the year than is possible using only ground-based measurements.

One of the main advantages that satellites can provide is the ability to identify patterns of poor pasture developing across the country at a relatively early stage in the growing season. These patterns would be much more difficult to observe using a sparse network of ground-based pasture measuring stations, which is in any case an expensive undertaking in a large country like Mongolia with a small population.



The ability to identify snow with satellite Earth observation data is another important aspect of the SIBELIUS system. Snow plays an important role in the lives of the herding community, because very heavy snow in the winter, and especially snow that melts and refreezes, can hinder livestock from reaching pasture beneath it, adding to the problems which create dzud conditions. However, snow also provides an important source of water for livestock during the winter, so herders in particular regions do not usually migrate back to their winter shelter regions, until there is a good layer of snow on the ground.

The SIBELIUS project is providing satellite derived environmental information, which can play an important role for improved livestock management.

Pasture

Snow

Drought

The benefits of satellite Earth observation compared to ground-based techniques.

Country-wide coverage

More frequent updates for more of the year

Better accuracy

Better resolution

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[2] Report on the State of the Environment of Mongolia, 2008-2010, Ministry of Nature, Environment and Tourism.

The satellite data used by the SIBELIUS project are freely available, which means that Mongolian stakeholders will not need to pay to receive them into the future, thus increasing the sustainability of the system.

Impact and the UN SDGs

The project's impacts have been monitored and evaluated using the global indicator framework for the UN's Sustainable Development Goals. Specifically, SIBELIUs is targeting SDG-1 "No Poverty" and SDG-13 "Climate Action".

As a vital component of the project, SIBELIUS has been working with herders at selected test sites to understand how the project has helped in increasing their resilience. This is not an easy task to accomplish, partly because currently the main SIBELIUS information services have only been available for one growing season. Also, for the final year of the project, the pasture conditions in the project's test sites were relatively good, which meant the SIBELIUS products were not as critical as they would have been during a bad year for pasture. COVID 19-related restrictions on herders and on the SIBELIUs team's fieldwork with herders presented an additional challenge. However, the engagement with the herding community has been very valuable for several other reasons, including allowing the project team to analyse their information requirements, to better understand barriers to uptake of previous products, and to ensure their voices and priorities are heard in the development and distribution of new satellite-based environmental products.

Project partners

The SIBELIUS project was conceived, developed and led by eOsphere Limited, who are satellite Earth observation specialists based in Oxfordshire in the UK. eOsphere assembled the SIBELIUS consortium to ensure that the team had all the technical expertise required, but also, importantly to include experts (in the UK and Mongolia) to make sure that the benefits of the technical solution would reach the intended beneficiaries of the project, i.e., the Mongolian herding community. The full team is introduced below.

eOsphere Limited

eOsphere is a UK SME focused on earth observation applications and technology, with a successful track-record working around the world through the provision and maintenance of ground receiving stations; working with local teams to build operational systems to provide environmental information feeding into national services.

eOsphere's offices are located at the growing Space Cluster in Harwell in Oxfordshire.

Information and Research Institute of Meteorology, Hydrology and Environment

IRIMHE is one of the institutes at National Agency for Meteorology and Environmental Monitoring of Mongolia (NAMEM), with their headquarters in Ulaanbaatar.

NAMEM's key aim is to promote sustainable development and management of Mongolia's natural, human and economic resources, through the development and appropriate application of remote sensing and GIS technologies.

University of Leicester

The University of Leicester is a leading UK University and has been working with herding communities and policymakers in Mongolia since 2004 on issues of: Livelihoods and conservation, Environmental governance and justice, Climate change, adaptation and resilience, Grassroots activism, Institutional change.

Deimos Space UK

Deimos Space UK was created in 2013 to contribute to the UK and UK-export market for space systems, services and applications. It is located at the Space Cluster on the Harwell Oxford campus.

The company offers expertise in flight systems, ground segment systems, space situational awareness, satellite navigation, applications and services. The knowledge of satellites, data systems and location-based services puts the company in a unique position when developing satellite applications.

Micro-insurance Research Centre UK (MIRCUK)

MIRCUK has over 25 years' experience working on international micro-insurance projects with expertise in disaster risk financing and risk transfer options, index-based agriculture insurance (crop and livestock), product development, distribution channels, awareness raising, training and business plans in Asia, Africa and Latin America.

Mongolian Reinsurance (MonRe)

The "Mongolian National Reinsurance" JSC, based in Ulaanbaatar has been tasked by the Mongolian government with administering the Mongolian Index Based Livestock Insurance scheme (IBLI).

Center for Nomadic Pastoralism Studies (CNPS)

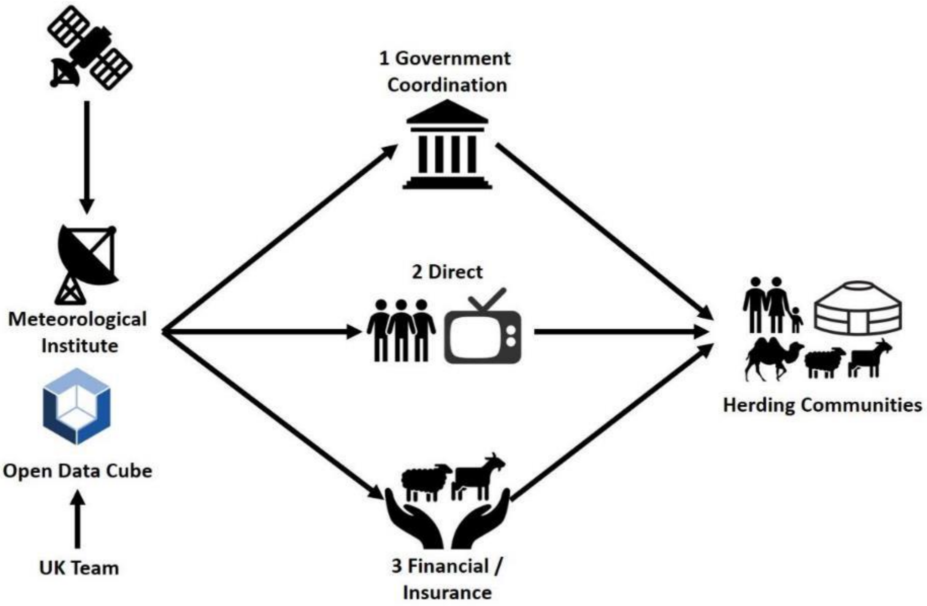
The Center for Nomadic Pastoralism Studies is an NGO based in Ulaanbaatar focused on development projects aiming to build resilience in nomadic herding populations in Mongolia.

Solution development/journey

Routes to impact

The figure below shows a schematic representation of the overall design of the SIBELIUS project. The key focus and intended beneficiaries are the herding communities, indicated on the right of the diagram. The main technical solution is shown by the left of the diagram. This includes the satellite Earth observation data, stored in the Mongolian Data Cube, which uses the Open Data Cube format, which is discussed in more detail in a later section. The Mongolian Data Cube has mainly been developed by the UK team and is hosted at NAMEM, Mongolia's meteorological institute. The satellite data can provide new information about important environmental parameters across Mongolia. However, this information is of no use to the herding community unless there are routes through which it can be channelled and unless it is targeted to their needs. For the SIBELIUS project, three "Routes to Impact" were identified at the beginning of the project, these being:

1. Government coordination: government agencies coordinating livestock and land use from national to local scales.
2. Direct: directly to the herders through social media and television broadcasts.
3. Financial/insurance: through finance and insurance sectors.



A schematic representation of the SIBELIUS's routes to impact.

Examples of Routes 1 and 2, are described in more detail in the "Results so far" section. The original intention for addressing Route 3 was to help the Mongolian Reinsurance company (MonRe) to improve their existing index-based livestock insurance scheme (IBLI), by using satellite data to help derive a more spatially precise index, which better reflected the hardships undergone by herders in a given year, i.e. by considering local pasture and snow conditions. It was not possible to make as much progress with this ambition as had originally been planned. However, a substantial body of research was conducted, which forms a firm basis for a new/ supplementary index in the future. Our key recommendations were also summarised in a White Paper which was circulated to MonRe and a number of other key institutions and which is discussed further in the "Results so far" section.

Understanding requirements

An important part of the design process for SIBELIUS were extensive consultations with stakeholders. This included discussions with institutions in Mongolia's capital, Ulaanbaatar, as illustrated below. MOFALI is the Mongolia Ministry of Food, Agriculture, and Light industry. The Inter Aimag Otor Reserve Group sits within MOFALI and was created to manage a series of otor reserves, to be accessed by herders in emergency situations, when dzud conditions are developing or ongoing.

Working with government and other institutions in Ulaanbaatar.

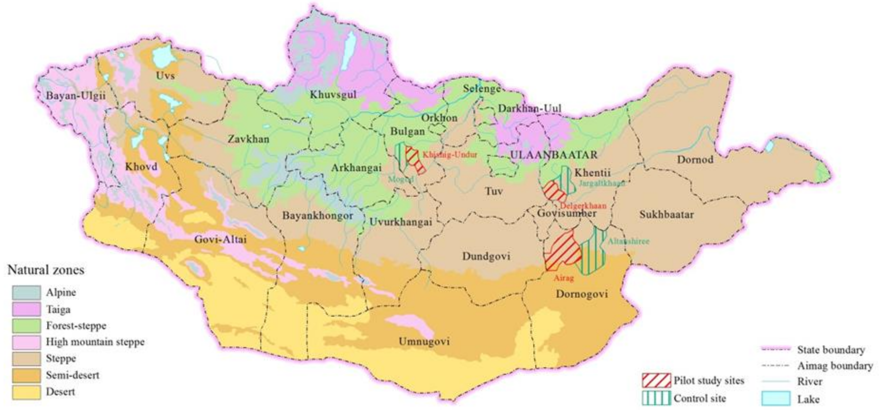
MOFALI Mongolian Reinsurance Land Management Agency Inter Aimag Otor Reserve Group

During the autumn months for each year of the project, Batbuyan Batjav from the Centre for Nomadic Pastoralism Studies visited the project's three test sites, to conduct interviews and surveys with the herders and local officials in those regions, initially to understand the herders' requirements and to identify the sources of information that they were typically using to make their herding decisions. Later, focus groups were held to trial SIBELIUs-derived pasture products with the herders. Specifically, herders were invited to provide feedback to help the project refine the draft products, in order to make them more informative and easier to use. This engagement with the herding community also formed an important component of the Monitoring and Engagement analysis which was designed to measure the impact of the project.

Three contrasting soums in different regions of Mongolia were selected as the project's test sites. The three test-site soums were selected:

1. To cover different climatic and ecological regions across Mongolia, which map onto degrees of dzud severity in recent events.
2. One soum (Delgerkhaan) was selected because of its proximity to one of the inter-aimag otor reserve regions, so herders' behaviour and experiences in relation to this initiative could be gauged.
3. The selection of a test site in the far west of Mongolia would have created substantial logistical challenges with associated costs, because of the large distances involved. So this was avoided, but without reducing the ranges of climate and ecology involved.

The selection of the three sites was taken in consultation with several of the project's in-country stakeholders, who each provided advice regarding regions which they would prefer to be used as test sites.

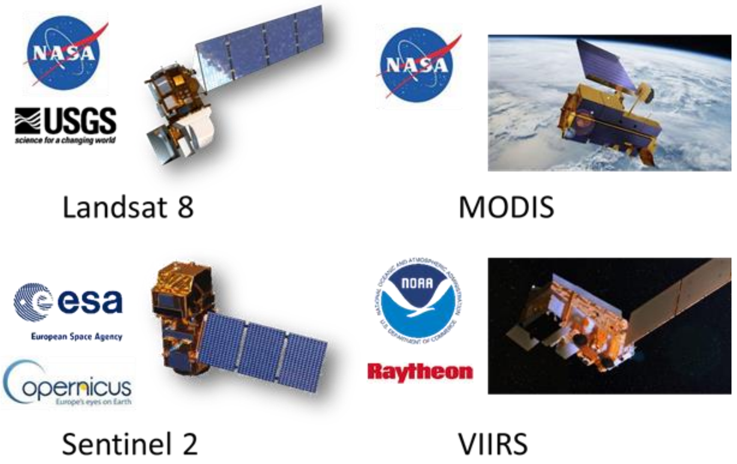


The SIBELIUS test sides are shown by the red cross-hatched regions.

The satellites

The satellites used by SIBELIUS can be divided into two types, higher and lower resolution. Landsat 8 and Sentinel 2 provide relatively high-resolution products (10-20 m) whereas Modis and VIIRS have lower resolutions (~250 m), but have much higher revisit frequencies, which means they have a greater opportunity for seeing through clouds, which is sometimes an issue in Mongolia.

Sentinel 2 and Landsat 8



SIBELIUS satellite data. Sentinel-2 (going back to 2015), Landsat 8 (going back to 2013), MODIS (going back to 2009), VIIRS (going back to 2012).

These are considered high-resolution satellites with pixel sizes of 10 m for Sentinel 2 and 30 m for Landsat 8. These satellites are designed to monitor the use of land, vegetation, forest, and water resources, as well as natural disasters.

The majority of the high-resolution products available through SIBELIUS are generated every 10 days, using the images acquired during the last month. New high-resolution images are acquired by the satellites every 5 days, however often the ground is obscured by cloud cover, which is why composite images are created using the best data collected over a monthly period. The first higher resolution products in the SIBELIUS archive are derived from data acquired in 2013. The optical (RGB) images used by SIBELIUS are derived using only Sentinel 2 images with 10 m pixels.

MODIS and VIIRS

These are considered as low-resolution satellites with a maximum resolution of 250 m for MODIS and 375 m for VIIRS. The lower resolution SIBELIUS products are produced combining data from MODIS and VIIRS together. One of the advantages of these satellites is the higher frequency with which they acquire images compared to the higher resolution satellites. There are 3 images per day from MODIS and from VIIRS. All the products are generated every 10 days, and their exact resolution depends on the specific product.

The Mongolian Data Cube

The Mongolian Data Cube is a key component of the SIBELIUS infrastructure which allows multiple time series of satellite data and derived products to be queried by the project’s partners. Output products, for example relating to pasture and snow, from the Data Cube can be ingested by desktop applications, web apps and dashboard front ends for stakeholders to integrate into their workflows.

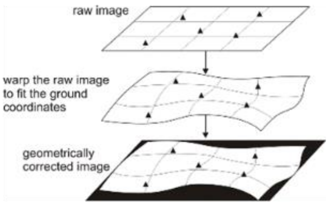
OPEN
DATA
CUBE

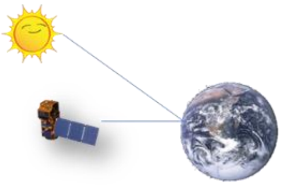
In 2021 the Mongolian Data Cube contained 95.1 TB (Terabytes) of data and is growing at 17.8 TB per year.

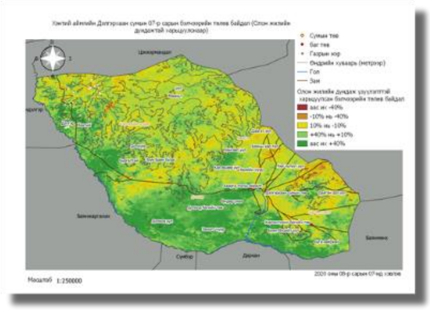
The Mongolian Data Cube is sited at the Information and Research Institute of Meteorology, Hydrology and

Environment (IRIMHE) at NAMEM (equivalent to the Met Office) in Ulaanbaatar.

The architectural framework for the Mongolian Data Cube was originally pioneered by Geosciences Australia in 2013, with the Digital Earth Australia. Since then, Open Data Cubes have been built to serve many countries around the world, including the continent wide, African Data Cube initiative being led by the Digital Earth Africa consortium. In addition to providing free access to the software, Open Data Cube[3] also provides a community, where interested researchers can share ideas and help each other to solve problems. This freely available resource is another feature which will help the long-term sustainability of the Mongolian Data Cube.







The processing chain that transforms the initially downloaded satellite data into useful products has several stages. The first stage is to generate the analysis ready data, which includes removing or masking unwanted atmospheric effects. The next stage is to generate several intermediate indices, from which a range of pasture and snow products are produced on regular cycles throughout the year

The Mongolian Data Cubes will allow for the rapid expansion in the use of satellite data, including unforeseen applications that might be stimulated once different user groups see what data and resultant information is available.

The SIBELIUS Visualisation Website

There are several different ways to access data and information from the Mongolian Data Cube. However, the simplest is by using the SIBELIUS Visualisation Website. The Visualisation Website was designed to be as simple to use as possible, so that end users with no background in satellite technology can access information they may need for making decisions relating to herding. These end users could be working in government departments, such MOFALI who might need to make national decisions to alleviate large scale problems, or they could be local officials, who need information to pass on to herders in their region or to use the information in their pasture management planning.

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[3] https://www.opendatacube.org/

An overview of the main products available on the Visualisation Website is provided below.

Optical (RGB)

The RGB product is a combination of the satellite's red, green and blue bands which produces an optical image of what the Earth's surface looks like from the satellite.

A cloud mask is applied to each image acquired, and the least cloudy images from a given time window are used to form a composite image. In theory the resultant optical images should not contain any visible clouds. However, it may sometimes be possible to see features in the images due to small imperfections from the cloud mask algorithm and solar illumination.

Vegetation Index (NDVI) (Normalized Difference Vegetation Index)

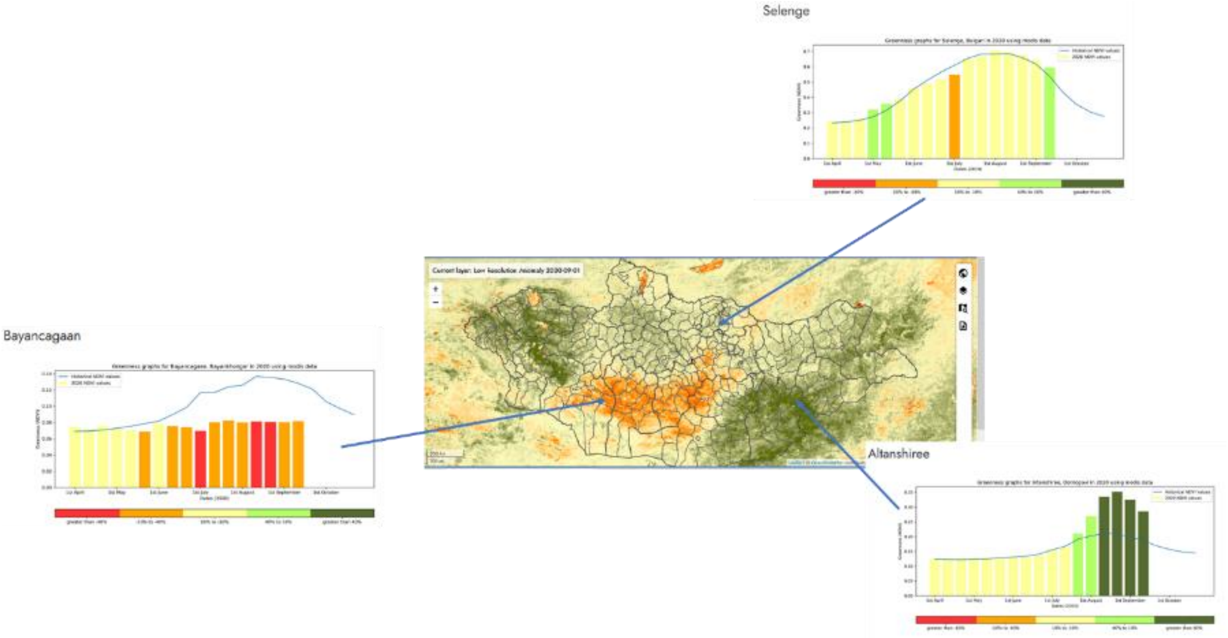
The Normalised Difference Vegetation Index (NDVI) measures how much green vegetation is present on the ground. The index is calculated by the absorption and reflection of the red and near-infrared bands by the chlorophyll within plants.

The NDVI is scaled between-1 and 1, with 1 describing very high levels of vegetation and 0 describing no vegetation at all (bare land). Values less than 0 are usually water, snow, cloud or other non-vegetative phenomena.

Pasture Anomaly

The Pasture Anomaly product compares the pasture biomass at a given time (usually the current time) to the historic time-averaged pasture biomass value at the same time of year. It therefore shows whether the current pasture is better or worse than average for a given region and time of year. It is expressed as a % deviation from the historical average. We colour the resultant image products, so that better than average regions are coloured in shades of green and regions worse than average are shades of orange and red, while average conditions are yellow.

The pasture anomaly product below shows the pasture conditions from the summer of 2020, where it can be seen there is a large red region in the central southern region, which indicates significantly worse pasture than normal. It can also be seen that the northwest and southeast and regions are significantly better than average. The figure also shows three "greenness graphs", which are also available from the Visualisation Website. These show the progression of the NDVI (therefore indicating pasture quality) throughout the season for individual soums, as indicated by the columns. These current conditions can be compared to the average for the last 10 years which is indicated by the blue line. The bars are coloured using the same scheme as the map product, i.e. red and orange for worse conditions than average and green, better than average.



The central image shows a pasture anomaly product from September 2020, with three “greenness graphs” which are available from the SIBELIUS Visualisation Website

Pasture Biomass

The Pasture Biomass product is the conversion of NDVI data to pasture biomass in kg/ha using an equation obtained comparing NDVI with ground measurement data. This should only be considered as an indication of the amount of pasture biomass that is present on the ground, because there are various ways in which inaccuracies can occur. For this reason, the SIBELIUS team have tried to promote the use of the pasture anomaly product as the most reliable indication of pasture conditions, because it is a relative measurement (comparing current to a historical average) rather than being dependant on the accuracy of the relationship between the satellite measurements and the biomass of the pasture on the ground.

Pasture Trend

The Pasture Trend product compares the pasture biomass values for a given time period to the previous time period.

Snow Percentage

The Snow Percentage product an estimation of the percentage of snow in a pixel for the time period considered. For example, if the snow percentage is 50, it means that there was snow for 50% of the time.

NDDI (Normalized Difference Drought Index)

The Normalised Difference Drought Index (NDDI) is a combination of NDVI (vegetation) and NDWI (water content), and it is used to determine the level of drought in a specific area.

The index is scaled between -∞ and ∞, where low positive values indicate no drought conditions and high positive values indicate drought conditions. Negative values generally indicate areas which don't correspond to pasture, due to having either a negative NDVI or NDWI value.

VHI (Vegetation Health Index (VHI))

The Vegetation Health Index (VHI) combines the TCI and VCI to create a drought index which uses information both about the vegetation levels and temperature.

NDWI (Normalized Difference Water Index)

The Normalized Differential Water Index is used to monitor changes of water content in leaves, using infrared and shortwave infrared bands.

The index is scaled between-1 and 1, where values less than 0.3 indicate no water being present and values greater than 0.3 indicate the presence of water. Usually, green vegetation has values between-0.1 and 0.4.

VCI (Vegetation Condition Index (VCI))

The Vegetation Condition Index (VCI) is an indicator of the current status of the vegetation relative to the historical values.

VCI values range from 0 to 1, reflecting changes in vegetation conditions, from dry to wet. For VCI greater than 0.7 the vegetation is in good condition, values between 0.3 and 0.7 reflect moisture conditions close to normal, while values less than 0.3 signal that vegetation is in a stress state or drought condition.

Sustainability model

The SIBELIUS sustainability plan was built on three main principles, as discussed below.

Working with Mongolia's meteorological institute

One of the main reasons for working with NAMEM, who are Mongolia's meteorological institute, is that they have a responsibility to provide services to protect Mongolian citizens, the environment and the economy. Therefore, running the SIBELIUs service into the future, beyond the lifetime of the UKSA funded project fits within NAMEM's existing remit as a part of the suite of services, such as regular weather forecast bulletins, it provides supported by funding from the state. Therefore, the continuation of the SIBELIUS service is not dependent on the herders or local governors themselves paying for the service they receive. NAMEM are also staffed by a highly trained workforce, many of whom have PhD-level qualifications.

Free data and free software

A key part of the SIBELIUS sustainability plan was to create a solution that will be very inexpensive to run in the future. This is possible by using satellite data sources that are free to access and use. The data from these satellites are ideal for obtaining information across the Mongolian rangelands, so nothing would be gained by accessing expensive higher resolution satellite data. In addition, by using open source software, which has formed the core of the Mongolian Data Cube architecture, this provides a resource that is free to use without licenses. Furthermore, the Open Data Cube community can provide a valuable learning resource for the in-country partners.

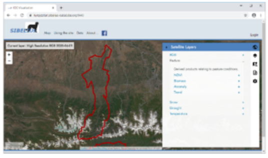
The Mongolian Data Cube is hosted on physical servers, which means there are no future charges for cloud computing and storage services.

Training and sustainability

SIBELIUS has conducted a series of technology training workshops, to ensure that Mongolian stakeholders are best placed to benefit from the new satellite technology. In-country training and Jupyter notebooks have been developed focused on skills required to exploit and maintain Open Data Cubes, using Python software.

Several different levels of training have been provided, which has been tailored to the requirements and pre-existing skills of the trainees.

The SIBELIUs Visualization system

	For **visualizing** satellite imagery and products	For everyone, including local officials countrywide meteorologists & citizens	Little or no training required
WMS (Web Map Service)	For **visualizing** satellite imagery and products	For casual users	Instructions required and some assistance where necessary
WCS (Web Coverage Service)	For **analysis** with satellite imagery and products	For expert users	
Python	For **developing** new products and maintaining the Data Cube into the future	For developers …	Python training required

Results so far

One of the first tasks completed in the SIBELIUS project was to define a locally relevant set of resilience metrics that would help us understand whether the project had genuinely created positive impact for the herding community; the overall objective of the project. Measuring resilience in rural populations is acknowledged to be a difficult problem. Our approach was led by Prof Caroline Upton from the University of Leicester, UK and Dr Batbuyan Batjav from CNP, Mongolia and incorporated the latest thinking on this topic. In this Results section we firstly present an overview of the findings from this approach. In the following subsections, we present other highlights where the project has created impact.

The final subsection presents some work on how the SIBELIUS project has helped with conservation efforts for the saiga antelope in Mongolia. This is a significantly different application to that of supporting the herding community, but it demonstrates that satellite Earth observation can stimulate applications in areas not previously considered. The intention is that the SIBELIUS project, including the Mongolian Data Cube and the environmental information it provides, should stimulate further applications and services to help build the Mongolian economy, protect its environment and serve its citizens.

Monitoring and evaluating resilience

At the start of the project, we set ourselves the challenge of improving the resilience for at least 10% of the herders in our three test sites. To understand if this had been achieved the herders' resilience was measured both at the start and end of the project, with Baseline and Endline surveys, which were then compared. Measuring resilience is not a simple task and is frequently discussed in academic circles. One point which is often emphasised is that there is no “one size fits all” metric that can be applied to all communities worldwide. The metric used in SIBELIUS was developed with the Mongolian herding community in our case study sites, considering their lifestyle and challenges such as dzuds, which can be damaging for their livelihoods.

The project's resilience metric was based primarily on herders' self-reported abilities to cope with changing pasture conditions and weather-related shocks and stresses, on their resilience or coping strategies and the proportions of positive or negative dzud preparation, management and recovery strategies (Endline 1 in the table below), and with the addition of changes in livestock losses to the metric to give Endline 2.

After the analysis comparing the Baseline and the Endline survey data, it was possible to conclude that SIBELIUS has partially achieved its impact targets. Specifically, the target of 10% of households showing increase in resilience against baseline, has been achieved in full and exceeded, as highlighted in the table below which presents data from Endline surveys that were conducted in March 2021 and at the end of the project extension in October 2021. There were two Endline surveys, because the original end date for the project was March 2021, but it was necessary to extend this by 7 months because of problems caused by the COVID-19 pandemic.

In evaluating these data, it is important to note that it is changes in scores against the Baseline that are important, rather than the actual figures themselves.

Changes in Resilience between Baseline and Endlines (% of Households).

SITE	March 2021: Endline 1			March 2021: Endline 2			October 2021: Endline 1			October 2021: Endline 2		
	No change	Decrease	Increase	No change	Decrease	Increase	No change	Decrease	Increase	No change	Decrease	Increase
Airag soum	22.7	27.3	50	27.3	50	22.7	-	-	-	-	-	-
Sain Us bag	15.4	30.8	53.8	38.5	38.5	23.1	-	-	-	-	-	-
Nart bag	33.3	22.2	44.4	11.1	66.7	22.2	-	-	-	-	-	-
Delgerkhaan soum	17.2	37.9	44.8	13.8	37.9	48.3	0	7.1	92.9	14.3	14.3	71.4
Kherlenbayan Ulaan	14.3	42.9	42.9	14.3	50	35.7	0	0	100	0	20	80
Kherlentoono bag	20	33.3	46.7	13.3	26.7	60	0	11.1	88.9	22.2	11.1	66.6
Khishig-Ondor soum	16.7	27.8	55.6	5.6	16.7	77.8	13.3	6.7	80	0	13.3	86.7
Teeg bag	0	30	70	10	10	80	0	12.5	87.5	0	25	75
Khuremt bag	37.5	25	37.5	0	25	75	14.3	0	85.7	0	0	100
Whole Dataset	18.8	31.9	49.3	15.9	36.2	47.8	6.9	6.9	86.2	6.9	13.8	79.3

The data indicates an overall increase in resilience for the October 2021 Endline sub-sample of herders against the initial Baseline figures, with the percentage of households showing improvement also increasing markedly by comparison with the March 2021 Endline. However, these figures need to be treated with caution and it should be noted that these changes cannot be solely attributed to SIBELIUs. For example,

And as highlighted above, the Endline 1 and Endline 2 metrics differ in that the latter also incorporates the percentage changes in livestock losses against Baseline losses. For both case study areas, herders reported good weather and pasture conditions over the preceding year, which for many households will have experienced decreases in livestock losses, which will have impacted primarily on the Endline 2 metric, independently of SIBELIUs products and activities.

Other aspects of resilience for which positive changes were noted in October 2021, and which impact on both Endline 1 and 2 metrics, is with respect to herders' self-reported resilience and ability to cope. A number of factors were highlighted as significant here by respondents, notably information provision, linked to improved TV weather forecasts. Social media such as Facebook were also highlighted as important for obtaining information, with awareness of SIBELIUS products apparent amongst herding populations in both case study areas. Improving access to 4G services in some more remote areas (e.g. Teeg bag) is also expected to increase knowledge and uptake of SIBELIUs in the future.

Net dzud strategies scores, a core part of the composite resilience metric, also showed improvement for 82.7% (n=29) of respondents overall, with increasing proportions of positive as opposed to negative strategies. These enhanced positive strategies typically took the form of putting greater emphasis on hay and fodder preparation for the winter and on the repair of winter shelters for livestock.

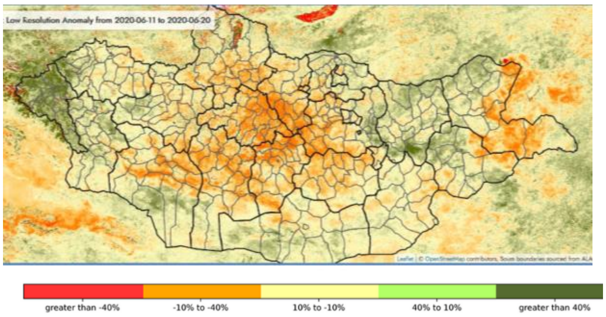
In evaluating these results, it should be noted that respondent numbers in October 2021 are relatively low compared to the Baseline, due primarily to the continuing impacts of COVID-19 and associated access restrictions to study sites and participating households. This smaller dataset, combined with a lack of opportunity to undertake more in-depth discussions, have continued to present challenges in isolating the impact of SIBELIUs. That said, marked improvements in resilience are evident and herders highlighted enhanced information provision as significant in respect of these changes.

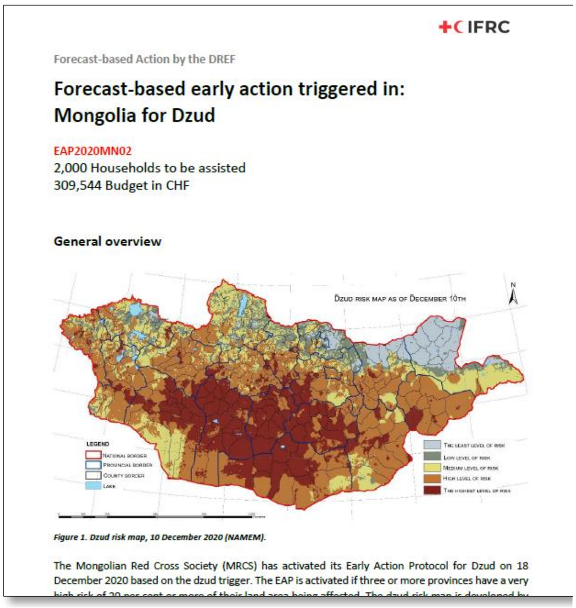
For herders, the recent favourable weather and pasture conditions have also affected the perceived need for SIBELIUs products during 2021, although there is a recognition of their potential importance in times of dzud in the future. Results for October 2021 therefore indicate that dissemination and awareness of SIBELIUs products and their potential utility has improved amongst herders since the March 2021 Endline, as well as by comparison with the original Baseline. These products are seen as being important in future dzud and adverse conditions. There is therefore the prospect for well-placed SIBELIUs products to have even more significant impact in the future, for herders directly as well as via other routes such as through soum and bag officials.

Highlighting pasture problems

One of the main aims of the SIBELIUS system was to detect problems with pasture growth as soon as possible, so effective mitigation measures can be implemented as soon as possible. During 2020, while many of the technical aspects of the SIBELIUS system were still being implemented, there was a significant drought in spring and early summer for a large region in the south-central region of Mongolia. Unfortunately, although the project team were able to see these problems developing, at this stage we had not fully established the network to distribute information to key stakeholders.

The figure below shows the pasture anomaly from June 2020, i.e. showing how the pasture at this time compared to the long-term average for the same time of year. The large orange/red region shows considerably worse pasture conditions than normal. The large extent of this region was particularly worrying because while small scale pasture problems can be accommodated by herders going on otor to find better pasture, when such a large region is experiencing problems, this is harder to manage.





IFRC

Forecast-based Action by the DREF

Forecast-based early action triggered in: Mongolia for Dzud

EAP2020MN02
2,000 Households to be assisted
309,544 Budget in CHF

General overview

Figure 1. Dzud risk map, 10 December 2020 (NAMEM).

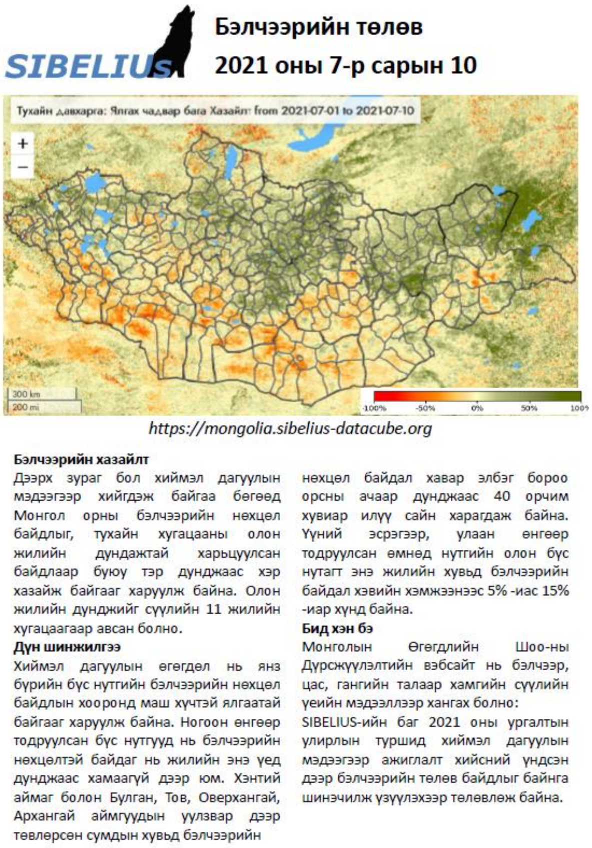
The Mongolian Red Cross Society (MRCS) has activated its Early Action Protocol for Dzud on 18 December 2020 based on the dzud trigger. The EAP is activated if three or more provinces have a very

The image above shows the pasture anomaly product from June 2020, highlighting (orange/red) regions with worse pasture than normal. On the right is the Red Cross alert which was issued in December 2020.

This figure also shows a Dzud alert that was issued by the Red Cross/Crescent organisation in December 2020. This alert was based on data collected from a variety of sources but is mainly reliant on pasture data that is collected by NAMEM in August every year at 1,500 sites across the country. This survey is extremely valuable, but the similarity between the regions highlighted by the satellite derived pasture anomaly map and the Dzud risk map, shows the power of satellite remote sensing for obtaining key information as soon as possible (in this case in June) and which can then be updated at regular intervals throughout the season. In contrast, it is only possible to conduct large scale ground-based measurement campaigns relatively infrequently and at selected sites.

The pasture problems in 2020 had an impact beyond the region highlighted in red above. This is because herders from the regions experiencing problems with their pasture may travel on otor to attempt to find better pasture, which then puts pressure on the herders in these regions. Batbuyan Batjav from the Centre for Nomadic Pastoralism Studies encountered several examples of tensions between herders when he was interviewing people as a part of the surveys being conducted in autumn of 2020. In Airag soum in Dornagovi province a local official told Batbuyan “There is a big problem with herders who came on otor from four aimags such as Uberkhangai, Bayankhongor, Dundgobi, Gobi Sumber aimags. In total 78 households, with 80,000 head of animal are staying in Airag soum.” Some of these journeys are over 800 km. While in the Delgerkhaan soum in the Khentii province an official said, “There is high tension between out-migrant and local herders”.

Following the lessons learnt in 2020, mechanisms were put in place to better distribute knowledge about pasture conditions ready for the growing season in 2021. One of the main approaches was the development of regular Pasture Summary Reports, which were distributed widely during 2021. The figure shows an example from July of a typical product. It is comprised of a pasture anomaly product, i.e. showing the relative health of the pasture in comparison to normal and a text-based summary, which provides a basic analysis of the current situation. The Report also contains a link to the Visualisation Website, so recipients can follow-up by checking conditions themselves, potentially zooming into their own region. The reports were delivered to the local officials in the project's three test sites and to the NAMEM meteorologists situated in the countryside who each have responsibility for one aimag.



Бэлчээрийн төлөв

2021 оны 7-р сарын 10

https://mongolia.sibelius-datacube.org

Бэлчээрийн хазайлт

Дээрх зураг бол хиймэл дагуулын мэдээгээр хийгдэж байгаа бөгөөд Монгол орны бэлчээрийн нөхцөл байдлыг, тухайн хугацааны олон жилийн дундажтай харьцуулсан байдлаар буюу тэр дунджаас хэр хазайж байгааг харуулж байна. Олон жилийн дунджийг сүүлийн 11 жилийн хугацаагаар авсан болно.

Дүн шинжилгээ

Хиймэл дагуулын өгөгдөл нь янз бүрийн бүс нутгийн бэлчээрийн нөхцөл байдлын хооронд маш хүчтэй ялгаатай байгааг харуулж байна. Ногоон өнгөөр тодруулсан бүс нутгууд нь бэлчээрийн нөхцөлтэй байдаг нь жилийн энэ үед дунджаас хамаагүй дээр юм. Хэнтий аймаг болон Булган, Тов, Оверхангай, Архангай аймгуудын уулзвар дээр төвлөрсөн сумдын хувьд бэлчээрийн нөхцөл байдал хавар элбэг бороо орсны ачаар дунджаас 40 орчим хувиар илүү сайн харагдаж байна. Үүний эсрэгээр, улаан өнгөөр тодруулсан өмнөд нутгийн олон бүс нутагт энэ жилийн хувьд бэлчээрийн байдал хэвийн хэмжээнээс 5% -иас 15% -иар хүнд байна.

Бид хэн бэ

Монголын Өгөгдлийн Шоо-ны Дүрсжүүлэлтийн вэбсайт нь бэлчээр, цас, гангийн талаар хамгийн сүүлийн үеийн мэдээллээр хангах болно:

SIBELIUS-ийн баг 2021 оны ургалтын улирлын туршид хиймэл дагуулын мэдээгээр ажиглалт хийсний үндсэн дээр бэлчээрийн төлөв байдлыг байнга шинэчилж үзүүлэхээр төлөвлөж байна.

The production and distribution of the Pasture Summary Reports were also augmented by a training programme for the countryside meteorologists, the distribution of products via Facebook and the use of television to present the latest pasture conditions evident from satellite data. These are all discussed below.

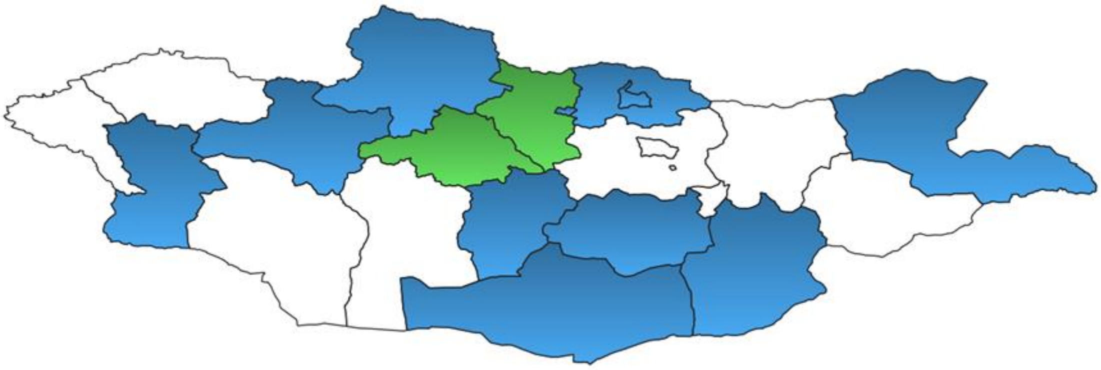
Training for locally based meteorologists

Training was conducted for ~25 locally based meteorologists and local officials from the project's test sites, on how to access environmental information through the SIBELIUs Visualisation Website. This was done virtually using the Skype platform. This is an example of the potential of virtual communications, which have become more apparent and much more widespread during the Covid pandemic. It would have taken many weeks and much expense to conduct in-person training in every aimag across Mongolia. However, using a virtual platform, people in relatively inaccessible regions could be reached simultaneously by a team of experts in the UK.

Two training sessions on the Visualisation website took place. The first of these was in February 2021 with local meteorologists and the second took place in May 2021 for the local officials from the three test sites. Both training sessions were conducted with coordination from Batbuyan Batjav and Odbayar Mishigdorj and other staff from IRIMHE/NAMEM.

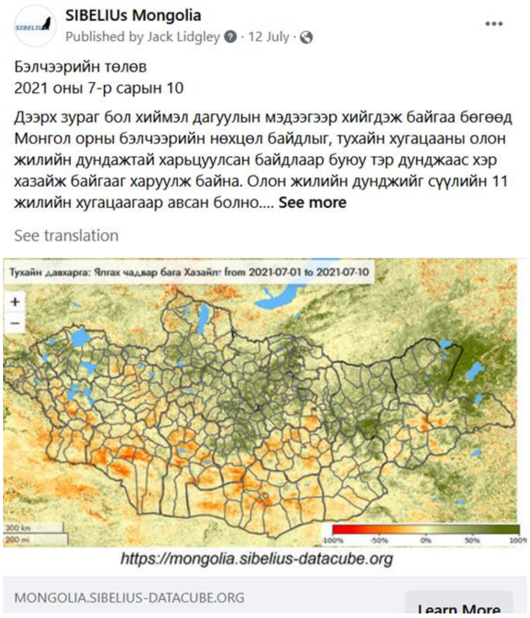
The aim of these training sessions was to demonstrate the capabilities of the Visualisation Website and encourage its use in the participants working practices. It was also an opportunity to gather feedback on the website and for any questions to be asked.

The following figure is one example of the feedback gathered from the meteorologists after they completed an online survey in October, which contained a further 18 questions. In total (at the time of writing) 13 meteorologists have responded to the survey. In the map shown, the white aimags are the regions where there was no response.



Which of the following best reflects your opinion of the Pasture Summary reports? Green: I read the Pasture Summary reports and usually found them very useful. Blue: I read the Pasture Summary reports and sometimes found them useful. White: No response.

Engagement using Facebook



SIBELIUs Mongolia
Published by Jack Lidgley · 12 July ·

Бэлчээрийн төлөв
2021 оны 7-р сарын 10

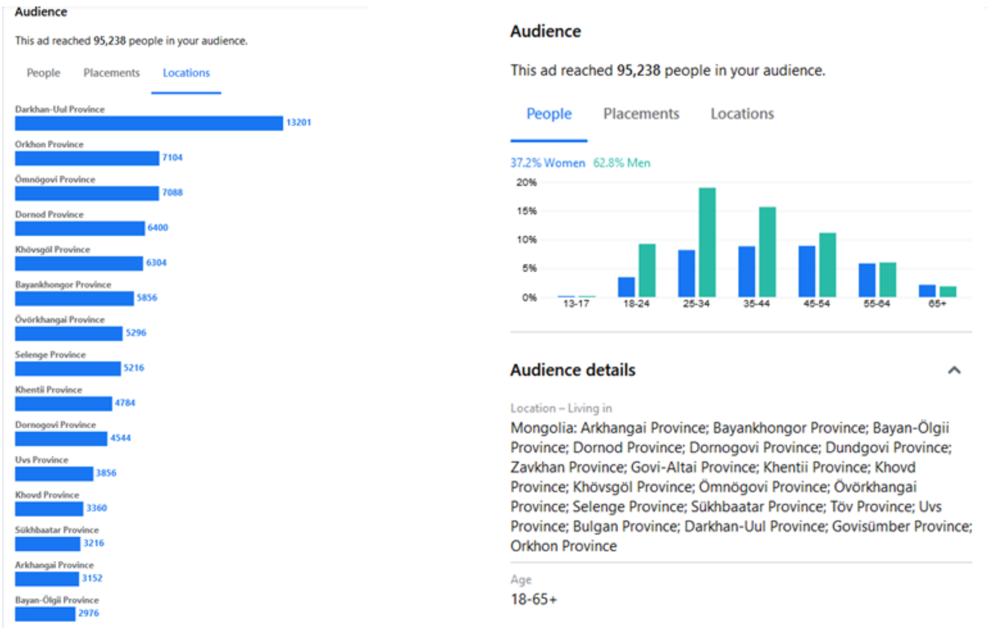
Дээрх зураг бол хиймэл дагуулын мэдээгээр хийгдэж байгаа бөгөөд Монгол орны бэлчээрийн нөхцөл байдлыг, тухайн хугацааны олон жилийн дундажтай харьцуулсан байдлаар буюу тэр дунджаас хэр хазайж байгааг харуулж байна. Олон жилийн дунджийг сүүлийн 11 жилийн хугацаагаар авсан болно.... **See more**

See translation

Facebook has proved to be an effective way of communicating with people in remote locations. Initially it was used in the project as a means for communicating achievements of the project, so the main intended audience were donor organisations and other companies and institutions providing satellite derived services. However, in the final years of the project, the Facebook page was used extensively to promote SIBELIUS products, such as the Pasture Summary Reports across the country.

At the time of writing the SIBELIUs Mongolia Facebook Page has 532 likes and 570 followers. The overall reach of the SIBELIUs Mongolia Facebook page over the course of the project is estimated by Facebook to be 892,950 people. Facebook's definition of "Reach" is as follows: "The number of people who saw any content from your Page or about your Page, including posts, stories, ads, social information from people who interact with your Page and more. Reach is different from impressions, which may include multiple views of your posts by the same people."

An example of a Pasture Summary report posted on Facebook is included above, along with statistics on the gender and location (broken down into aimags) of the viewers of the post. The example was posted on 12th July 2021 and is the post with the greatest reach.



Audience

This ad reached 95,238 people in your audience.

Darkhan-Uul Province	13201
Orkhon Province	7104
Ömnögovi Province	7088
Dornod Province	6400
Khövsgöl Province	6304
Bayankhongor Province	5856
Övörkhangai Province	5296
Selenge Province	5216
Khentii Province	4784
Dornogovi Province	4544
Uvs Province	3856
Khovd Province	3360
Sükhbaatar Province	3216
Arkhangai Province	3152
Bayan-Ölgii Province	2976

Audience

This ad reached 95,238 people in your audience.

Audience details

Location – Living in

Mongolia: Arkhangai Province; Bayankhongor Province; Bayan-Ölgii Province; Dornod Province; Dornogovi Province; Dundgovi Province; Zavkhan Province; Govi-Altai Province; Khentii Province; Khovd Province; Khövsgöl Province; Ömnögovi Province; Övörkhangai Province; Selenge Province; Sükhbaatar Province; Töv Province; Uvs Province; Bulgan Province; Darkhan-Uul Province; Govisümber Province; Orkhon Province

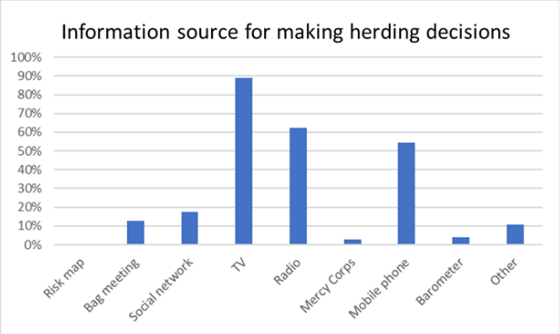
Age

18-65+

The left picture shows the breakdown of viewers by aimag for the pasture summary posted in July, while the right picture shows the gender breakdown of viewers.

Getting satellite derived products on TV

One of the things we learnt early in the project, from the surveys conducted by Batbuyan Batjav from CNPS, is that TV is one of the most important information sources for herders on pasture and weather conditions, and thus may influence herding decisions, in conjunction with a range of other factors and information sources. Most herders have satellite TVs and solar panels to power them and other electrical devices.



We therefore decided to aim to use television as one key means of distributing satellite derived information about pasture. The idea being this would feature in a similar manner to the normal weather broadcasts that are a familiar part of most TV stations output. The project team therefore spent considerable efforts engaging with Malchin TV, which is specially targeted to cater for herders' interests and is the most popular channel watched by herders. However, after extensive discussions, they decided they did not want to pursue this, so we turned our attentions to the Mongolian National Broadcaster (MNB), which is the second most popular channel for herders. This has proved more fruitful and three staff from NAMEM have now appeared on MNB. The pictures here show Baku and Elbeg taking part in separate interviews on the channels Breakfast programme, where they presented satellite derived information about the latest pasture conditions in Mongolia during the growing season in 2021.

Elbeg and Baku have now left NAMEM, but a new member of staff, has taken up the role of appearing on MNB, which we hope will continue into the future and become as common and anticipated by herders, and others, as the regular weather forecasts.

The PRISM Decision Support System

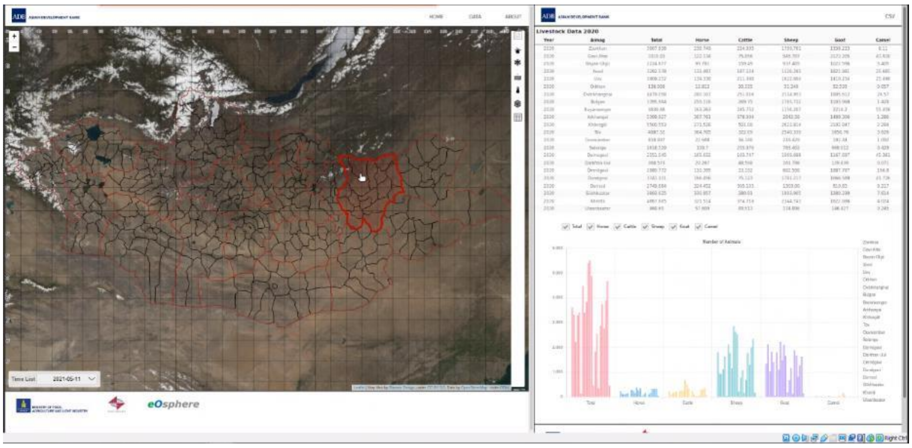
The Mongolian National Emergency Management Agency (NEMA) requires up-to-date information on the extent and severity of natural hazards alongside statistics on vulnerable groups, and local capacities to mitigate risks.

The SIBELIUS Mongolian Data Cube is now feeding satellite derived information into a single, user-friendly dashboard called PRISM hosted at NEMA. PRISM was set up in NEMA with the support of the World Food Programme, with whom the UK and Mongolian SIBELIUS team have collaborated throughout the project. As well as the satellite derived information, PRISM also connects to a series of relevant data from the National Statistics Office (NSO) on vulnerability, demographics, and the distribution of herders and their livestock.

The system set up by the SIBELIUs/PRISM collaboration, therefore enables NEMA to have a bird's eye-view of hazards, exposure, and vulnerability across the country, and to zoom into areas of high risk to plan risk mitigation activities including cooperation with the international community to take early actions that can help to reduce the loss of livestock and livelihoods.

Sustainable fodder

eOsphere, who have been leading the SIBELIUS project, have also been working on a project supported by the Asian Development Bank, to develop a decision support system (DSS) for MOFALI to support sustainable fodder management in Mongolia. A DSS is a simple and user-friendly monitoring and analysis tool which integrates satellite EO data and public domain data, to support the sustainable management of fodder production and distribution. Like the PRISM system, described above, the MOFALI DSS also makes use of satellite derived environmental information.


The Sustainable Fodder DSS allows information to be viewed in map format of graphically, as here showing livestock numbers in all the aimags for each type of animal.

The DSS dashboard has been designed to facilitate decision making by MoFALI staff to promote sustainable fodder management in Mongolia. The DSS database combines data from the following range of sources to create information products that highlight key information regarding the current and historical status of pasture, livestock, fodder and other factors.

- Earth Observation (EO) satellite imagery and EO derived products, served by the SIBELIUS project's Data Cube.
- Further EO derived rangeland pasture products, generated in the DSS and served by the DSS database.
- Livestock and fodder crop data from the National Statistical Office (NSO) databases.
- Geotagged livestock data. Livestock from selected herders have been geotagged, so their movements can be tracked as they graze in the rangelands, including picking up any long distance otor movements, which might be indicative of pasture problems.
- Other economic and environmental data.

A satellite-derived index insurance product based on pasture conditions for Mongolian livestock

One of the original aims of the SIBELIUS project, was to use satellite derived information to improve the current Index-Based Livestock Insurance (IBLI) scheme in Mongolia. However, while this aim was not realised within the duration of the project, important groundwork has been laid through i) SIBELIUs-led surveys to better understand herders' uptake/ non uptake of IBLI livestock insurance and needs and preferences for improved products; ii) SIBELIUs team's development of pilot products, reflecting this information from i) and iii) SIBELIUs team's production of a White Paper highlighting a series of recommendations regarding how to take this topic further in the future, which would require additional support. This has been shared with key stakeholders in country namely MonRe, the main government-linked insurance company, as well as the Food and Agriculture Organization of the United Nations (FAO) who have an active presence in Mongolia.

Background

To support herders' livelihoods and the Mongolian economy as a whole against the impacts of dzuds, the World Bank led the development of a tailored market-based solution known as Index-Based Livestock Insurance (IBLI). Under this scheme, insured herders are not compensated specifically for their losses (e.g. how many of their own livestock have died, which would be extremely difficult and expensive to administer), but instead they are compensated if the overall livestock losses in their region, defined by the administrative soum, exceeds a certain percentage, which is usually set at 5-6% (depending on the region). The livestock losses are estimated twice yearly by local officials and provide an indication of the hardships faced by the herders for each region for that year.

The IBLI scheme was started as a pilot scheme, covering 3 Aimags (Mongolian administrative regions) in 2006, and by 2012 had been rolled-out to the whole country. As with all insurance schemes this can be seen as a form of risk management that helps to protect against disruptive and uncertain loss. Affordable insurance can increase security and confidence which can lead to investment and economic growth.

Although IBLI now covers the whole of Mongolia, the take-up rate covers only 15.76%, of all herder households, which is down from a peak of 19.87% in 2018, as is shown in Figure 2.

During the SIBELIUS fieldwork surveys, several herder households reported that the only reason that they had taken out IBLI insurance, was because it was a required by a bank before they could take out a bank loan, or in other cases because it was a precondition for entering a "herder of the year" competition. If herders were not compelled and incentivised in this way, IBLI take-up might be lower than it is currently.

Our recommendation

Our proposal is that an index insurance product is based on pasture anomaly, as measured by satellites throughout the growing season (May to October). Pasture can be estimated by the satellite derived index NDVI, which has been used in similar pasture and agricultural applications worldwide. In Mongolia, NDVI is relatively well correlated with pasture biomass, because, in general, the pasture rarely reaches levels where saturation effects become significant. The pasture anomaly, for any given region, is calculated by comparing the current pasture condition, with the eleven-year historical pasture average for the same seasonal time period. Eleven years is the length of time for which MODIS satellite data is stored in the Mongolian Data Cube. However, it is important to note that this historical average will grow with each year that passes.

In summary, the key advantages of the approach recommended by the SIBELIUS team are as follows:

- A pasture-based insurance policy would be able to pay out before the winter, thereby enabling herders to purchase provisions to help their livestock to survive through the winter, unlike the existing IBLI insurance scheme which pays out after livestock have been lost.
- Surveys conducted with herding communities in three test site regions have shown that poor pasture caused by drought is the most common single environmental risk factor they would like to be insured against
- An insurance policy based on a single environmental parameter, such as pasture quality, is simple to understand, and would therefore be relatively simple to explain by insurance sales teams
- The Mongolian Data Cube, hosting current and historical satellite data acquired since 2009, makes calculating pasture anomaly statistics a relatively easy task

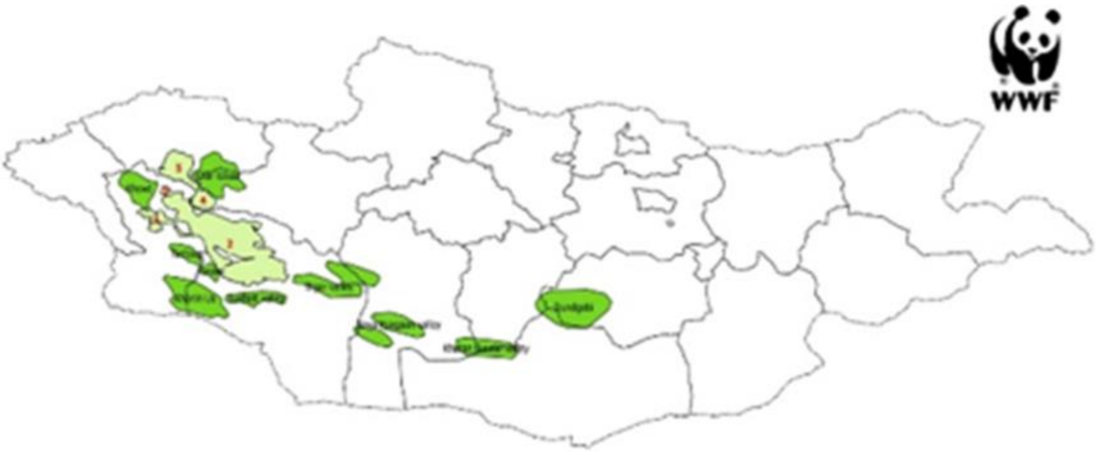
Supporting conservation work for the endangered Mongolian saiga antelope

The SIBELIUs project is all about helping the herding communities in Mongolia, but Zuzanna Skorniewska, an intern student working with eOsphere over the summer of 2019 demonstrated that the pasture information being derived as a part of the project can also help support conservation work for endangered animal species.

The saiga antelope is listed as critically endangered on the IUCN Red List and since the early 1990s over 95% of the saiga population has disappeared. Saiga live in a limited number of regions in Kazakhstan and Russia, while the Mongolia saiga sub-species is now reduced to inhabiting a few small regions in western Mongolia. Saiga are under pressure from several perspectives. A key problem in Mongolia is competition with the herding community for access to pasture. The number of livestock in Mongolia has risen by a factor four since 1990, so pasture is increasingly under pressure and if the spring and summer rains are late or if there is a drought, then the pasture can be badly affected, leading to saiga becoming malnourished as they enter the harsh Mongolian winter. In recent years saiga have also been subject to diseases that have had a dramatic impact on their numbers.

Between 2016 and 2017 the Mongolian Saiga population was reduced by over 50 percent because of "goat plague" outbreak and according to the 2018 data, there are approximately 3,800 saiga left in Mongolia. Poaching can also be a problem for saiga. They are hunted for their translucent amber horn, which is sold for Chinese traditional medicine.

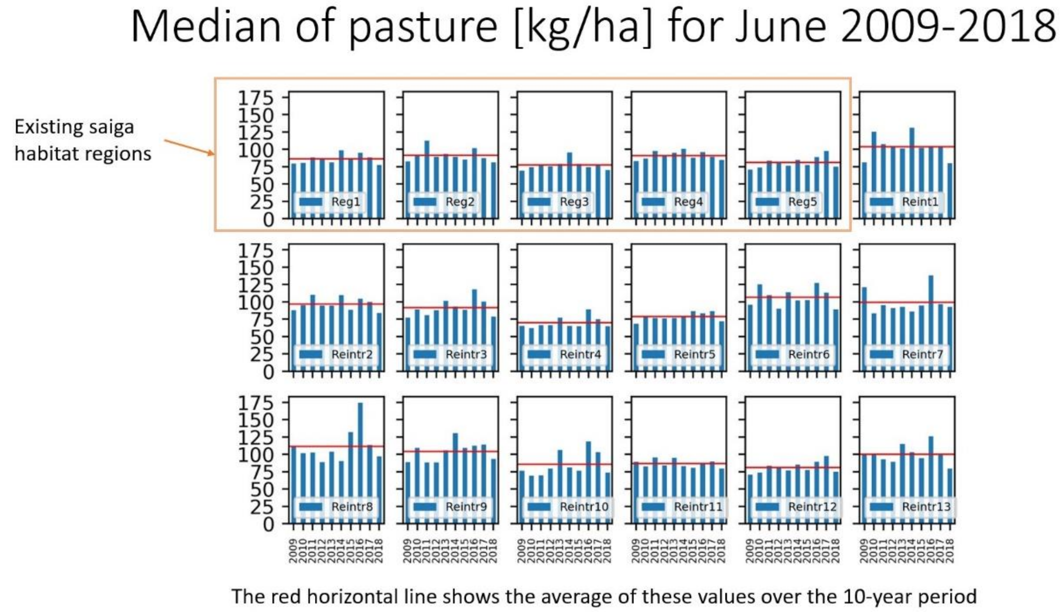
The World Wide Fund for Nature (WWF) in Mongolia have been working to re-establish saiga numbers, to help make them resilient to further shocks from disease and drought. WWF have identified 13 regions which are potentially suitable for reintroducing saiga populations. These 13 regions are all situated where saiga used to live in the past when their numbers were greater. These are several factors which need to be considered when looking to reintroduce saiga. One of these factors is the quality and stability of the pasture in the potential reintroduction regions and this is the topic where Zuzanna has been able to help provide useful information for WWF.



Light green areas show the regions where the Mongolian saiga antelope is currently living. The dark green areas indicate the regions being evaluated to assess their suitability for saiga reintroduction.

The SIBELIUs project, in collaboration with NAMEM, is monitoring pasture levels and pasture trends across Mongolia. At the heart of the SIBELIUs system is the Mongolian Data Cube, which is an efficient method for storing large time series of satellite data and useful products derived from satellite data, including pasture maps.

The Data Cube allowed Zuzanna to extract information about pasture levels for the existing saiga habitat and for each of the proposed reintroduction sites, for a period of 10 years from 2009 to 2018. The bar charts below show the median pasture biomass, measured in kilograms per hectare, for each of the regions (existing habitat and proposed reintroduction sites) for the month of June for the ten years between 2009 and 2018. We started working with the June data, because this is a critical month in terms of pasture establishing itself, however the Data Cube structure allows us to interrogate any time periods that we wish.



Median of pasture values (kg per hectare) for June between 2009-2018. Each red horizontal line shows the average of these values for that region over the 10-year period.

There are many factors to be considered when reintroducing saiga. However, based solely on the pasture information here, it is possibly to identify the regions which appear to show the best promise. The bar charts above show that the best reintroduction regions are those numbered: 1, 6, 8 and 9. The reintroduction regions 6 and 9 would provide the most additional total pasture, 117.29 and 154.15 million kg respectively compared to the existing habitats, because they are relatively large regions as well having relatively good average pasture levels.

It is also interesting to note, that all of the 5 existing saiga sites have average pasture densities of less than 100 kg/ha, for the month of June, with regions 3 and 5, being particularly low, which helps confirm that other factors are at play as well as just pasture conditions. For example, saiga antelope are known to avoid regions close to human habitation, or near roads or tracks.

Gantulga Bayandonoi, from WWF-Mongolia has provided input and feedback throughout the duration of Zuzanna’s project. After reviewing the outcomes from this project, he told the SIBELIUs team “Thank you very much for the help. I see the result to be one of the crucial factors for choosing a reintroduction site. Summer biomass is very important for the Saiga. … Such a result you guys produced will help us to assess the rapid pasture changes within and between years which can decide a long-term survival of the saiga population at sites.”

We provided WWF with information about pasture conditions, derived from satellite data, in a range of sites where they plan to try to reintroduce saiga populations

Conclusions and lessons learnt

The evidence discussed in the previous "Results so far" section points to a project which has successfully achieved many of the original aims and which has also successfully embedded the project's technical solution and its outputs within the wider Mongolian context, which will help to ensure the sustainability of the solution, into the future.

One of the reasons for the success of the project has been the project team's flexibility and willingness to adapt when some aspects of the project didn't work as well as intended and when new opportunities presented themselves, which hadn't previously been anticipated.

The main area where SIBELIUS did not develop mature satellite derived solutions, is in the development of a new insurance product, which would have augmented the existing IBLI livestock insurance scheme with information about pasture conditions, to be provided by satellite Earth observation data. Our main in-country partner in the insurance initiative was Mongolian Re, who administer the IBLI scheme on behalf of the government. They were keen to conduct a survey of the herding community for a very wide series of regions across Mongolia. This survey would have been helpful for helping to develop the new insurance product, but it delayed the project's timetable. However, when the COVID-19 pandemic arrived the survey had to be cancelled and collaboration with Mongolian Re, became much more difficult because of the lockdown restrictions, which left no opportunity to complete this initiative. However, based on the project team's extensive research and development in this area, a series of recommendations were published as a White Paper, which has been circulated among Mongolian and donor organisation stakeholders.

The two main areas where SIBELIUS has been successful, outside the original scope of the project, were the collaborations with the Mongolian National Emergency Management Agency (NEMA), via the World Food Programme's PRISM initiative and the Sustainable Fodder initiative at MOFALI (the Department for Agriculture) being supported by the Asian Development Bank. In both cases these collaborations help to ensure that the Mongolian Data Cube will be required to keep functioning into the future.

The main areas where the SIBELIUS project has been successful inside the original project scope, is the production and widespread distribution of pasture information products. However, some of the routes for distributing the products were not originally anticipated. The importance of Facebook as a means for communication within herding communities became more apparent as the project developed, and therefore this presented an opportunity to help disseminate satellite derived pasture information, which the project embraced. The other route which hadn't previously considered, was that making use of the network of meteorologists employed by NAMEM who each have responsibility for an aimag. These meteorologists have a good level of scientific and technical training and are also very well connected within the regions where they are located. They therefore provide an excellent route for getting information into the hands of the local officials who make decisions about livestock management, in particular those having responsibility for managing the otor movements of herding households, which is a difficult role, especially in conditions of poor pasture, when scarce pasture resources need to be managed amongst many competing interests.

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