МОНГОЛ УЛСЫН ЗАСГИЙН ГАЗАР
БАЙГАЛЬ ОРЧИН, НОГООН ХӨГЖЛИЙН ЯАМ

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# IDENTIFYING CONSERVATION PRIORITIES IN THE FACE OF FUTURE DEVELOPMENT:

## Applying Development by Design in the Mongolian Gobi

2013

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# Identifying Conservation Priorities in the Face of Future Development: Applying Development by Design in the Mongolian Gobi

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The products of this assessment, including this report and a web-based GIS application, are available online: http://s3.amazonaws.com/DevByDesign-Web/MappingApps/Gobi/demo/gobi.html

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Ulaanbaatar, July 2013.

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## PHOTO CREDITS

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# FOREWORD

Due to human activities, almost half of the world's arid land has undergone changes to the structure and function of natural systems, including severe depletion of biodiversity. In the next two decades, trillions of dollars will be invested in energy, mining, and infrastructure development, much of it in undeveloped landscapes with high conservation value. The resulting development activities will have profound effect on nature and people. Following global patterns, Mongolia is also experiencing significant economic growth that will create challenges for people and biodiversity. Mitigation policy and its implementation (how we avoid, minimize, and compensate for impacts) will affect the future for biodiversity and human habitat in Mongolia.

Following the joint order A-358/235/282/120 passed on October 24, 2011 by the Minister for Nature, Environment and Tourism; Minister for Mineral Resources and Energy; Minister for Road, Transportation, Construction and Urban Development; and Director for National Development and innovation Committee, a working group was formed to establish a Development by Design approach for the South Gobi region of Mongolia. The goal of the working group was to provide scientific and legal recommendations and review and present guidance on eco-regional planning to guide impact mitigation decision making for development projects and programs implemented in South Gobi region of Mongolia. Now, as a result of this work, the analysis and the report is complete.

For centuries the South Gobi region of Mongolia has been home to Mongolian herders, a favorable pastureland for livestock, as well as habitat for many rare species of animals and plants. Therefore, when planning and implementing development projects in the Gobi region, successful mitigation will require scientifically proven approaches that provide protection for ecosystems and wildlife habitat, and favorable living conditions for people in the face of future development.

The Nature Conservancy has initiated their Development by Design approach to balance increasing development needs with nature conservation. This approach is now being successfully piloted and implemented in many countries of the world. The Development by Design approach is a methodology for scientifically sound landscape level planning aimed at integrating economic development decisions for mineral resources and related infrastructure with the conservation of biodiversity.

This South Gobi report follows The Nature Conservancy's work on the Mongolian steppe conducted in 2010. As a result of this work, utilizing the latest technology and research methods, areas were identified for protection that support biodiversity and ecological processes in Mongolian steppe, Dauria steppe and South Gobi regions. Similar assessments are also underway in the western and central regions of Mongolia. The results will create a national level unified database that will support the coordinated planning of infrastructure development and conservation of nature.

I am fully confident that this report will be a significant contribution to landscape level implementation of biodiversity conservation and application of Development by Design approach, and will serve as an important resource for mining entities and decision makers.
Sincere appreciation is extended to The Nature Conservancy for sharing their knowledge and expertise in balancing increasing needs of development with biodiversity conservation works in Mongolia, and to all working group member, scholars, researchers and specialists who generously contributed their time, knowledge and expertise.

S.Oyun

S.Oyun

Member of Parliament,
Minister for Environment and
Green Development of Mongolia

# EXECUTIVE SUMMARY

This report describes a regional conservation plan for the Mongolian Gobi that balances the government commitment to protection of natural habitats with planned development of mineral resources and related infrastructure. To complete this analysis, we compiled available data, literature and expert knowledge to identify a set of priority conservation areas and built a supporting information system that can guide decisions about habitat protection and mitigation.

1. The Mongolian Gobi spans an area of 510,000 $km^2$, or the southern third (32%) of the country that is bounded by the Altai and Khangai Mountains to the northwest, the Eastern Steppe to the northeast and the border with China to the south. This region is one of the world's largest remaining wild areas and supports a large assemblage of native wildlife. However, the wildlife and pastoral livelihoods of this area are threatened by rapid growth in mining and related infrastructure.

2. We identified a set of areas that could maintain the biodiversity and ecological processes representative of the region, given adequate protection and management as high quality core habitat within a larger landscape matrix that supports habitat use and movement. This set of priority conservation areas is referred to here as a portfolio. The methods that we used were developed to address the scope and scale of conservation planning across the study area using available data. Focal biodiversity elements are defined by a mapped ecosystem classification and modeled habitat distributions of 33 species of birds, mammals and reptiles listed by the National Red Lists as endangered, threatened, vulnerable or near threatened. We designed the portfolio to a) meet representation goals for the amount and distribution of each ecosystem type and b) optimize for ecological condition based on an index of disturbance and cumulative anthropogenic impacts.

3. The portfolio includes a) areas already designated within the National Protected Area system, b) a set of other priority conservation areas including Important Bird Areas and the Tost Uul community conservation area and c) sites selected with the conservation planning software MARXAN to meet representation goals for ecosystems and optimize ecological condition. The portfolio consists of 50 sites that cover 195,000 $km^2$, or 37 % of the study area. National Protected Areas are 57% of the portfolio area. To evaluate the conservation significance of all planning units across the study area, we developed an index of the relative conservation value of ecosystem occurrences that is based on rarity and relative contribution to the MARXAN optimization.

4. We identified areas of potential conflict between the conservation portfolio and areas leased for mining development or exploration. Within these conflict areas, the areas a) with relative conservation value in the highest $30^{th}$ percentile or b) containing high-value Khulan range were designated as areas to avoid development. The remaining conflict areas were removed from the portfolio and replaced with sites of similar composition and condition outside existing leases. We also identified six existing or planned transportation corridors that are potential barriers and urgent threats to wildlife movement.

5. We also illustrate how the conservation portfolio can be used to offset impacts associated with mining and other types of development. For development outside the portfolio, we demonstrate how to determine potential impacts of development projects and identify a portfolio of best offset opportunities.

## Uses of this report

Traditional approaches to mitigating development impacts have several problems. In too many places, mitigation is still conducted on a project-by-project basis, with piecemeal mitigation actions taken on-site or nearby. Traditional mitigation efforts give little or no consideration to how these actions contribute to wider goals for the landscape, such as supporting an ecologically functional landscape or connecting important habitat to prevent confining species to ever-shrinking "islands". Traditional mitigation also ignores the future. Too often mitigation occurs without considering the projected cumulative impacts of all the other mining and infrastructure in the region.

The primary goal of this analysis is to provide the necessary forethought so that today's conservation investments will provide lasting benefits. This analysis will not address all of the outstanding environmental issues facing the Gobi Region of Mongolia given the future impacts from development and climate change (i.e., increasing dust, desertification, groundwater impacts, social impacts). Many of these issues must be addressed at a finer scale, such as through individual project environmental impact assessments (EIAs). Nonetheless, this analysis provides guidance to ensure individual developments and conservation investments contribute to regional conservation goals. Below we list the primary uses of the project GIS:

- Guide the selection of protected areas necessary to meet the Mongolian Government's commitment to protecting 30% of the country's natural habitats (See Sections 2.8 and 3.1.1).
- Provide a framework to address changes to the environment caused by future actions in combination with other past, present, and future human actions - i.e., cumulative impacts (See Appendix 4).
- Reduce development-conservation conflicts, steering development projects away from lands and waters critical for biodiversity conservation and, to the extent possible, direct conservation efforts to areas least likely to conflict with strong development pressures.
- In concordance with IFC Performance Standard 6, use a landscape level plan to identify critical, natural and modified habitats, and assign specific mitigation recommendations for each habitat (See Section 3.1.3).
- Encourage comprehensive and effective mitigation where development occurs. Ensure that when utilizing offsets, they are ecologically equivalent to impacts, aligned with regional conservation goals and integrated into governmental and business planning (See Sections 2.9 and 3.1.4).
- Achieve positive outcomes for biodiversity by ensuring that conservation actions appropriately compensate development impacts (See Section 3.1.4).
- Inform land-use planning at the Aimag and Soum levels.
- Provide a baseline and maps of potential habitat to guide future biological surveys.

To be effective, conservation efforts must consider distribution of habitat, threats, and impacts at a regional or landscape level and align with a systematic, landscape level identification of conservation priorities. With this study, we hope to demonstrate that it is possible to produce a landscape level conservation plan and decision support framework in a relatively data-poor setting within a short time frame. The results and supporting information should be considered an initial step in an iterative process of data collection, monitoring and revision. Our analytical methods were chosen and developed to be transparent and replicable, and thereby easy to verify and revise, and we will make all results and most source datasets publicly available.

# 1.0 INTRODUCTION

## 1.1 STUDY AREA

Arid lands cover close to 11% of the world's land mass (Mortimore et al. 2009) and support unique biodiversity and many endangered species (Durant et al. 2012, IUCN 2011). However less than 10% of global arid biomes benefit from some form of protection (Hoekstra et al. 2005), and as much as 20% has experienced degradation (Reynolds et al. 2007, Safriel et al. 2005, UNCCD 1994). Arid biomes exist on every continent, and are home to 6% of the world's population, mostly subsistence farmers and pastoralists that depend on these arid landscapes to maintain a sustainable livelihood (Mortimore et al. 2009; Safriel et al. 2005).

Arid biomes by definition receive extremely low precipitation, less than enough to support growth of most plants, because more water is lost to evapotranspiration than falls as precipitation. This dry condition helps promote the formation and concentration of important minerals. Gypsum, borates, nitrates, potassium and other salts build up in deserts when water carrying these minerals evaporates. According to UNEP statistics, half of the world's copper and uranium comes from arid lands, and 75% of world oil reserves are in arid lands (Safriel et al. 2006).

Parts of the Mongolian Gobi region have been identified as among the world's largest and most intact (least converted) remaining wild areas (Sanderson et al. 2002). Among arid ecoregions of the world (Olson et al. 2001), the Alashan Plateau is among the top 20% most intact (Oakleaf et al. in prep.). This region supports a large assemblage of native wildlife, including 33 animals listed as nationally threatened or endangered (Clark et al. 2006, Terbish et al. 2006, Gombobataar et al. 2012). The Mongolian population of the endangered Khulan (*Equus hemionus*), Goitered gazelle (*Gazella subgutturosa*), the Mongolian gazelle (*Procapra gutturosa*), Siberian ibex (*Capra sibirica*), wild Bactrian camel (*Camelus ferus*) and several smaller species are the largest in the world (Moehlman et al. 2008, Mallon 2008a, Mallon 2008b). The Great Gobi A Strictly Protected Area (also called Ikh Gobi A SPA), a UNESCO Biosphere reserve, contains the entire range of the last remaining population of the Gobi Brown bear subspecies (*Ursus arctos isabellinus*; Galbreath et al. 2007) and one of three remaining ranges of wild camels. The current status and ecology of many of these threatened/endangered species remains unknown or data deficient. There is an urgent need for basic research and surveys of wildlife in the region (Batsaikhan et al. 2010, Clark et. al 2006).

The density of human settlements in the region was historically and remains very low (MAS 2009), and the level of human influence is among the lowest of the world (Sanderson et al. 2002). However, threats and pressures on the arid grasslands, including desert steppe in the Gobi region, have increased dramatically following the transition to a market economy in 1990. Across Mongolia, pastoral systems and grazing practices have changed in response (Fernandez-Gimenez and Batbuyan 2004, Fernandez-Gimenez 2001, Fernandez-Gimenez 1999), and the number of livestock has nearly doubled over the last two decades, reaching approximately 40 million animals, although that number fluctuates widely from year to year (National Statistical Office of Mongolia 2008). This has resulted in overgrazing, particularly in areas near rural population centers and water sources, and long-term degradation of rangeland capacity to support livestock and wild ungulates (Reading et al. 2006, 2010, Stump et al. 2005).

Mineral resources exploration and exploitation is increasing dramatically. To date, 15% of the country has been leased for mineral and petroleum exploration, with another 26% available for lease (MMRE 2012). Mining development in the Gobi region is occurring faster than the national trend; 24% of the Gobi study area has been leased for exploration and another 32% is available for lease (MMRE 2012). Though the direct impacts of mining on land and water are significant and can reach far beyond the mine site, perhaps the most urgent threat to wildlife is created by transportation infrastructure and traffic to support mining operations that create barriers to movement (Ito et al. 2005, Ito et al. 2013, Kaczensky et al. 2011, Kaczensky et al. 2006, Olson 2012, Lkhagvasuren et al. 2011, Lkhagvasuren 2000).

The study area for this assessment includes the Mongolian portion of the Central Asian Gobi Desert ecoregion, as delineated by WWF Mongolia Programme Office for the National Gap Assessment (Chimed-Ochir et al. 2010), and its four sub-ecoregions: the Eastern Gobi, the Gobi-Altai, the Southern Gobi-Altai and the Dzungarian Gobi (Figure 1). The study area covers an area of 510,000 km$^2$, or the southern third (32%) of the country. This region is a cold desert with a continental climate and long, cold winters. Mean annual precipitation ranges from less than 40 mm in extreme arid areas in Southern Govi-Altai and Bayanhongor Aimags to over 200 mm in the Gobi-Altai mountains (Figure 2; Hijmans et al. 2005). However, precipitation varies greatly interannually, with some areas not receiving any measureable precipitation for years at a time. Long-term monthly average temperature ranges from below -20° C in January to over 33 °C in July (Hijmans et al. 2005).

## 1.2 CONSERVATION PLANNING

Systematic conservation planning provides a methodical and comprehensive process for identifying a set of places or areas that, together, represent the majority of native species habitats, natural communities and ecological systems found within a planning area. To be effective, conservation efforts should consider distributions of habitats, threats and impacts at a regional-or landscape level, and be guided by a systematic, landscape level identification of conservation priorities (Margules & Pressey 2000, Groves 2003). A conservation portfolio of priority sites, the end product of conservation planning, contains a set of areas selected to represent the full distribution and diversity of native species and ecosystems (e.g. Noss et al. 2002). Often, systematic conservation plans utilize an optimization approach automated with spatial analysis tools such as Marxan (Ball and Possingham 2000), where the design of the

**Figure** 1: Major Habitat Types and Terrestrial Ecoregions of Mongolia

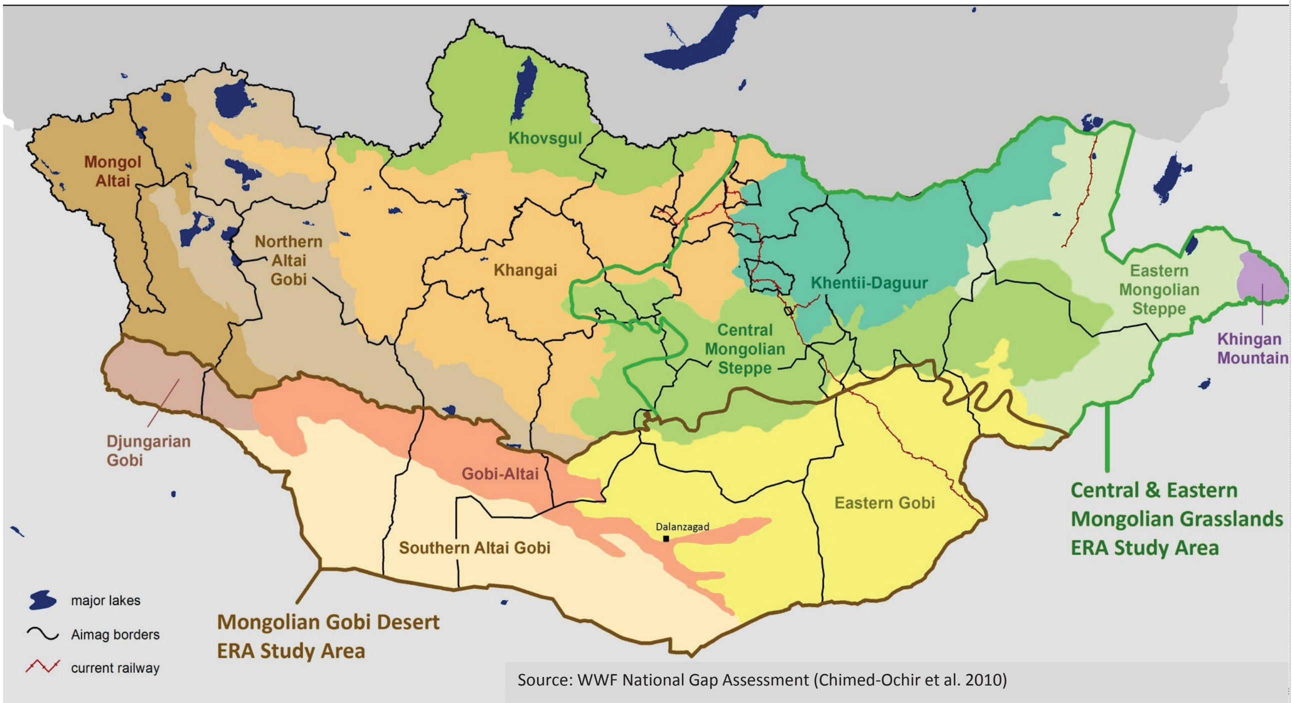
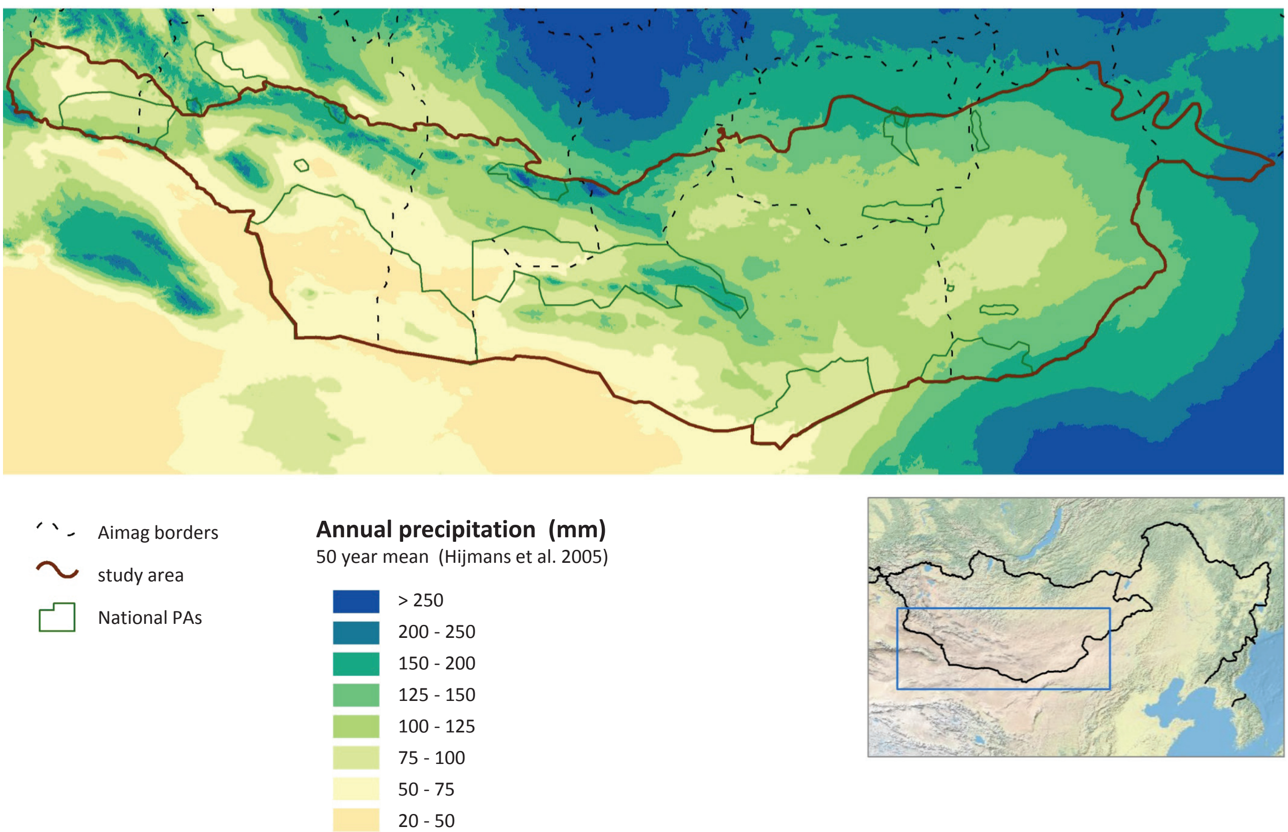



**Figure 2:** Study area: Mongolian Gobi



portfolio strives to meet at least the assumed minimum viability needs of each biological element in a configuration that minimizes the amount of area selected (Pressey et al. 1997, Ball 2000, Ball and Possingham 2000).

This approach is based on ecoregional assessment practices and standards described by Groves et al. (2002), Groves (2003) and Higgins & Esselman (2006). The basic components are: (1) define and map distributions of a suite of biodiversity elements including species, ecosystems or other features that collectively represent the biological diversity of the study area; (2) set quantitative goals for the estimated abundance and distribution of biodiversity elements necessary to maintain ecological and evolutionary potential over time; (3) evaluate the relative viability and ecological integrity of, and threats to, occurrences (populations and examples of communities and ecosystems) of the suite of biodiversity elements; and (4) use this information to identify the occurrences of biodiversity elements that collectively meet representation goals and are the most likely to persist, i.e. are viable, with the highest relative ecological integrity and minimal risk from future threats (Figure 3).

## 1.3 PREVIOUS REGIONAL CONSERVATION PLANS AND PRIORITY-SETTING EFFORTS

Mongolia established perhaps the world's longest continuously protected nature reserve, Bogd Khan, in 1778. In 1996, the Mongolian Ministry of Nature and Environment published their Biodiversity Conservation Action Plan for Mongolia (MNE 1996). This report recommended designing eight strictly protected areas, 40 national parks, and 37 heritage areas. As of 2008, approximately 40% of the recommended areas have been designated as National Protected Areas (Chimed-Ochir et al. 2010). The Master Plan for Mongolia's Protected Areas (1998) established a goal of designating 30% of the country's land as national and local protected areas. Resolution #13 of the Parliament of Mongolia (2008) refined this goal and specified that national protected areas will cover 15% of the country and local protected areas will conserve the remaining 15%.

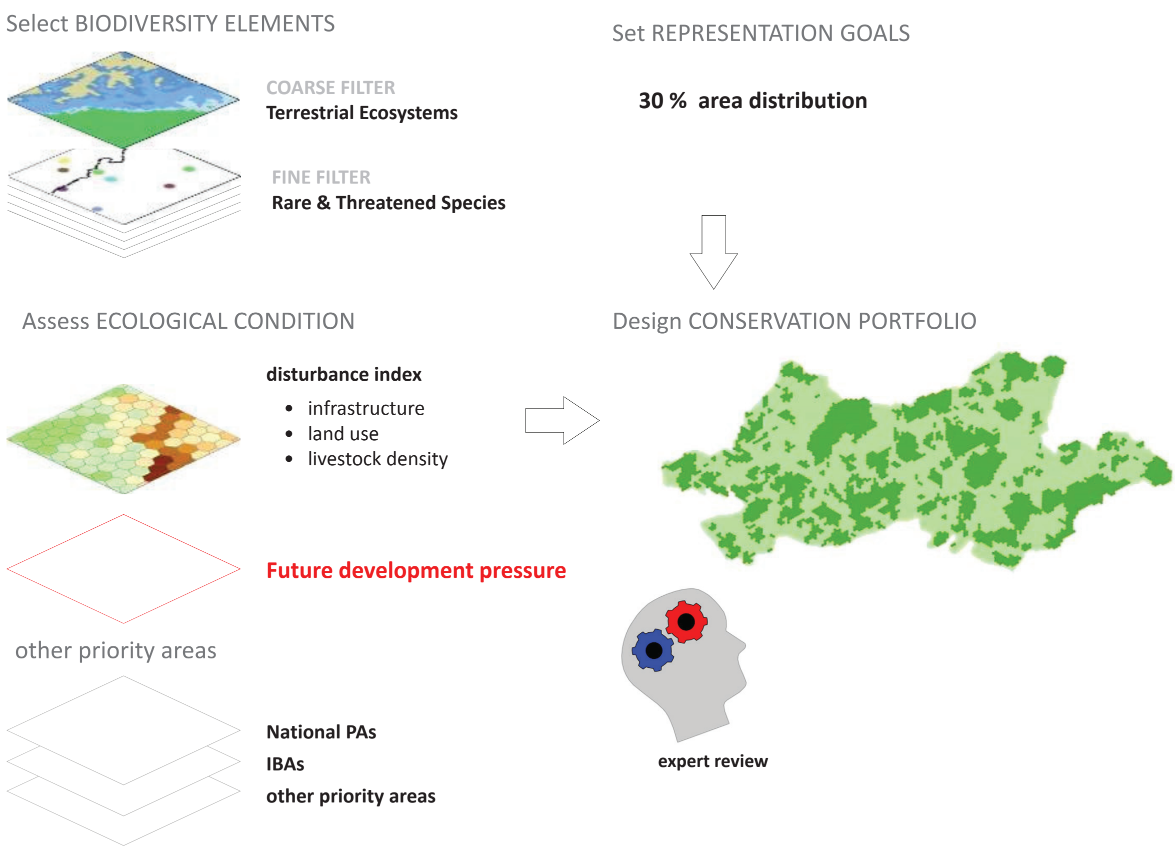
Today, Mongolia has designated 90 national protected areas covering about 27.2 million hectares or 17.4% of the country (Myagmarsuren and Namkhai 2012). Mongolia also contains six Biosphere Reserves (UNESCO 2011a), two World Heritage Sites (UNESCO 2011b) and 11 Ramsar sites (Ramsar 2011). Bird Life International has identified 70 Important Bird Areas (IBAs) in Mongolia (Nyambayar & Tsveenmyadag 2009). In 2010, the National Gap Assessment (WWF 2010) proposed 34 new protected areas to complement the National Protected Area system, six of which fall in the Gobi study area.

The Gobi study area contains 14 National Protected Areas that cover 110,000 $km^2$ or 21% of the study area and ten Important Bird Areas (seven lie entirely within National Protected Areas). These sites formed the foundation, or starting point, on which we built the conservation portfolio.

## 1.4 DEVELOPMENT BY DESIGN

In partnership with the Government of Mongolia, The Nature Conservancy is working to balance mineral and energy development with pastoral livelihoods and the conservation of habitat through a science-based approach called "Development by Design" (Kiesecker et al. 2009, Kiesecker et al. 2010, McKenney and Kiesecker 2010, Kiesecker et al 2011, Kiesecker et al. 2013). Development by Design (DbD) promotes a proactive approach to help guide sustainable development decision-making by looking beyond individual projects to identify the cumulative

**Figure 3:** Process for designing a portfolio of conservation areas




impacts of development on natural areas across the landscape. Incorporating landscape-level conservation planning can dramatically improve traditional mitigation efforts. Development by Design supports blending conservation planning with the "mitigation hierarchy" - first avoid, then minimize/restore, and finally offset - to address critical issues for effective mitigation:

- Look beyond individual projects to identify the cumulative impacts of development on natural areas and wildlife across the landscape.
- Identify conflicts between conservation priorities and development plans before the damage is done.
- Provide effective options for mitigation that balance development and conservation needs, avoid impacts to sensitive natural areas and wildlife, and identify opportunities to offset remaining impacts to wildlife.
- Determine when to avoid project impacts and when to use offsets.
- Identify offsets that deliver ecological equivalence (i.e., reach the same ecosystems and wildlife affected by development), contribute to landscape-level conservation goals, are located at an acceptable proximity from the impact site and deliver the greatest conservation value.
- Assess the extent to which offsets compensate for project impacts - with the goal of achieving 'net gains' for biodiversity.

Development by Design (DbD) operates at two distinct spatial scales. First, DbD functions at a landscape level (e.g. the Mongolian Gobi study area) to evaluate conservation priorities, assess cumulative impacts in the region, identify potential conflicts between development and conservation goals, and inform decision-making about where avoidance and minimization of impacts should receive priority (Steps 1 &2). Second, DbD is applied at a project or site level (e.g. a mine site) to assess project impacts and their suitability for offsets, and where



appropriate, support design of an offsets strategy for mitigating these impacts (Steps 3 & 4).

**Landscape Level:**
1. Develop a landscape conservation plan (or use an existing conservation plan, such as an Ecoregional Assessment).
2. Blend landscape planning with the mitigation hierarchy to evaluate conflicts based on vulnerability and irreplaceability.

**Project Level:**
3. Determine residual impacts associated with development and select an optimal offset portfolio.
4. Estimate the offset contribution to conservation goals.

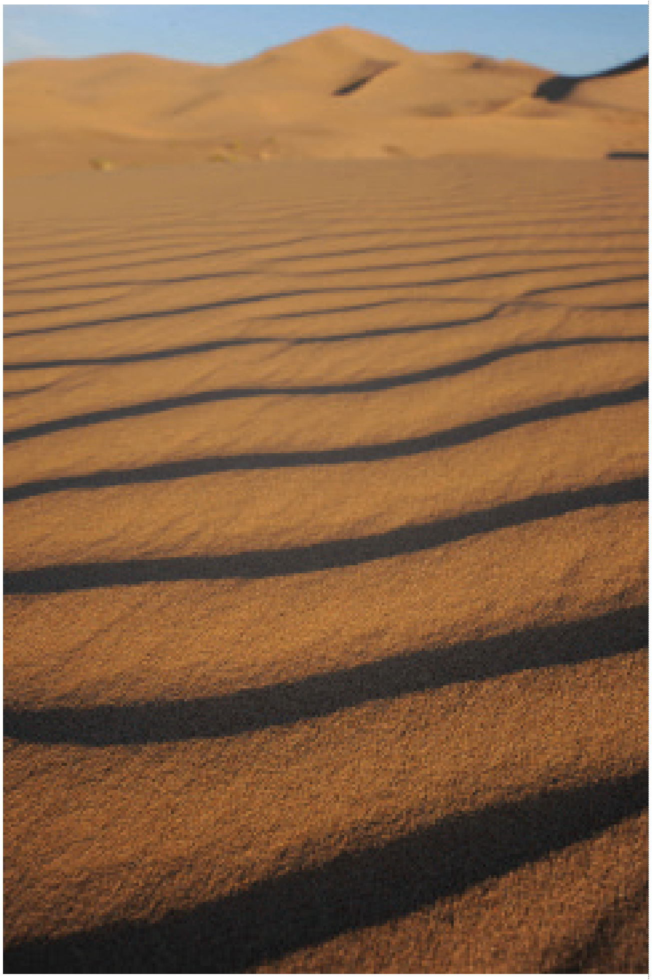
This study focuses on providing a landscape-level analysis, as this is essential for addressing the first critical question when applying mitigation: when should impacts from planned developments (mining, energy) be avoided altogether, minimized onsite, or offset? (Kiesecker et al. 2010, Thorne et al. 2006). Conservation planning, and specifically the ecoregional assessment carried out for this study, provides the structure to ensure mitigation is consistent with conservation goals by maintaining large and resilient ecosystems to support human communities and healthy wildlife habitat. Blending the mitigation hierarchy with landscape planning offers distinct advantages over the traditional project-by-project approach because it considers the cumulative impacts of both current and projected development, provides regional context to better guide the step at which the mitigation hierarchy should be applied (i.e. avoidance versus offsets) and offers increased flexibility for choosing offsets that maximize conservation return by focusing efforts towards the most threatened ecosystems or species.

## 1.5 APPLICATIONS OF THIS STUDY

A primary objective of this study was to identify a set of areas that could maintain the representative terrestrial biodiversity and ecological processes of the Mongolian Gobi by providing adequate protection and management of high quality, core habitat within a larger landscape matrix that supports habitat use and movement. We designed a conservation portfolio that meets the Mongolian government's goal of preserving 30% of all natural systems in a configuration optimized to meet the following design criteria: avoid ecologically degraded areas, require the smallest amount of land and meet ecological goals in balance with projected mining development. We developed methods for regional terrestrial conservation planning that address the scope and scale of the 510,000 km$^2$ study area using available data. The result is an information system and landscape level decision-making framework to balance conservation, development, and land use.

The portfolio and underlying information system are intended to support a range of applications to conservation and management of natural resources, including:

- Protected Area Design and Management: As noted above, the Master Plan for Mongolia's Protected Areas (1998) established a goal of designating 30% of the country's land as national and local protected areas. Resolution #13 of the Parliament of Mongolia (2008) specified that national protected areas will cover 15% of Mongolia and local protected areas will conserve an additional 15%. Today, Mongolia contains 90 national protected areas that cover about 27.2 million hectares or 17.4% of the country (Namkhai and Myagmarsuren 2012). At the National- and the Aimag-level, the results of this study support 1) new designations to meet the Mongolian government's goal of protecting 30% of natural habitat, and 2) the development of priorities and strategies for improving management effectiveness of existing protected areas.
- Identify conflicts between development and conservation: By identifying potential conflicts between development and conservation goals, pro-active steps can reduce conflict and meet both development and conservation goals.
- Mitigating mining and energy development impacts: Providing a framework to implement the mitigation hierarchy promotes science-based and well-informed decision-making about impact avoidance, appropriate impact mitigation practices, and compensatory mitigation (offsets).
- Offset design: Understanding conservation values in the context of existing and potential cumulative impacts provides the necessary foundation for designing offsets that can contribute effectively to landscape conservation goals in the face of development.
- Land use planning: The conservation portfolio and supporting information can guide land use zonation at National, Aimag and Soum levels. The regional maps of habitat types, herder household density and other land use can inform grazing management and coordination of pasture use to maintain range condition and minimize competition and conflict with wildlife, and specifically to identify and manage of pasture reserves (more discussion in Section 3.1.5).
- Basis for iterative improvements in surveys, research, and our understanding of ecological systems and processes: Vegetation and ecosystem maps and species habitat distribution models can inform the design of surveys for species or vegetation. Survey results can then provide basis for revising the vegetation and ecosystem maps and species distribution models.



# 2.0 METHODS & RESULTS

## 2.1 OVERVIEW

Our objective was to identify a portfolio of sites that support native biodiversity and ecological processes representative of the Mongolian Gobi. To define biodiversity elements, we developed a terrestrial ecosystem classification that maps 193 types. We designed the portfolio to meet the following criteria.

- **Representation:** Meet goals for a specified number or amount of each biodiversity element required to maintain ecological and evolutionary potential over time. We defined biodiversity elements with the terrestrial ecosystem classification and set representation goals as a fraction of the geographic distribution of each ecosystem type across the study area.
- **Ecological Condition:** Within limits of knowledge and available data, ensure that the selected areas contain biodiversity elements that have the highest relative viability or ecological integrity, as measured by an index of disturbance from human impacts.
- **Efficiency:** The portfolio contains the least area and number of sites necessary to meet biodiversity goals, with some redundancy to withstand current and future threats.
- **Connectivity:** Where possible, select adjacent planning units in contiguous groups, following the general principle that a portfolio consisting of fewer, larger contiguous sites is preferable to one consisting of many, smaller sites.

We designed the portfolio through several steps or components, listed below and described in detail later in the report.

Step 1: **Assemble a working group.** We convened experts and stakeholders to advise and review the planning process, forming two working groups focused on science and policy. The science advisory group consists of biologists and geographers with expert knowledge of the study area and available data, and was responsible for advising data development and reviewing results. The science advisory group reviewed data development and analyses at several intervals during the course of the study, including at three team meetings and many informal interviews. The policy advisory group consists of senior managers in government and NGOs with knowledge and expertise regarding implementation strategy. The dates and topics of the working group meetings and the stakeholder outreach meetings are listed in Appendix 7.

Step 2: **National Protected Areas.** We delineated the boundaries of all National-level protected areas within the study area, including strictly-protected areas, national parks, national monuments, and nature reserves, but excluding buffer zones. These areas served as the foundation, or starting point, for portfolio design.

Step 3: **Other priority conservation areas.** We delineated other priority conservation areas, including Important Bird Areas (IBAs), with some changes described below, and the Tost Uul local protected area. We selected these areas, in combination with National Protected Areas, as the foundation, or first sites, to include in portfolio design.

**Tost Uul local protected area**. Tost Mountain and the Toson Bumba mountain range (Gurvantes Soum, Omnogovi Aimag) support a high density of endangered Snow leopards (*Panthera uncia*) and their prey, especially Ibex (G. Tsogtjargal, Tom McCarthy, Rodney Jackson pers. comm.). In 2010, this area was designated as a local protected area by Tost, Govoot and Urt bags, and it has been proposed for designation as a National Protected Area.

**Important Bird Areas (IBAs).** The study area includes ten areas designated by Bird Life International that support globally threatened species, restricted-range species, biome-restricted assemblages or large congregations (Nyambayar & Tseveenmyadag 2009). We list these areas below. All but three (Bulgan River, Galba Gobi, Borzon Gobi) lie entirely within National Protected Areas. For two IBAs, the Galba Gobi and Bulgan River, we excluded sections that contain disturbed habitat according to the disturbance index (Section 2.4) as described below.

- Bulgan River: includes the Bulgan River floodplain in Bulgan River Nature Reserve and 320 km$^2$ upstream. NOTE: a section upstream contains the Bulgan Soum center and a high concentration of winter households (approx. 85 households in a 40 km$^2$ area), and thus we did not include this area in step 4 (below).
- Ikh Bogd Mountain: inside Ikh Bogd Nature Reserve
- Govi Gurvan Saikhan Mountain: inside Govi Gurvan Saikhan National Park
- Borzon Gobi: most lies in Small Gobi A Strictly Protected Area (SPA)
- Galba Gobi: spans the eastern part of Small Gobi A SPA and western part of Small Gobi B SPA. Note: the area between the two SPAs is bisected by a high-traffic road carrying coal from Tavan Tolgoi mine to the Gashuun Sukhait border crossing, a parallel national highway under construction that will support the Oyu Tolgoi mine and a recently constructed transmission line. Two mining application leases, for the Tsagaan chuluut and Shar chuluut mines, also lie along the Oyu Tolgoi road corridor. We did not include this section in step 4 (below), but the Science Advisory Group did designate it in step 6 (below).
- Ikh Gazriin Chuluu: inside Ikh Gazriin Chuluu Nature Reserve.
- Ikh Nartiin Chuluu Nature Reserve.
- Three IBAs (Boon Tsagaan Nuur, Taatsiin Tsagaan Nuur, Orog Nuur) lie at the north edge of the study area, and are part of a RAMSAR site (Valley of Lakes; Ramsar 2011). Small sections of two of these IBAs lie within the study area.

Step 4: **Site selection for ecosystem representation**. Through a GIS analysis, we identified a set of areas that, in combination with National-level PAs, IBAs and the Tost Uul local protected area, would meet representation goals for ecosystems. This analysis involved three main components:

First, develop a GIS to **represent biodiversity elements**, specifically a terrestrial ecosystem classification to define and map terrestrial habitat types based on a hierarchy of biogeographic zones, ecosystem types based on vegetation, and landforms, as described in section 2.2.1.

Second, develop an **index of ecological disturbance** derived from spatial data representing current human impacts, to identify areas that are ecologically degraded and areas with competing economic values, such as high livestock use, as described in section 2.4.

Third, conduct **site selection** using a conservation planning software (MARXAN), to identify a set of planning units that, in combination with National-level PAs and selected IBAs, meets representation goals for ecosystems in a configuration that optimizes for ecological condition and connectivity (contagion), as described in sections 2.5 – 2.8.

Step 5: **Re-design to minimize conflict with planned mineral development**. We examined areas of the conservation portfolio with high potential for future development. To represent future development pressure, we mapped all mining leases (active, application and exploration) within the study area. Areas of conflict or intersection between the portfolio and mineral leases were re-designed as follows. Conflict areas with high biological value and habitat value, as defined by a combination of metrics described in sections 2.7 – 2.8, were designated as areas to avoid development. The remaining conflict areas were removed from the portfolio, and replaced with sites of similar composition and condition outside existing leases.

Step 6: **Expert review**. Because GIS site selection (steps 4 and 5) depends on existing data that is coarse and incomplete, expert review and input is an essential step in portfolio design. Through a series of meetings between January – March 2013, members of the Science Advisory Group met to review the site selection and designated 17 additional sites based on their expert opinion from decades of field work in the region (Figure 21, Appendix 5). This set includes five proposed PAs identified by WWF for the National Gap Assessment (Chimed-Ochir et al. 2010) that the MEGD adopted for formal protection.

## 2.2 BIODIVERSITY ELEMENTS

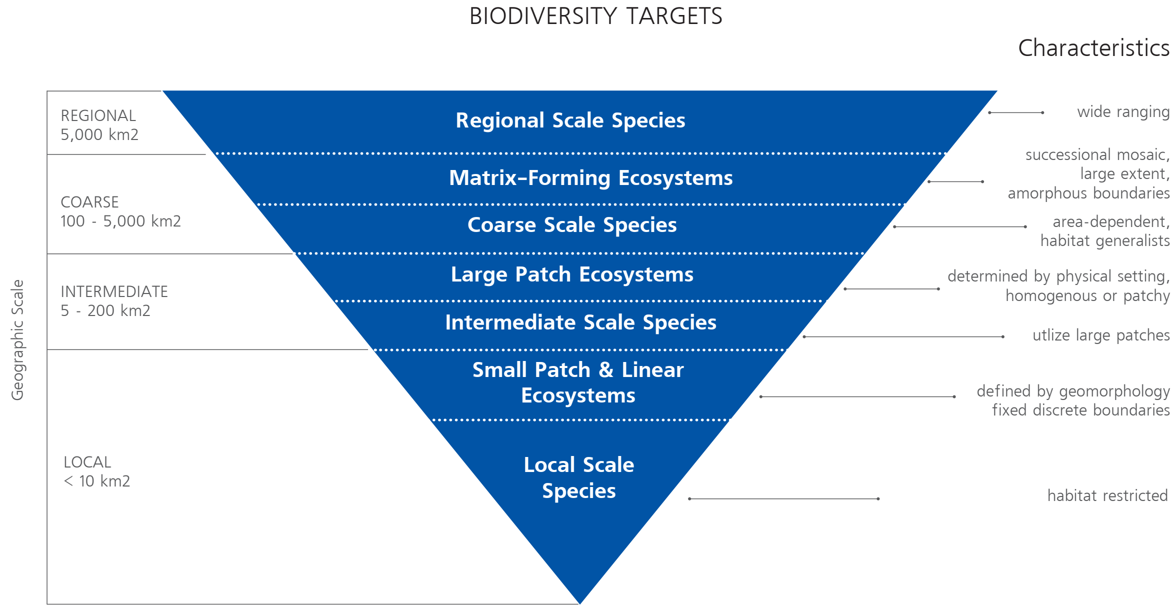
The essential feature of systematic conservation planning is clear articulation of a biodiversity vision that incorporates the full range of biological features, the distribution of those features, and the minimum needs of each feature to maintain long-term health and viability. Given the complex organization of biological systems and the limits of existing data and knowledge, it is neither feasible nor desirable to individually analyze the many thousands of biodiversity elements for a given region. Therefore, we must select an effective representative subset of species and environmental features, or biodiversity elements, that best represents the broad range of native biodiversity and for which

data exists to map current distributions. Biodiversity is expressed at a variety of spatial scales and ecological levels of organization. Therefore, a comprehensive regional vision must consider spatial scales and levels of organization from species to ecosystems (Noss 1996, Margules and Pressey 2000, Groves 2003). Biodiversity elements are often organized by spatial scale in a framework created by Poiani et al (2000) that defines local, intermediate, coarse and regional scales (Figure 4).

Regional conservation plans often apply a 'coarse filter/fine filter approach' to define biodiversity elements. This includes treatment of all ecosystem types (the coarse-filter) and a sub-set of natural communities and species which will not be well represented by ecosystems alone (the fine filter), such as those that are rare, with highly specific habitat requirements, or are migratory over long distances (Groves et al 2002; Groves 2003). The coarse-filter premise is that conserving representative ecosystems conserves many common species and communities, species that are unknown or poorly sampled, and the environments in which they evolve (Jenkins et al 1976, Hunter 1991). A sole focus on species is not adequate because species sampling data does not represent the environmental matrix and broad-scale processes necessary to maintain habitat.

This coarse filter/fine filter approach has ecological advantages in that it considers multiple scales of organization, environmental patterns and processes that influence habitat structure and function. Choosing elements that represent the range of environmental gradients and settings addresses the dynamic nature of ecosystems and the uncertain impacts of climate change (Hunter 1988, Halpin 1998, Groves 2003, Beier & Brost 2010, Anderson & Ferree 2010).
This approach also has practical advantages in that it makes the best use of available data to represent the full range of representative biodiversity with a practical number of elements. Our knowledge regarding species ranges and habitat needs will always be incomplete. As coarse filter elements, ecosystems can often be mapped with available GIS data. This alone provides a basis for conservation planning and fills a significant information gap. Fine-filter species and natural community data are typically more limited and dependent on survey effort, and therefore vary in geographic coverage. Thus, the coarse but geographically consistent ecosystem classification complements the locally accurate but uneven coverage of species data.
To define and map coarse-filter biodiversity elements, we developed an ecosystem classification based on biogeographic zones, vegetation, and geomorphology. Fine-filter elements include 33 species of mammals, herptiles, and birds listed as endangered, threatened, vulnerable or near threatened in the National Red Lists (Gombobaatar et al. 2011, Clark et al. 2006, Terbish et al. 2006) (Table 3).
To map the habitat and distribution of these 33 species, we developed species distribution models based on literature and available observation records. Because the models are based on literature and limited data, and the results are mapped using coarse GIS data, the results represent working hypotheses regarding the distribution and habitat selection of these species.

**Figure 4:** Selecting focal biodiversity elements: Spatial scales and Biodiversity elements (adapted from Poiani et al. 2000)




## 2.2.1 Terrestrial ecosystem classification

The terrestrial ecosystem classification is organized as a hierarchy of biogeographic zones, terrestrial ecosystems based on vegetation and geomorphology, and landforms. This classification defines 193 types (Tables 1 and 2). Several vegetation maps have been developed using Landsat 5 TM images for National Protected Areas in the Gobi study area (Wesche et al. 2005, von Wehrden and Wesche 2006, von Wehrden et al. 2006, 2009). However, given the goal of developing a single consistent map of habitat and vegetation across the large study area over a short time frame, a Landsat-based approach was not feasible. Instead, we used a combination of datasets and methods. To map steppe and desert at a coarse scale, we classified satellite imagery (MODIS 13A3 NDVI at 1km resolution; NASA 2012) based on field surveys of plant communities. To map patch-forming systems including dense vegetation around oases, dry riparian areas and ephemeral water bodies at a fine scale, we combined a DEM-derived hydrologic model (78m resolution) with several remote sensing indices (Landsat 5 TM at 30 m resolution).

## Tier I: Biogeographic zones

Biogeographic zones represent broad, regional patterns of climate, physiography and related variation in species and genetics. For most ecosystem types distributed across the study area, stratification by biogeographic zone captures regional differences in species composition and environmental patterns, and ensures that site selection will include multiple occurrences that are geographically distributed across the study area. This geographic redundancy provides some insurance against local extinctions caused by disturbance events such as climate extremes, disease and/or invasive species. To define and map biogeographic zones for this study, we chose the four ecoregions delineated by the National Gap Assessment (Chimed-Ochir et al. 2010): Eastern Gobi, Gobi-Altai, Southern Gobi-Altai and the Dzungarian Gobi (Figure 1). To capture the unique biogeography of the Trans-Altai Gobi in southwestern Mongolia (N. Batsaikhan pers. comm.), we further divided the Southern Gobi-Altai ecoregion based on the Trans-Altai Gobi Landscape-Ecological zone delineated by Vostokova and Gunin (2005).

## Tier II: Terrestrial ecosystems

Ecosystems are generally defined as a biotic component (vegetation) and abiotic component (physical environmental features and processes) and occur at distinct spatial scales and in patterns driven by the underlying physical processes. We defined and mapped ecosystems at two levels, or spatial scales. First, matrix-forming types, such as desert steppe, are broadly distributed and mapped here according to coarse-scale patterns of annual productivity, elevation and precipitation. Second, patch-forming types, such as oases or wet depressions, form distinct patches and are mapped here at a relatively fine scale based on topography, surface hydrology and satellite imagery. For each ecosystem type, we identified the source data and mapping method (Table 1) and then determined the distribution of each ecosystem type by biogeographic zone (Table 2, Figure 7). Appendix 1 lists the ecological descriptions of the ecosystems types.
Matrix-forming systems cover most of the land area and follow broad patterns of climate and precipitation. These include desert, semi-desert, desert steppe, dry steppe and mountain steppe as described in existing literature (Hilbig 1995, von Wehrden et al. 2006, von Wehrden et al. 2007, Wesche et al. 2005). In the Gobi region, precipitation, vegetation productivity, and the spatial pattern of plant communities are highly correlated (von Wehrden and Wesche 2007). Based on this strong relationship, we developed a predictive model of the distribution of general steppe and desert types based on annual productivity, annual precipitation, and elevation of 1,145 survey records of diagnostic plant communities collected by von Wehrden et al. (2009) and Wesche et al. (2005). In this case, productivity is represented by the 11-year (2000-2011) mean Normalized Difference Vegetation Index (NDVI) during the growing season (June through September), derived from MODIS satellite imagery (MODIS 13A3, NASA 2012). The precipitation values are 50 year monthly averages from WorldClim (Hijmans et al. 2005). Based on the results (Figure 5), we chose NDVI thresholds to map the predicted distribution of the following matrix-forming vegetation types:

- barren: virtually no vegetation
- extreme arid desert: diagnostic species is Iljinia
- true desert: characteristic desert shrubs, Haloxylon and Rheaumaria, dominate.
- semi-desert: grasses appear, mixed with desert shrubs.
- steppe and desert wetland vegetation: Stipa grasses dominate, desert shrubs disappear.

To further distinguish three steppe types (desert-, dry- and mountain-) and large patches of dense wetland vegetation, we developed a set of decision rules based on annual NDVI, elevation and annual precipitation (Hijmans et al. 2005).

Patch-forming systems include five general types and sets of mapping methods, described below. All of these are groundwater-dependent systems that have disproportionately high biological value for wildlife, livestock and people, with sparse and patchy distribution following groundwater hydrology. These systems support high species diversity and provide critical habitat, particularly for small mammals, reptiles and birds, and provide valuable forage for large desert mammals.

*i.* *Wet depressions*: dry river beds or salty depressions with shallow water table following broad drainage patterns. These areas typically support distinct vegetation types including Saxaul (*Haloxylon ammodendron*)

forests and Siberian elm (*Ulmus pumila*) and contain physically diverse soil types due to near-surface groundwater and hydrology. Because of the relatively high productivity and structural diversity of vegetation and soils, these areas also often support high diversity of small mammals and reptiles (N.Batsaikhan pers. comm.). We mapped these features using a GIS topographic model that delineates potential riverine wetlands based on regional flow accumulation and local topography of the stream channel, as derived from a digital elevation model (Lehner et al. 2008) at 3-second (77m) resolution.

ii. *Dense vegetation*: large patches of closely-spaced tall shrubs and trees, typically near oases, including Tamarisk (*Tamarix ramosissima*), *Populus diversifolia*, Elm and Saxaul. We mapped these features with a vegetation index derived from satellite imagery. First, we compiled and processed 54 Landsat 5 TM satellite scenes to cover the study area (NASA 2011). The acquisition date for most scenes was between June 15 and September 28, 2011. For six scenes, the best available image was acquired in 2010. Pre-processing included an atmospheric correction algorithm, tasseled cap transformation (ERDAS 1999) and calculation of the Soil-Adjusted Total Vegetation Index (SATVI; Marsett et al 2006). The SATVI was developed specifically to measure biomass of aridlands vegetation. Dense vegetation in an arid desert setting produces distinct high SATVI values (Figure 6). We classified areas with high SATVI values as dense vegetation. Finally, we separated the result by likely water source or hydrology into patches occurring in either a) dry stream beds and wet depressions (described above), or b) spring-fed seeps (remainder).

iii. *Ephemeral water bodies*: we digitized the boundaries and point locations of water bodies through manual interpretation of the 2011 Landsat 5 TM satellite imagery described above. The tasseled cap transformation produces a 3-band image that improves the contrast between bare ground, water, and vegetation. The resulting image is useful for classification and manual interpretation of landscape features. Using the transformed images, we digitized over 1,200 water bodies on-screen at 1:200,000. Because precipitation was relatively high during the summer of 2011, many ephemeral water bodies had surface water and were more visible in the Landsat imagery.

iv. *Sand massives:* large areas of sand dunes that we digitized manually from 1:200,000 topographic maps. The unique hydrology of sand dunes often creates small wetlands that support distinct plant communities and habitat with high species diversity.

v. *Mountain valleys:* mapped as valley bottoms, per the landform classification (described below), in mountain steppe or rugged mountain vegetation, per the matrix-forming ecosystem classification.

### Tier III: Landforms

Five matrix-forming ecosystem types – extreme arid desert, true desert, semi-desert, desert steppe and dry steppe – occupy over 80% of the study area as a heterogeneous, patchy matrix of plant communities formed by topography, disturbance regimes and successional cycles. Patterns of plant species composition within these matrix-forming ecosystems generally follow topographic environmental gradients. To capture this ecological, environmental and genetic diversity, we stratified these widespread steppe ecosystem types by landforms. We defined and mapped landforms according to a cluster analysis of a topographic soil moisture index (Moore et al. 1991), insolation (Rich et al. 1995) and terrain ruggedness (Sappington et al. 2007) (Table 2, Figure 8).

**Figure 5:** Vegetation classification based on productivity and the distribution of plant communities. This box plot shows the distribution of plant community survey records (n=1,145; von Werden et al. 2006 and Wesche et al. 2005) across the range of 11-year mean NDVI values (MODIS 13A3, NASA 2012). Based on the distribution of several diagnostic plant communities, we classified 11-year mean NDVI to map general vegetation types.

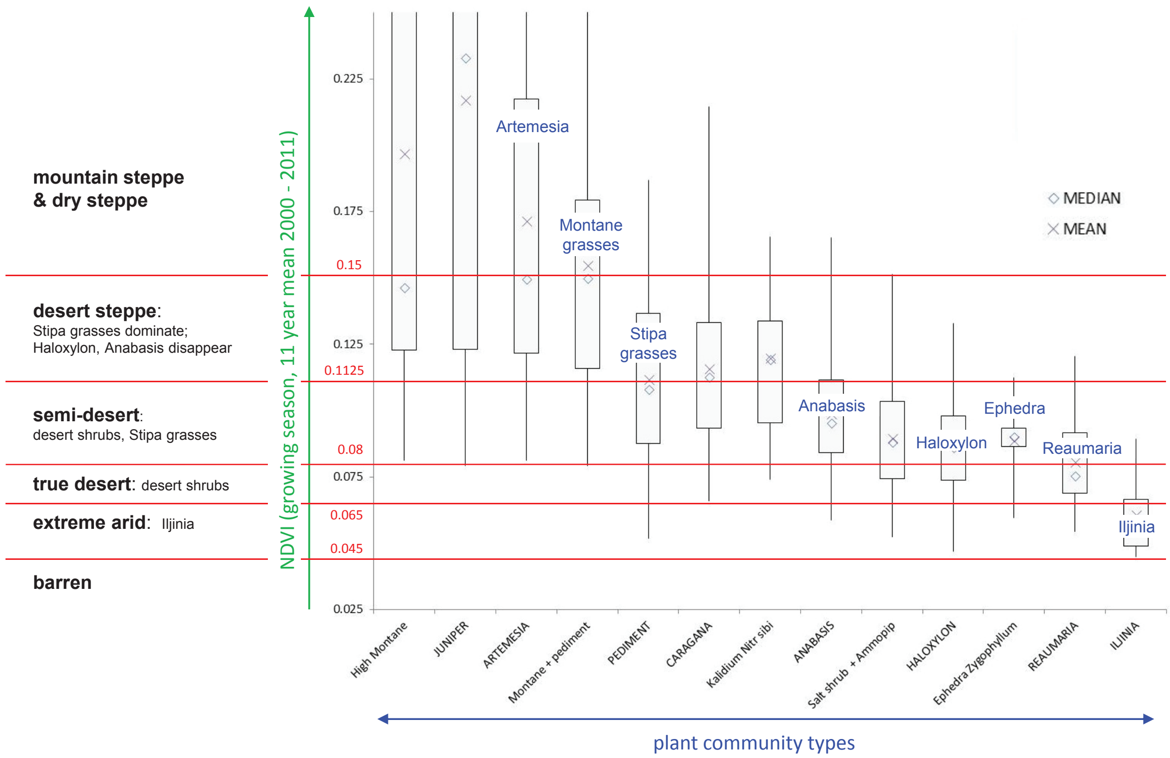



**Figure 6:** The Soil-Adjusted Total Vegetation Index (SATVI), derived from Landsat 5 TM imagery (NASA 2011), was designed for mapping aridlands vegetation. We classified SATVI to map patches of dense vegetation that typically occur around oases and areas with near-surface groundwater. SATVI may also be used to measure biomass, and biomass changes in response to groundwater changes, as described in Appendix 6.

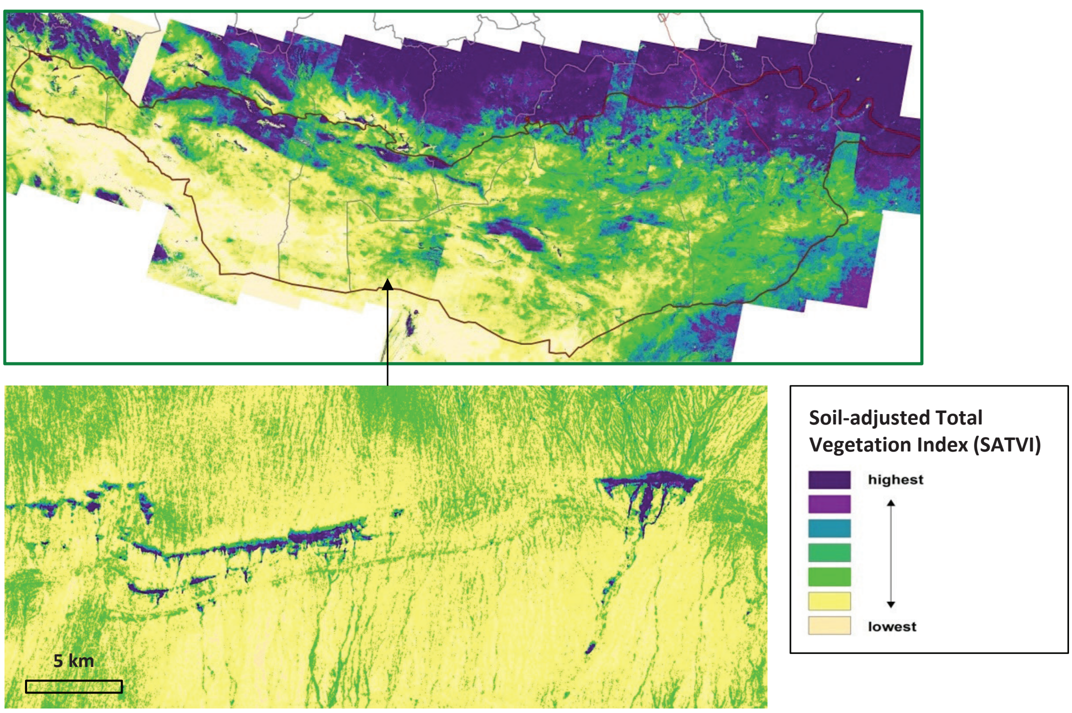


**Table 1: Terrestrial Ecosystem Classification: Source datasets and mapping methods.** The ecosystem classification is organized as a hierarchy of (i) biogeographic zones, (ii) ecosystem types based on vegetation and (iii) landforms. The result is 193 unique types.

**i. Biogeographic Regions** (WWF National Gap Assessment - Chimed-Ochir et al. 2010)

Djungarian Gobi

Gobi-Altay

Southern Gobi

Eastern Gobi

Trans-Altai Gobi - Dr. N. Batsaikhan pers. comm. Digitized from Vostokova EA & Gunin PD (2005).

**ii. Ecosystem Types**

**Matrix–forming systems** follow broad patterns of climate and precipitation.

| | |
|---|---|
| barren<br>extreme arid *<br>true desert *<br>semi desert *<br>desert steppe *<br>dry steppe *<br>mountain steppe<br>mountains rough terrain | • 1,145 vegetation survey records of plant community types (von Wehrden et al. 2009, Wesche et al. 2005) to classify NDVI according to vegetation types.<br>• NDVI: satellite imagery (1 km resolution) measuring vegetation biomass during the growing season (June – September), covering 11 years (2000-2011; MODIS 13A3, NASA 2012).<br>• annual precipitation (50 year mean – Hijmans et al. 2005) |

**Patch–forming systems** follow finer-scale pattern of soil moisture, drainage and microclimate.

| | |
|---|---|
| Wet depressions: dry river beds or salty depressions with shallow water table following broad drainage patterns | |
| small basins (drainage area < 1,000 km²) | • DEM-derived topographic model at 3-arc second (78m) resolution. |
| large basins (drainage area > 1,000 km²) | |
| Dense vegetation: large patches of closely-spaced tall shrubs and trees, typically near oases, including Tamarisk, *Populus*, Elm and Saxaul | |
| seeps: spring-fed | • Soil-adjusted total vegetation index (SATVI) from Landsat 5 TM satellite imagery (July -September 2010 and 2011). |
| riparian: shallow water table | |
| ephemeral water bodies | • digitized manually from Landsat 5 TM satellite imagery |
| sand massives | • digitized manually from 1:200k topographic maps |
| mountain valleys | |

**iii. Landforms** capture finer-scale variation in plant communities following patterns of soil moisture and microclimate. They are used here to stratify five matrix-forming ecosystem types ( * labeled above).

| | |
|---|---|
| rough steep N-facing<br>rough steep S-facing | mapped by cluster analysis of three DEM-derived topographic indices at 3-arc second (78m) resolution: |
| hills N-facing | • Topographic moisture index (CTI; Moore et al. 1991) |
| hills S-facing | • Insolation (SolarFlux; Rich et al. 1995) |
| upland | • Terrain ruggedness (VRM; Sappington et al. 2007) |
| low flat | |
| depression | |
| valleys water tracks | |

**Table 2: Terrestrial Ecosystem Classification: area distribution.** This table lists the area distribution of the ecosystem types across the study area and by bio-geographic zone.

| | study area | Dzungarian Gobi | | Southern Gobi-Altay | | Trans-Altai Gobi | | Gobi-Altay | | Eastern Gobi | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | $km^2$ | $km^2$ | % | $km^2$ | % | $km^2$ | % | $km^2$ | % | $km^2$ | % |
| **Matrix-forming types** | | | | | | | | | | | |
| barren | 2,909 | 201 | 1 | 161 | 0.2 | 2,451 | 5 | 95 | 0.1 | | |
| extreme arid | 19,931 | 803 | 3 | 4,749 | 5 | 13,332 | 25 | 823 | 1 | 224 | 0.1 |
| true desert | 50,427 | 2,919 | 10 | 22,306 | 22 | 18,147 | 34 | 5,110 | 6 | 1,943 | 1 |
| semi desert | 176,610 | 13,522 | 48 | 57,254 | 56 | 14,302 | 27 | 27,714 | 33 | 63,816 | 26 |
| desert steppe | 128,654 | 5,691 | 20 | 5,428 | 5 | 697 | 1 | 22,599 | 27 | 94,238 | 38 |
| dry steppe | 57,186 | | | | | | | 24 | 0.0 | 57,163 | 23 |
| mountain steppe | 13,057 | 495 | 2 | 89 | 0.1 | 3 | 0.0 | 12,470 | 15 | | |
| steep mountains | 10,803 | 600 | 2 | 375 | 0.4 | 18 | 0.0 | 9,810 | 12 | | |
| **Patch-forming types** | | | | | | | | | | | |
| wet depressions, small basins | 23,524 | 1,018 | 4 | 5,492 | 5 | 2,811 | 5 | 2,066 | 2 | 12,138 | 5 |
| wet depressions, large basins | 9,145 | 1,114 | 4 | 1,459 | 1 | 703 | 1 | 653 | 1 | 5,216 | 2 |
| dense vegetation – seeps | 1,024 | 19 | 0.1 | 394 | 0.4 | 94 | 0.2 | 206 | 0.2 | 311 | 0.1 |
| dense vegetation – dry river beds | 6,913 | 1,118 | 4 | 739 | 1 | 12 | 0 | 866 | 1 | 4,178 | 2 |
| ephemeral waterbodies | 323 | 7 | 0.0 | 21 | 0.0 | 3 | 0.0 | 64 | 0.1 | 228 | 0.1 |
| sand massives | 11,953 | 373 | 1 | 3,147 | 3 | 90 | 0.2 | 689 | 1 | 7,654 | 3 |
| mountain valleys | 1,104 | 38 | 0.1 | 5 | 0.0 | | | 1,062 | 1 | | |
| total area | 513,544 | 27,917 | 100 | 101,619 | 100 | 52,664 | 100 | 84,249 | 100 | 247,109 | 100 |
| percent of study area | 100 % | 5 % | | 20 % | | 10 % | | 16 % | | 48 % | |

**Figure 7a:** Terrestrial Ecosystem Classification, Western Gobi
The classification approach, mapping methods and source data are described in section 2.2.1. Ecosystem types are described in Appendix 1.

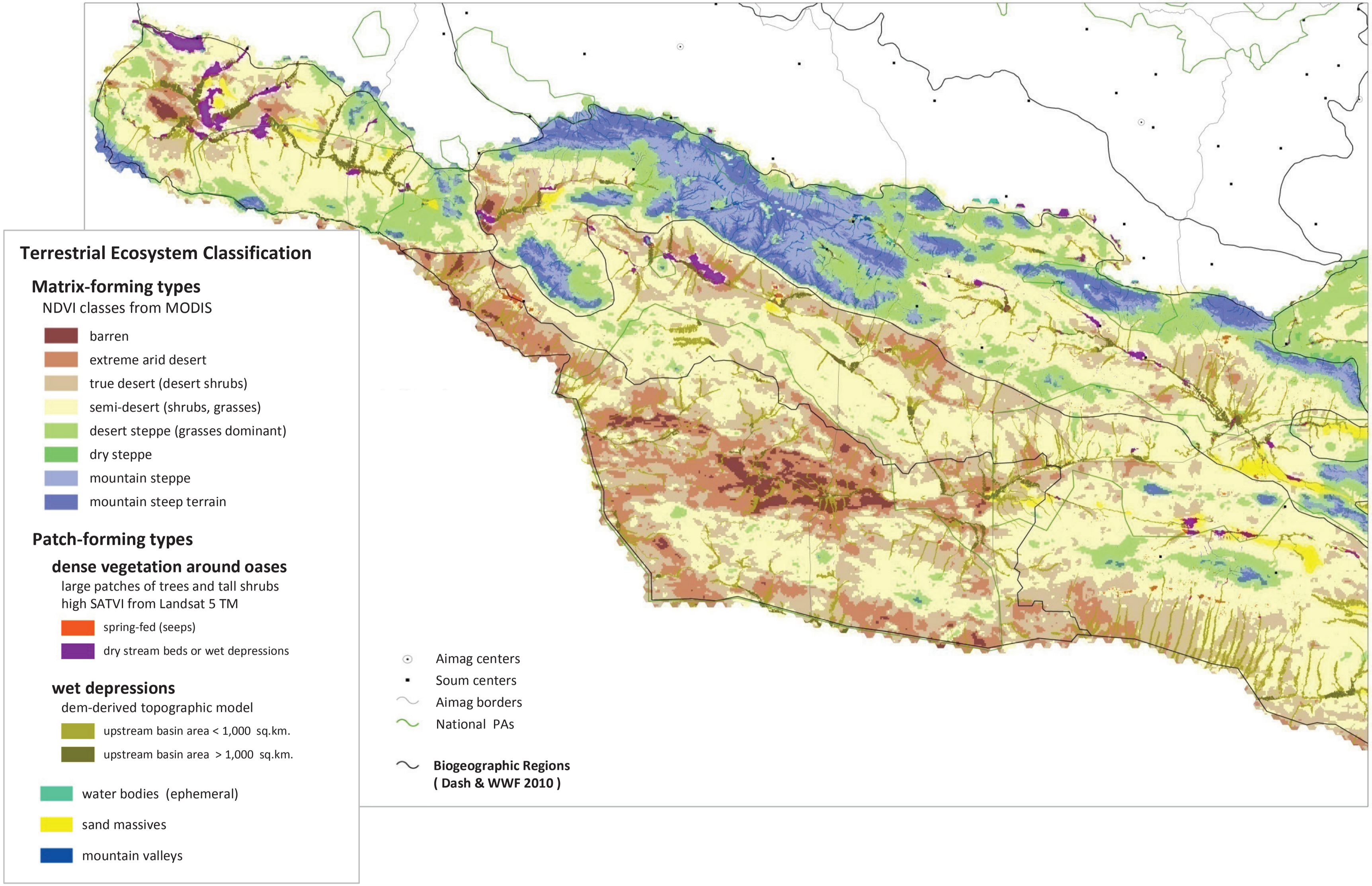


**Figure 7b:** Terrestrial Ecosystem Classification, Eastern Gobi.
The classification approach, mapping methods and source data are described in section 2.2.1. Ecosystem types are described in Appendix 1.

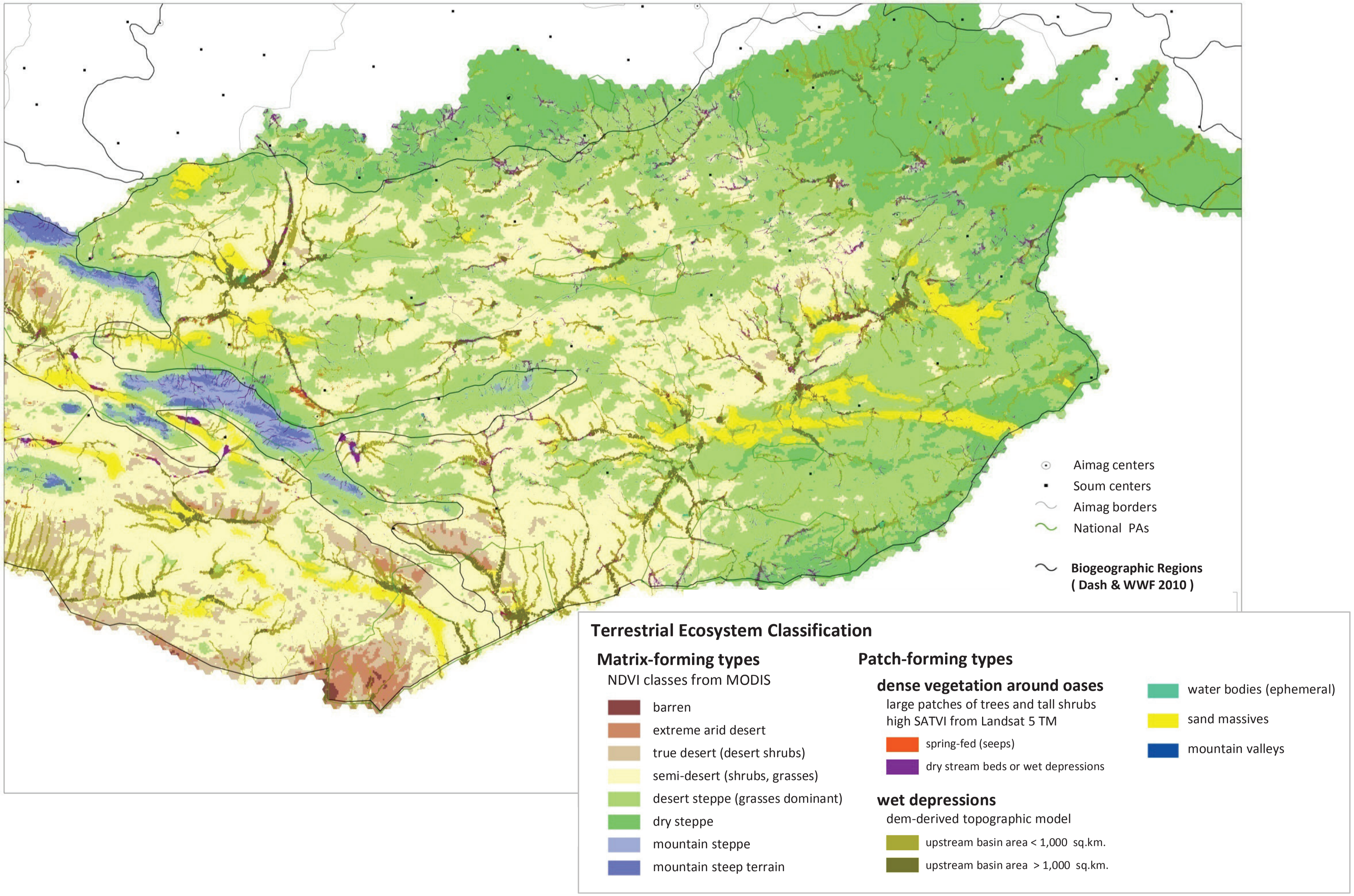


**Figure 7c:** Terrestrial Ecosystem Classification - detail showing patch-forming ecosystem types. The classification approach, mapping methods and source data are described in section 2.2.1. Ecosystem types are described in Appendix 1.

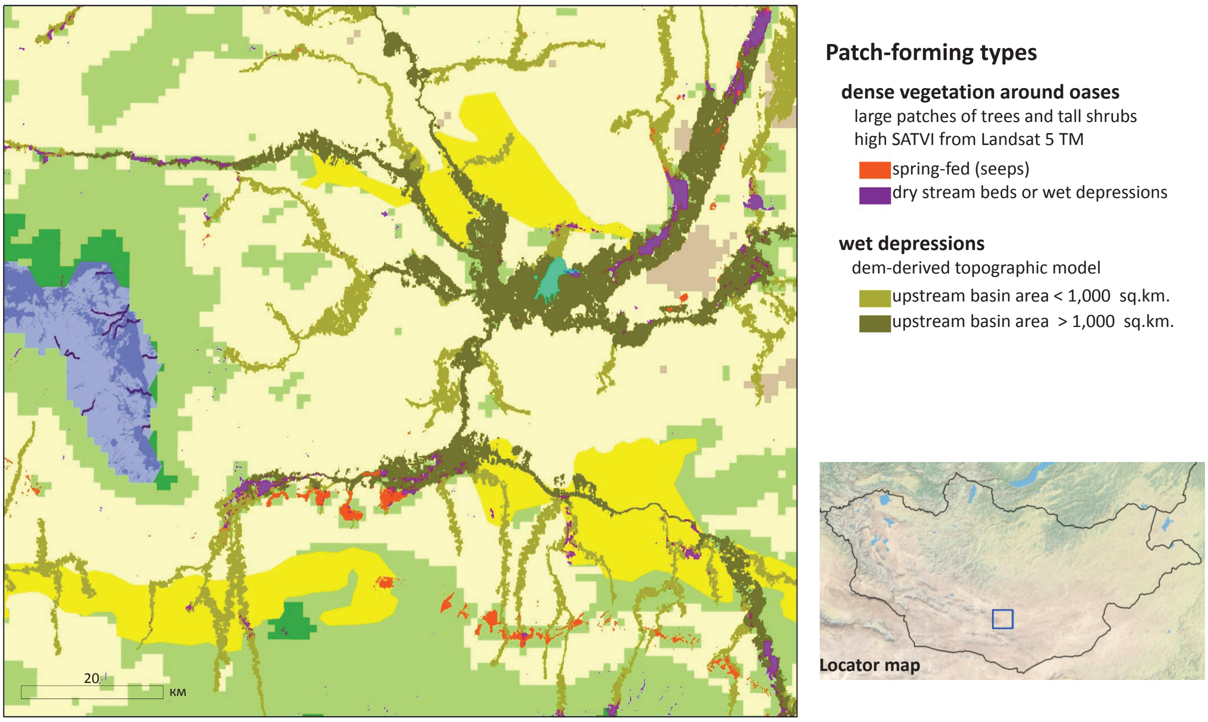
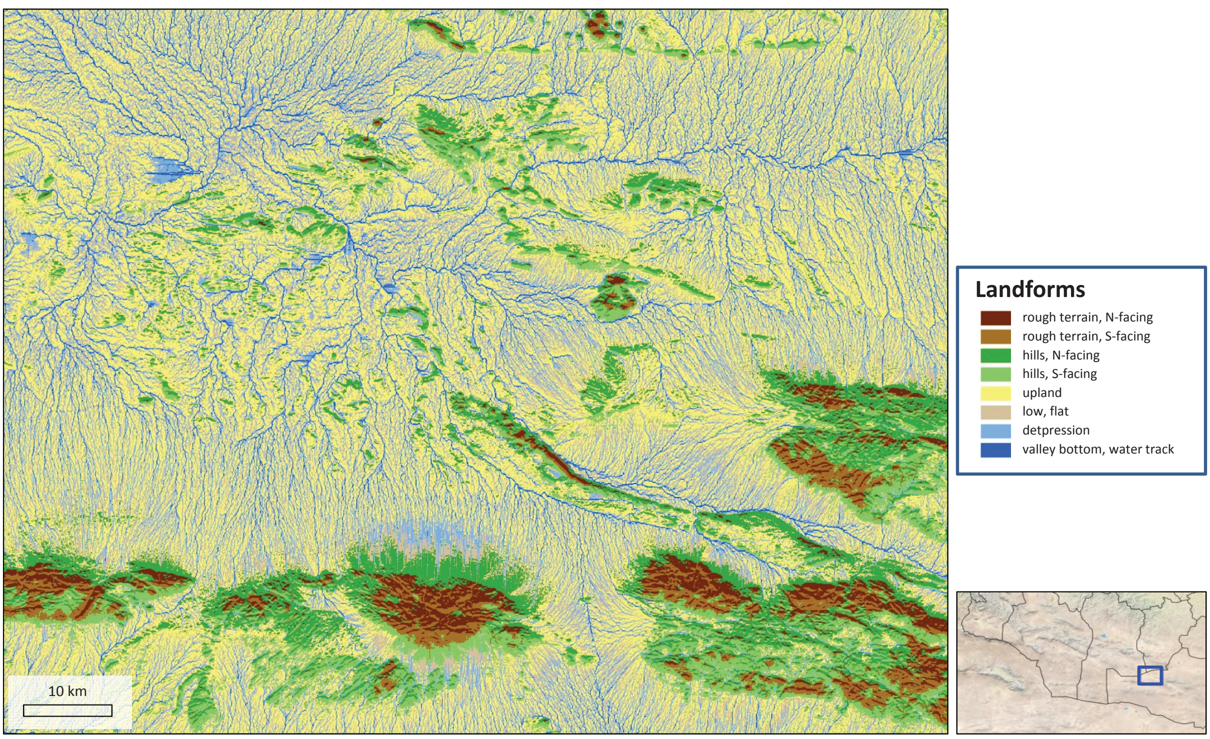



**Figure 8:** Landform classification based on cluster analysis of three DEM-derived topographic indices. The result defines and maps 8 landform types characteristic of the Gobi region. We used this 1) to stratify matrix-forming ecosystem types and 2) in the focal species distribution models.



### 2.2.2 Focal species

To assess the distribution and protection of rare and endangered species, or fine-filter biodiversity elements, we developed GIS models of habitat distribution for 33 species of mammals, herptiles, and birds selected based on threatened status in the National Red Lists (Table 3) (Gombobataar et al. 2012, Clark et al. 2006, Terbish et al. 2006). Most of the habitat models are deductive models based on habitat descriptions in literature and map units in the ecosystem and landform classifications. Three models are inductive (data-derived statistical) models based on analysis of survey records and habitat selection (see Appendix 3).

We compiled existing survey records from the following sources:

- amphibians and reptiles: Dr. Kh. Terbish (NUM)
- large mammals: G. Tsogtjargal (MAS), Ya. Adiya (MAS), B. Munkhtsog (MAS), B. Lkhagvasuren (MAS), Yad. Adiya (MAS)
- small mammals: Dr. N. Batsaikhan (NUM)
- vegetation: Dr. D. Suran (NUM), Dr. D. Zubmerelmaa (MAS), Dr. D. Ariungerel (Mercy Corps)

We also conducted a literature review to find information describing habitat preferences and distribution. Because there are relatively few published studies describing habitat of the focal small mammals, reptiles, and birds in Mongolia, we asked several experts for written summaries of the ecology and habitat of focal species, as follows.

- amphibians and reptiles: Dr. Kh. Terbish (NUM)
- birds: Dr. N. Tseveenmyadag (MAS)
- mammals: Dr. N. Batsaikhan (NUM), G. Tsogtjargal (MAS)

## 2.3 REPRESENTATION GOALS

Choosing a preliminary set of quantitative representation goals is an elementary step in any portfolio design, and necessary for optimized site selection. Quantitative goals provide transparent, flexible measures of representation and progress that are essential to the iterative, adaptive process of portfolio design, review, data collection, analysis, and revision (Carwardine et al., 2009). The representation goals that we chose for ecosystems are based on the goal set by the Mongolia government to protect 30% of natural habitat (Master Plan for Mongolia's Protected Areas, 1998; Resolution #13 of the Parliament of Mongolia, 2008).

Many regional conservation plans have also set coarse filter goals as 30% of historic areal extent (Tear et al. 2005, Groves 2003), based loosely on the species-area relationships derived from studies of island biogeography and "habitat islands" (MacArthur & Wilson, 1967; Dobson, 1996; Groves 2003). Loss of habitat tends, over time, to result in the loss of species within an approximate range. The species/area relationship (Figure 9), adapted from Dobson (1996), suggests that coarse filter representation within the range of 10%-30% of historic extent of each ecosystem type would retain approximately 55%-85% of native species. This relationship may not hold for arid lands, where many species have different range requirements due to the lower productivity and higher variability of habitat.

**Table 3: Focal Species.** To predict the distribution of rare and endangered species, or fine-filter biodiversity elements, we developed GIS habitat distribution models for the 33 species listed below, selected based on National Red List status (Gombobaatar et al. 2011, Clark et al. 2006, Terbish et al. 2006).

| Scientific name | Common name | Red List Status Region | Red List Status Global |
|---|---|---|---|
| **MAMMALS** (19 species) | | | |
| **Small mammals** (Order Rodentia; 11 species) | | | |
| *Spermophilus alashanicus* | Alashan ground squirrel | EN | LC |
| *Dryomys nitedula* | Forest dormouse | DD | NT |
| *Allactaga bullata* | Gobi jerboa | DD | NT |
| *Allactaga elater* | Small five-toed jerboa | EN | LC |
| *Cardiocranius paradoxus* | Five-toed pygmy jerboa | DD | VU |
| *Euchoreutes naso* | Long-eared jerboa | VU | EN |
| *Salpingotus crassicauda* | Thick-tailed pygmy jerboa | DD | VU |
| *Salpingotus kozlovi* | Kozlov's pygmy jerboa | DD | NT |
| *Stylodipus sungorus* | Mongolian three-toed jerboa | EN | EN |
| *Cricetulus migratorius* | Grey hamster | DD | NT |
| *Meriones tamariscinus* | Tamarisk gerbil | EN | LC |
| **Carnivores** (Order Carnivora; 2 species) | | | |
| *Panthera uncia* | Snow leopard | EN | EN |
| *Ursus arctos gobiensis* | Gobi bear | EN | CR |
| **Ungulates** (Order Artiodactyla; 6 species ) | | | |
| *Equus hemionus* | Asiatic wild ass | EN | VU |
| *Camelus bactrianus ferus* | Bactrian camel | EN | CR |
| *Gazella subgutturosa* | Goitered gazelle | VU | VU |
| *Procapra gutturosa* | Mongolian gazelle | EN | LC |
| *Ovis ammon* | Argali | EN | VU |
| *Capra sibirica* | Siberian ibex | NT | LC |
| **AMPHIBIANS & REPTILES** (7 species) | | | |
| *Bufo pewzowi* | Pewzow's toad | VU | LC |
| *Cyrtopodion elongatus* | Gobi naked-toed gecko | VU | NE |
| *Teratoscincus przewalskii* | Przewalski's wonder gecko | NT | NE |
| *Laudakia stoliczkana* | Mongolian agama | NT | NE |
| *Eryx tataricus* | Tatar sand boa | NT | NE |
| *Coluber spinalis* | Slender racer | NT | NE |
| **BIRDS** (8 species) | | | |
| *Chlamydotis undulata* | Houbara bustard | VU | |
| *Ciracaetus gallicus* | Short-toed snake-eagle | EN | |
| *Falco cherrug* | Saker falcon | VU | |
| *Gypaetus barbatus* | Lammergeier | VU | |
| *Passer ammodendri* | Saxaul sparrow | NT | |
| *Podoces hendersoni* | Mongolian ground-jay | VU | |
| *Tetraogallus altaicus* | Altai snowcock | NT | |
| *Aegypius monachus* | Cinereous vulture | | NT |

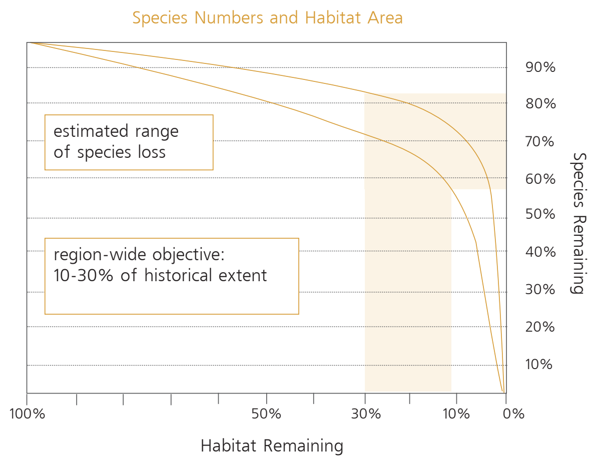
CR Critically Endangered, EN Endangered, VU Vulnerable, NT Near Threatened, LC Least Concern, DD Data Deficient, NE Not Evaluated

Setting goals is a challenge given the limited existing knowledge and supporting data. Few species have been studied thoroughly enough to estimate population size, number of populations, and habitat distribution required for long-term persistence. Therefore, representation goals provide only an initial estimate of the amount and distribution of habitat required to support the long-term persistence of species and ecological processes. We should consider these goals to be working hypotheses that provide the basis for adaptive management. Our intent was to identify a set of areas that represent the full range of habitat and environmental settings with sufficient redundancy to withstand current and future threats. The representation goals in area units ($km^2$) and portfolio composition for all ecosystem types are listed in Appendix 2a.

We did not include species distribution models directly in the site selection analysis and portfolio design. Instead, we measured representation of each focal species habitat in the portfolio post-hoc. Including focal species directly in portfolio design would require setting explicit representation goals for each focal species, which is problematic because 1) most of the distribution models are un-tested and based on limited data and knowledge, 2) goal-setting for species requires some understanding of population viability, and 3) as threatened or endangered species, the practical conservation objective is to maintain or expand the distribution of existing populations.

As mentioned previously, the 30% area representation goal has been widely applied to ecosystems, or general habitat types (coarse-filter elements). However, the 30% area goal is not applicable to Threatened / Endangered (T/E) species. We possess very little data and knowledge about the range of many of the T/E species, in particular small mammals and herptiles, so users should regard the models with caution as they are not reliable for identifying last remaining habitat to protect those species. However, the models do provide a basis for future surveys and an estimate of how much habitat is contained in protected areas and the portfolio (Appendix 2b). Wide-ranging species in particular, such as Khulan, Mongolian gazelle, Goitered gazelle, Argali (*Ovis ammon*) or Snow leopard, require access to their full range, beyond protected habitat cores in nature reserves.

**Figure 9:** Species / Area Curve: Relationship between species numbers and habitat area. Adapted from Dobson (1996).




## 2.4 DISTURBANCE INDEX

To measure cumulative human impacts as an indirect measure of ecological integrity, or departure from historic or natural conditions, we calculated an index of disturbance derived from available GIS data for sources and types of current human disturbance. We used this disturbance index 1) to optimize portfolio site selection for ecosystem occurrences in good condition, 2) to classify modeled species habitat distributions and identify areas where habitat may be degraded and 3) to analyze cumulative impacts across the study area to ecosystem types and habitat, both current and projected (based on mining exploration leases). The components are described below (see also Table 4, and Figures 10 and 11).

- Population centers and associated areas of impact: areas around population centers (Aimag centers, Soum centers, border crossings) are typically overgrazed (Fernandez-Gimenez 2001), and hunting (Wingard and Zahler 2006) and predation and harassment by dogs (Young et al. 2012) are common.
- Road density and railways: Roads have multiple negative impacts on wildlife habitat and habitat use (Trombulak and Frissell 2000). In the Gobi study area, most roads are simply dirt tracks and routes constantly shift. However, drivers use some routes more frequently than others, and several road corridors are designated as highways. We digitized roads from several maps and a road atlas (Monsudar 2009). Though incomplete, the resulting GIS is intended to represent frequently-used routes of vehicle traffic.
- Mines and supporting infrastructure: Aside from the site-level impacts, impacts to vegetation and groundwater can extend far from the mine footprint (pit and infrastructure). Water extraction for mining operations causes drawdown of near-surface groundwater in the local cone of depression, and potentially over large distances depending on groundwater hydrology (Walton 2010). This can affect wells, springs and vegetation productivity, reducing water and forage availability, and impacting groundwater dependent systems such as oases, elm stands and Saxaul forests. Mine operations and high traffic on mining roads also create large amounts of dust that can travel far and affect vegetation growth (Walton 2010). The impacts and movement of dust are well studied (e.g. http://www.roaddustinstitute.org/; http://www.dirtandgravel.psu.edu/Research/research.html).

- Livestock grazing intensity: Livestock grazing can affect plant species composition (Fernandez-Gimenez and Allen-Diaz 2001) and may impact availability and quality of habitat for wildlife, through exclusion and competition (Wingard et al. 2011, Yoshihara et al. 2008, Campos-Arceiz et al. 2004), or by reducing palatable species (Gana Wingard pers comm.). Olson et al. (2011) found that Mongolian gazelle avoid areas near herder households, and high densities of herder households may create barriers to movement and limit access to forage. Hunting (Wingard and Zahler 2006) and predation or harassment by feral dogs (Young et al. 2011, Buuveibaatar et al. 2009) also likely increase with proximity to and density of herder households.

We used the disturbance index in portfolio site selection to maximize selection of undisturbed ecosystems, i.e. those in good ecological condition, and minimize selection of areas with competing economic values, such as areas heavily grazed by livestock. As such, this index functions as a generalized, coarse-scale measure of the relative cost of conservation effort and investment. We also used the disturbance index to classify the modeled distributions of focal species according to disturbance, and identify areas of potentially unsuitable habitat, competition with livestock, or other conflicts. This classification divides the study area into three classes, as follows.

- High disturbance (approximately 5% of the study area with the highest cumulative disturbance index values). Areas in this class include population centers (Aimag centers, Soum centers or border crossings), active mines, and major transportation corridors (highways, mining traffic or railways), or areas that support high density of herder households (more than one household per 3 km$^2$) or some combination of the above.
- Moderate disturbance (approximately 45% of the study area): This class identifies areas more than 5 km from population centers, but with relatively high herder household density and presumably livestock numbers.
- Low disturbance (remaining 50% of the study area): These areas lack roads and infrastructure and contain very low herder household density (less than one herder camp per 60 km$^2$).

To estimate cumulative impacts to ecosystems and focal species habitat, we measured the portion of each ecosystem type and modeled species distribution in each disturbance class and in active or exploration mining leases (Appendix 4). In terms of area affected, oases bear the highest cumulative impacts of all ecosystem types. Within the area mapped as oasis vegetation, 10-20% is classified as highly disturbed, and over 50% is classified as moderately disturbed. Steppe types are proportionally more affected than desert types. The area of mountain, dry and desert steppe vegetation classified as moderately- or highly-disturbed is 80%, 69% and 65%, respectively.

**Figure 10:** Disturbance Index factors and GIS data. The disturbance index was calculated with the GIS data representing sources and types of impacts shown here.

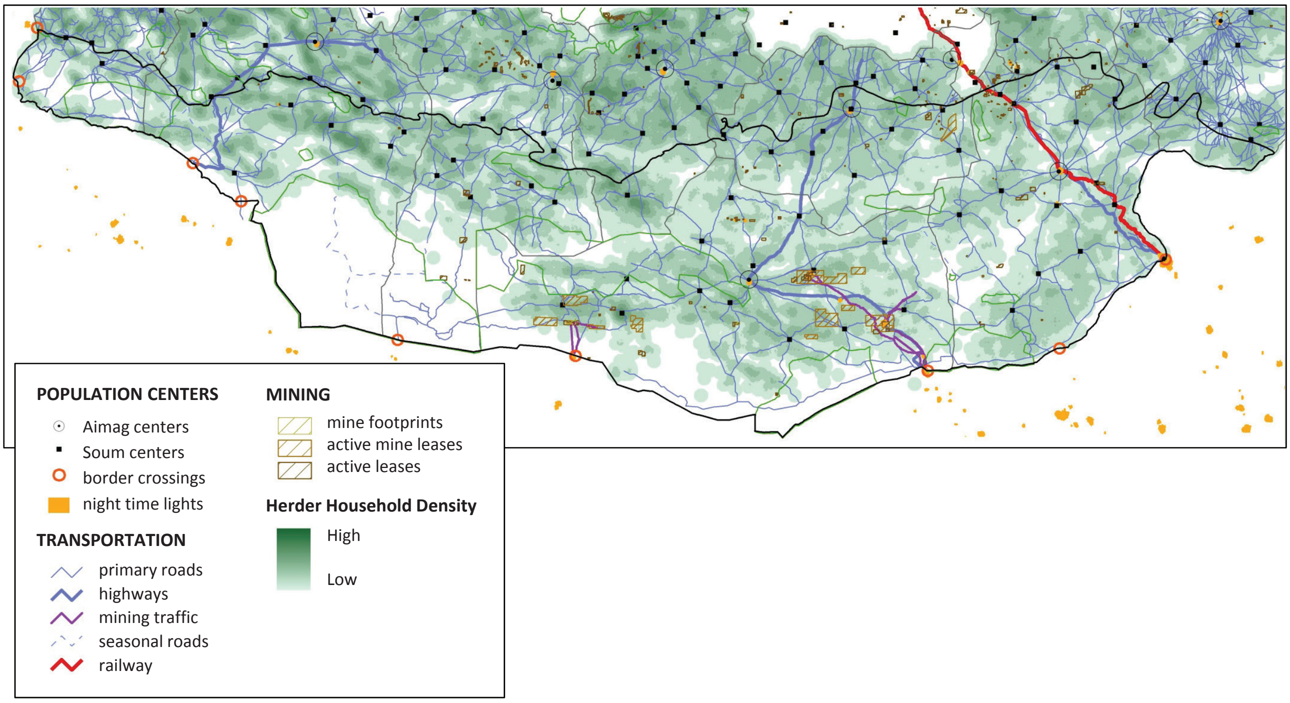



**Figure 11:** Disturbance Index

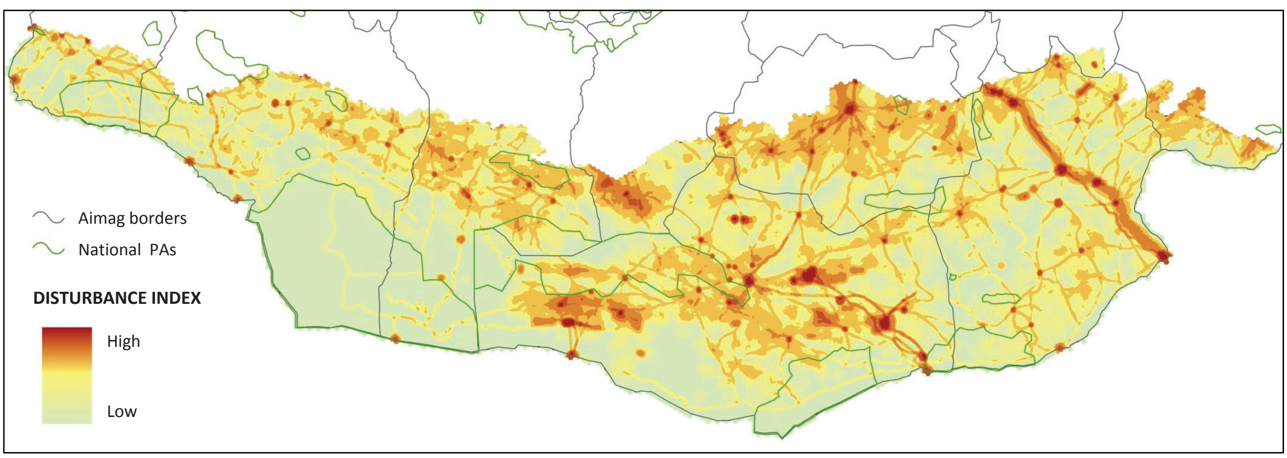


**Table 4: Calculation of the disturbance index.** This table lists the disturbance factors, source data, GIS measurements and the steps followed to calculate the disturbance index.

| **category**<br>factor | **data source** | **GIS measurement** |
|---|---|---|
| **A. population centers** | | |
| 1. Aimag centers | urban land use zones (Edleber) - ALACGC | Euclidean distance, 10km radius |
| 2. Soum centers | urban land use zones (Edleber) - ALACGC | Euclidean distance, 5km radius |
| 3. Border crossings | digitized from road maps (1:1 M scale) | Euclidean distance, 10km radius |
| 4. Night-time lights (indicator of urban or industrial activity) | NOAA 2011 | Euclidean distance, 5km radius |
| **B. transportation** | | |
| 5. primary roads | digitized from road maps (1:1 M scale) | density, 2.7km* radius moving window |
| 6. seasonal roads | digitized from road maps (1:1 M scale) | density, 2.7km* radius moving window |
| 7. highways | digitized from road maps (1:1 M scale) | density, 2.7km* radius moving window |
| 8. mining roads | digitized from Google Earth | density, 2.7km* radius moving window |
| 9. railway | ALACGC | density, 10km radius moving window (the result is similar to a distance-decay function with a 10km radius) |
| **C. mining** | | |
| 10. active mine infrastructure | digitized from Google Earth | density, 5km radius moving window |
| 11. active mine leases | MMRE November 2012 | lease area |
| **D. livestock grazing** | | |
| 12. herder households - summer | ALACGC | density of herder camps (10 km radius moving window) |
| 13. herder households - winter | ALACGC | density of herder camps (5 km radius moving window) |

**Disturbance index calculation:**

i. re-scaled the values of each factor (1 to 13 above) from zero to one.

ii. calculated each disturbance category (A. to D. above) as the sum of the re-scaled factors.

iii. re-scaled each category sum from zero to one.

iv. the disturbance index is the sum of the four re-scaled factors.

* In a review of impacts of roads associated with mining and energy development in grasslands of the Western US, Hebblewhite (2008) reported reduced habitat use within 2.7 – 3.7 km of infrastructure.

## 2.5 ANALYSIS FRAMEWORK

To create a GIS framework for site selection analysis, we divided the study area into approximately 10,550 planning units (PUs) of uniform shape (hexagons) and size (50km²). We then populated this PU framework as follows:

- identified PUs occupied by National PAs, Tost Uul local protected area and portions of IBAs (see section 2.1, Step 3).
- calculated cost/condition value of each PU by summarizing the disturbance index values.
- calculated amount (area or count) of each ecosystem type, by PU.

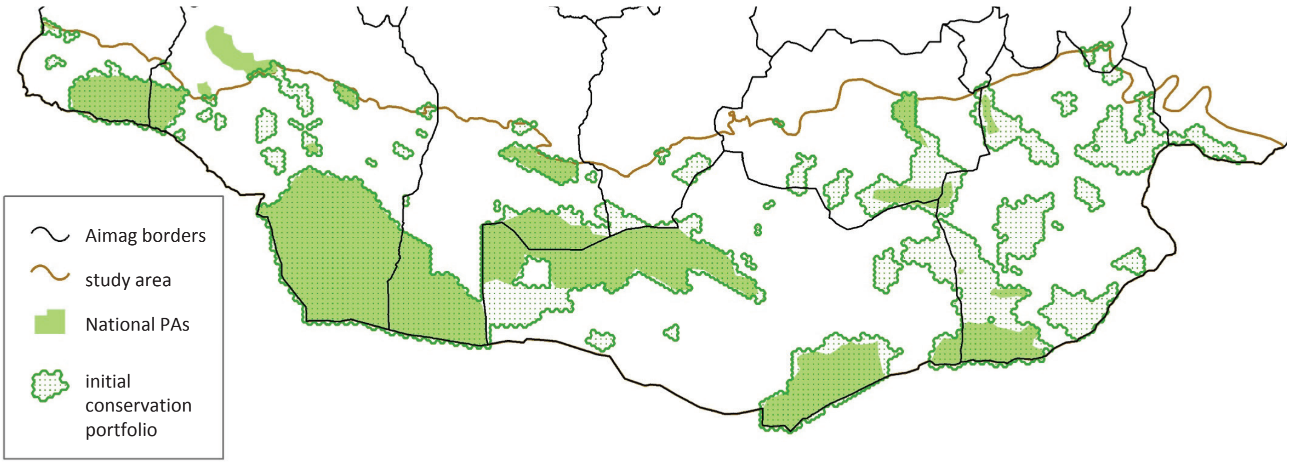
## 2.6 SITE SELECTION

MARXAN is a software package developed for conservation planning that optimizes site selection to meet user-defined representation goals for biodiversity elements, while optimizing for minimal user-defined planning unit cost (Ball & Possingham, 2000; Possingham, Ball & Andelman, 2000). The MARXAN cost function includes an optional connectivity component that provides a cost savings for sites that share a boundary. This has the effect of driving site selection towards configurations that include more connected sites and fewer isolated areas. See Ball & Possingham (2000) and Game & Grantham (2008) for more detail.

In this analysis, the 10,550 hexagons form the planning unit framework. The biodiversity elements are the 193 ecosystem types. We derived planning unit cost from the disturbance index by summarizing disturbance index by planning unit. The National protected areas, Tost Uul local protected area and portions of IBAs were the initial set locked into the site selection optimization, which added planning units to meet ecosystem representation goals. Through MARXAN analysis, we produced a portfolio of sites that included the sites locked-in and that meets the ecosystem representation goals. Simultaneously, the analysis optimized for efficiency and condition (based on the disturbance index), and for configuration that maximized adjacency or contagion among PUs (Figure 12).

For a given set of input parameters (biodiversity elements, goals, cost index, boundary lengths and weighting coefficients), a MARXAN analysis will generate multiple possible solutions and report the results as a 'best solution' and a 'sum of solutions.' Each individual solution is a set of sites identified by the MARXAN algorithm to optimize for the lowest combination of planning unit cost (based on disturbance index), goal shortfall and boundary length. The 'best' solution is the solution with the lowest combined score relative to the other individual solutions evaluated. The 'sum of solutions' is the frequency with which each planning unit was selected. These two results are both useful and serve complementary purposes. The best solution identifies one optimal, efficient configuration of planning units that collectively meets representation goals, while the sum of solutions is a measure of the relative contribution of any planning units towards an optimal solution. Because portfolio design must continually adapt to new data and changing land uses, the sum of solutions is a useful measure of the relative conservation value of any part of the study area and useful for visualizing alternative portfolio designs.

**Figure 12:** Initial portfolio of conservation areas. This shows the initial portfolio of conservation areas selected to include National PAs, Tost Uul CCA and IBAs (Section 2.1.3) and capture 30% area distribution of all ecosystem types (section 2.2.1) in optimal condition (per disturbance index - section 2.4) and configuration (section 2.6).




## 2.7 MEASURES OF BIOLOGICAL VALUE

The sum of solutions is derived from a single set of MARXAN parameters, and a single set of representation goals. Wilhere et al. (2008) designed an index for site prioritization using MARXAN that provides a measure of relative contribution to an optimal solution, but remains independent of a single set of goals. This measure, called optimacity, is calculated as the sum of solutions across the full range of goals, from zero to 100%. Therefore, optimacity measures the relative value of any part of the study area towards an optimal solution, regardless of the representation goal. We calculated optimacity as the sum of the sum of solutions at nine goals levels: 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% and 90% (Figure 13).

Because the optimacity calculation is largely a function of the disturbance index and MARXAN parameters and does not measure rarity directly, we developed a second metric of the conservation value for each PU in terms of the rarity of the biodiversity elements that occur within it. This rarity calculation measures the relative abundance of a given ecosystem type in a given PU compared to its abundance across the study area. This modifies the Relative Biodiversity Index, or RBI (Schill and Raber 2009), by removing the influence of the size of the planning units and standardizing the distribution and range of values. The Rarity value is calculated for each ecosystem occurrence within each PU, and these values are summarized by PU. We chose to rank PUs by the maximum Rarity value occurring in each PU (Figure 14).

The resulting rarity ranking of PUs is a primarily a function of the size of the biogeographic region and the abundance of small patchy ecosystem types. For example, because the Dzungarian region is relatively small, the area distribution of Dzungarian ecosystem types is small relative to the study area, so Dzungarian PUs generally receive higher rarity rankings. Similarly, PUs that contain oasis vegetation, ephemeral water bodies and other patch-forming types also receive higher rarity rankings because patch-forming ecosystem types have relatively small total area distribution. To calculate a combined biological value for each PU, we standardized the values for optimacity and maximum rarity from 0 to 1 , and added the two values. This index of combined biological value is a component of portfolio design and the basis for identifying areas to avoid development.

## 2.8 PORTFOLIO DESIGN

To minimize conflict with planned mineral and oil development, we redesigned the initial portfolio as follows. First, we identified the portions of

**Figure 13:** Optimacity: relative contribution to optimal MARXAN site selection. Optimacity is a measure of value for marxan optimization across all goal levels 0 – 100% (see section 2.7).

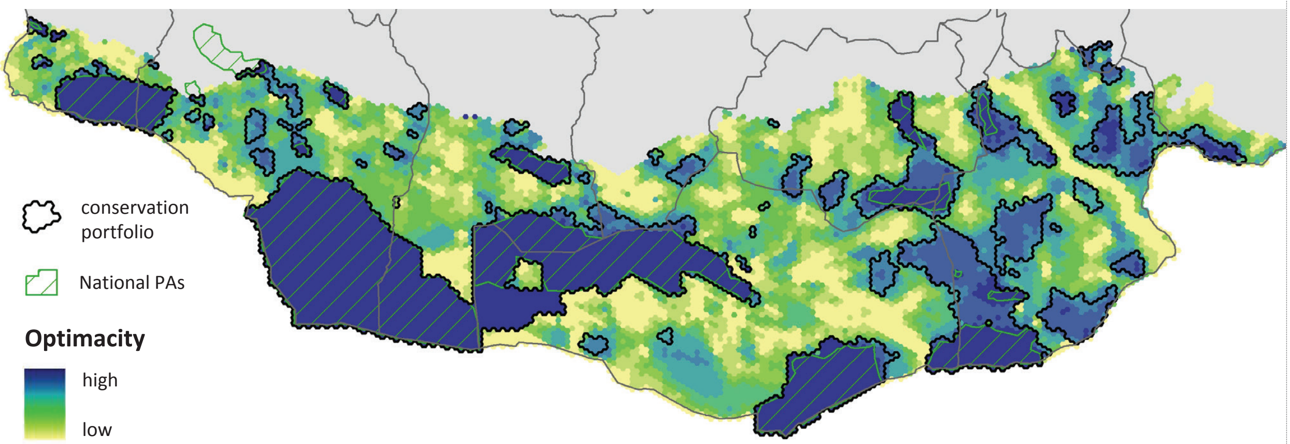
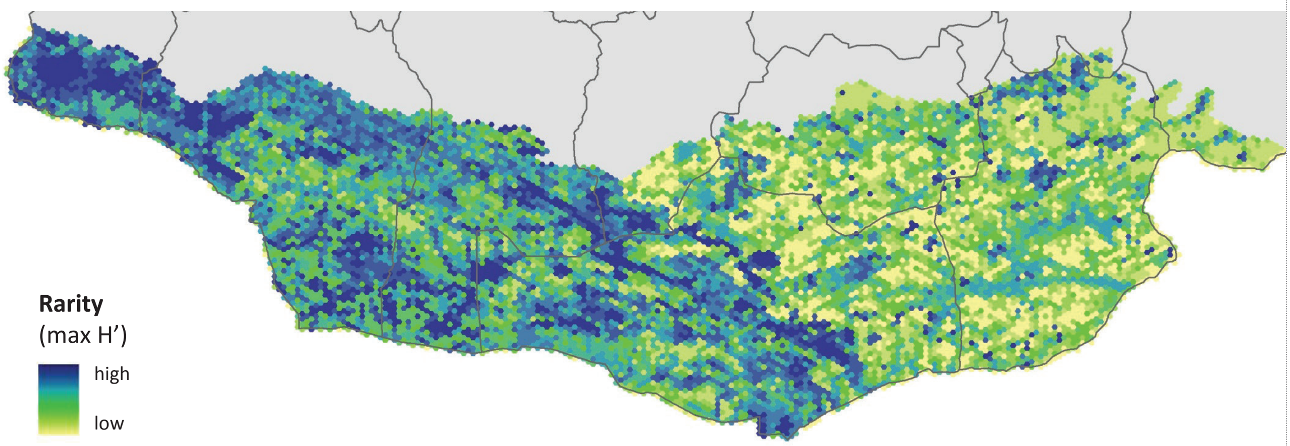



**Figure 14:** Rarity: PUs ranked according to the maximum rarity value of constituent ecosystem types. Rarity as calculated here measures the abundance of a given ecosystem type in a given PU relative to its abundance across the study area (see section 2.7).




conservation priority areas already leased for exploration or development (Figures 16 and 17). The combined area of these conflict areas was 30,950 km$^2$, or 16% of the portfolio and 6% of the study area.

Within this set of conflict areas, we identified the PUs with high conservation value based on two criteria:

1. PUs with combined biological value (optimacity + rarity) in the upper 30$^{th}$ percentile (13,850 km$^2$or 45% of the conflict areas).
2. PUs containing high-quality Khulan habitat (5,700 km$^2$or 18% of the conflict areas), defined as undisturbed areas with productive forage in the Eastern Gobi, based on the Khulan SDM (Figure 15). This area supports the largest remaining population of the endangered, wide-ranging Khulan in Mongolia and the world (Moehlman et al. 2008). The current range of this population has been reduced by the railway to the northeast and mining roads to the west and is further threatened by planned mines and planned railway connecting Sainshand to Tavan Tolgoi and road improvement and mining traffic from the Tayan Nuur iron ore mine to the Burgastai border crossing between Great Gobi B and Great Gobi A.

We designated PUs meeting either of these criteria as areas of high conservation value where development should be avoided. These PUs covered 19,850 km$^2$ or 64% of the conflict areas

(Figure 18). The remaining PUs in conflict areas occupied an area of 11,100 km$^2$, or 36% of the conflict areas. We replaced these remaining PUs with sites of similar composition and condition outside existing leases (Figure 19). The result is a redesigned portfolio that avoids mining leases except in areas of high biological value (Figure 19). The portfolio consists of 50 sites covering 195,000 km$^2$, or 37 % of the study area, with current National Protected Areas covering 110,000 km$^2$, or 56% of this portfolio area. Because National Protected Areas contain more than 30% of some ecosystem types, the portfolio is larger than 30% of the study area.

**range:** map shows current (Kaczensky et al. 2011) and potential range.

**habitat:** based on Kaczensky et al. (2011), who assessed habitat and connectivity and mapped suitable habitat according to biomass production and terrain (excluding mountains).

**classify by condition / disturbance** (disturbance index)

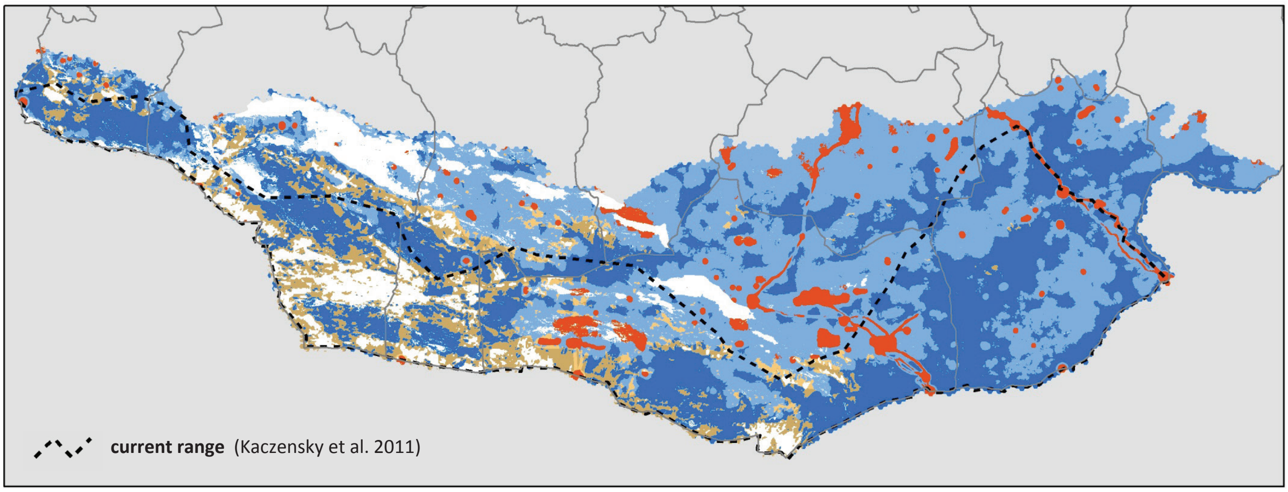
- unsuitable: most disturbed 5% of study area
- moderate: remaining 45%
- best: least disturbed 50%

## 2.9 OTHER PRIORITY CONSERVATION AREAS

### 2.9.1 Rangelands critical for wildlife forage and movement

For wide-ranging plains ungulates, specifically Khulan, Goitered gazelle, and Mongolian gazelle, protected areas alone cannot effectively conserve the current populations. In the deserts and grasslands of Central Asia, vegetation productivity is highly variable and irregular in time and space (von Wehrden et al. 2012, von Wehrden et al. 2010, Zhang et al. 2010, Yu et al. 2004, Fernandez-Gimenez and Allen-Diaz 1999). Steppe productivity varies from year to year, from month to month, and geographically in response to precipitation patterns (Figure 20). Nomadic ungulates such as Mongolian gazelle have evolved to track the shifting forage, covering large distances to follow vegetation growth that follows precipitation (Mallon and Zhigang 2009, Mueller et al 2008, Mueller and Fagan 2008). In the Mongolian Eastern Steppe, Mongolian gazelle home ranges are between 14,000 and 32,000 km$^2$ (Olson et al 2010). Khulan home ranges in Mongolia reach as high as 70,000 km$^2$ (Kaczensky et al. 2011, Lkhavgasuren et al. 2009). The dependence of grassland ungulates on movement to access forage across large distances makes them vulnerable to habitat fragmentation and increases their exposure to hunting, livestock competition, and disease (Berger 2004). The most significant threat to Khulan, Goitered gazelle, and Mongolian gazelle is loss of access to habitat due to barriers created by transportation infrastructure (Ito et al. 2013, Lkhagvasuren et al. 2011, Kaczensky et al. 2006) – either fences along

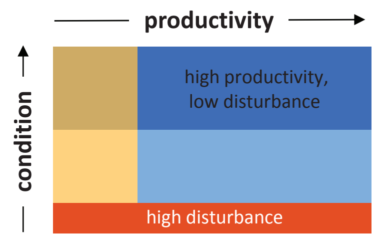
**Figure 15:** Khulan (*Equus hemionus*) habitat model




### Khulan (*Equus hemionus*) habitat model

1. **range:** map shows current (Kaczensky et al. 2011) and potential range.
2. **classify habitat:** based on Kaczensky et al. (2011), who assessed habitat and connectivity and mapped suitable habitat according to biomass production and terrain (excluding mountains).
   - high: semi-desert and desert steppe [1]
   - low: true desert [1]
   - exclude extreme arid desert [1]
   - exclude hills, rugged terrain [2]
3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)




white: not habitat
gray: not evaluated (outside study area).

**Figure 16:** Initial portfolio and existing mineral leases

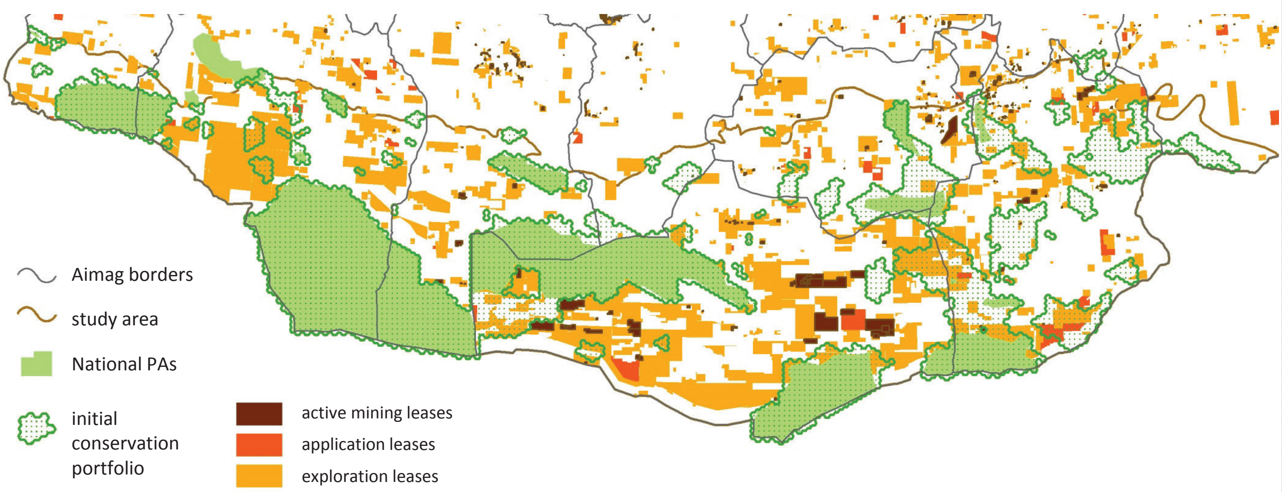


**Figure 17:** Areas of potential conflict with mineral development

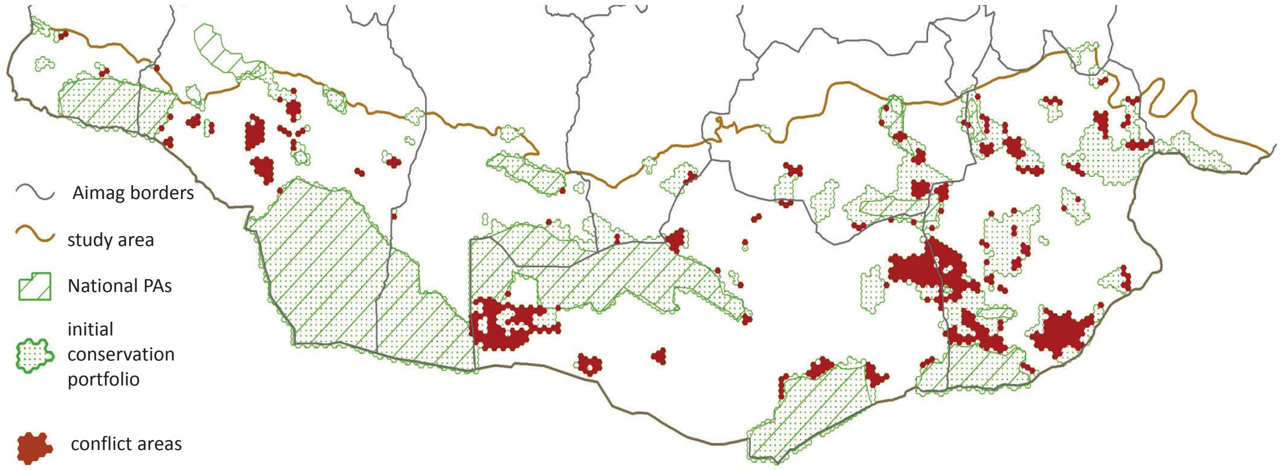



**Figure 18:** Conflict areas classified by biological value

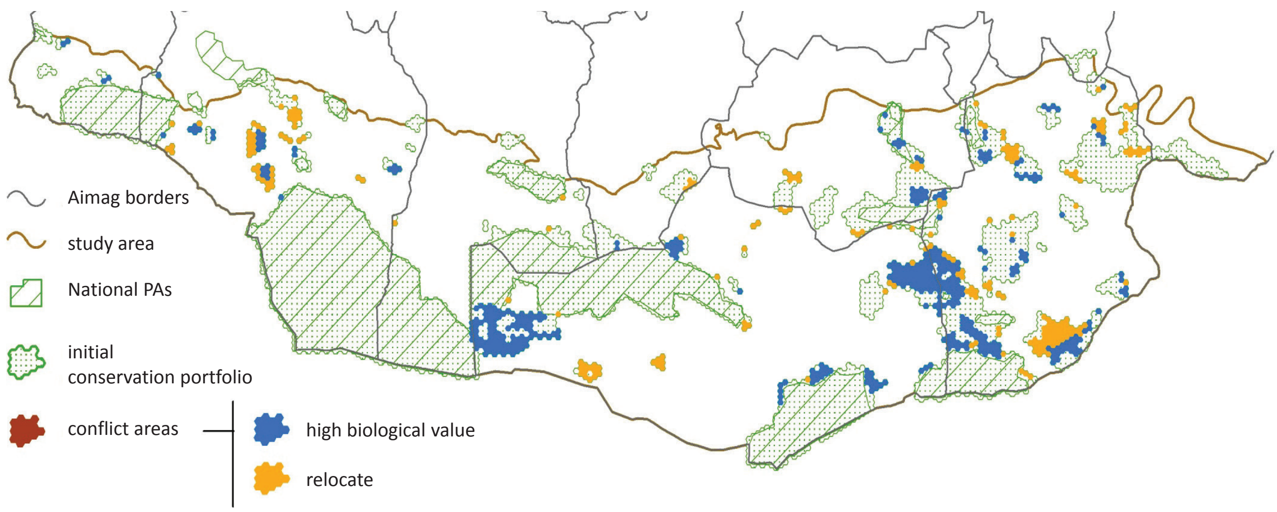
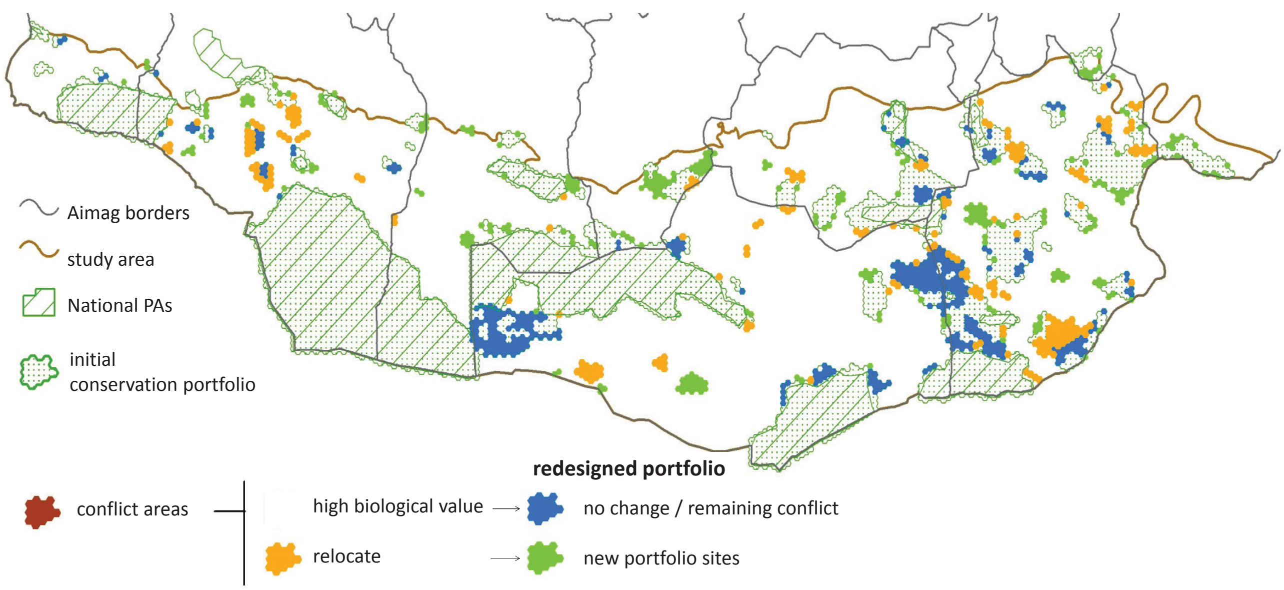



**Figure 19:** Portfolio re-designed to minimize conflict with mineral development



borders and railways (Olson 2012, Kaczensky et al. 2011, Ito et al. 2005, Lkhagvasuren 2000), or high traffic, as in the case of the Tavan Tolgoi coal road.

Protection of sites selected to meet the 30% area goal for ecosystem representation (section 2.8 above) are not adequate to support such wide-ranging plains ungulates (Figure 23). Additional areas that may represent important seasonal ranges and movement corridors because of the low potential conflict or competition, based on the disturbance index, are shown in Figure 21. Major threats to wildlife movement from existing and planned transportation infrastructure are shown in Figure 23.

Impacts to the populations and movements of these three species have important implications for herders, other wildlife and the rangelands in general. Wide ranging plains ungulates perform important ecological functions, including redistributing nutrients that may influence diversity patterns of plant communities (Mazancourt et al. 1998) and providing a prey base for predators and scavengers. Wild ungulates also represent an important food source for subsistence hunters (Olson 2008).

### 2.9.2 Expert-designated priority conservation areas

In all landscape-level conservation planning, the GIS data development, analysis, and site selection often depends largely on coarse and/or incomplete datasets and maps. Given the size of the Gobi study area, the results and decision-support framework function at a relatively coarse scale. Therefore, expert review and input is an essential step in portfolio design to complement and guide the GIS analysis. Through a series of meetings between January – March 2013, members of the Science Advisory Group met to review the site selection and designated 17 additional sites (Figure 21, Appendix 5). This set includes five proposed PAs identified by WWF for the National Gap Assessment (Chimed-Ochir et al. 2010) that MEGD adopted for formal protection. These expert sites cover an additional 58,000 km², or 11% of the study area.

**Figure 20:** Grassland variability and home ranges. Large desert herbivores, including Khulan, Mongolian gazelle, Black-tailed gazelle and Wild Camel, cover large home ranges to find forage, which is highly variable and irregular in time and space. The maps illustrate the difference in productivity between dry and wet years, the variability over an 11-year period (CV, 2000-2011) and the size of typical home range of Khulan and Mongolian Gazelle.

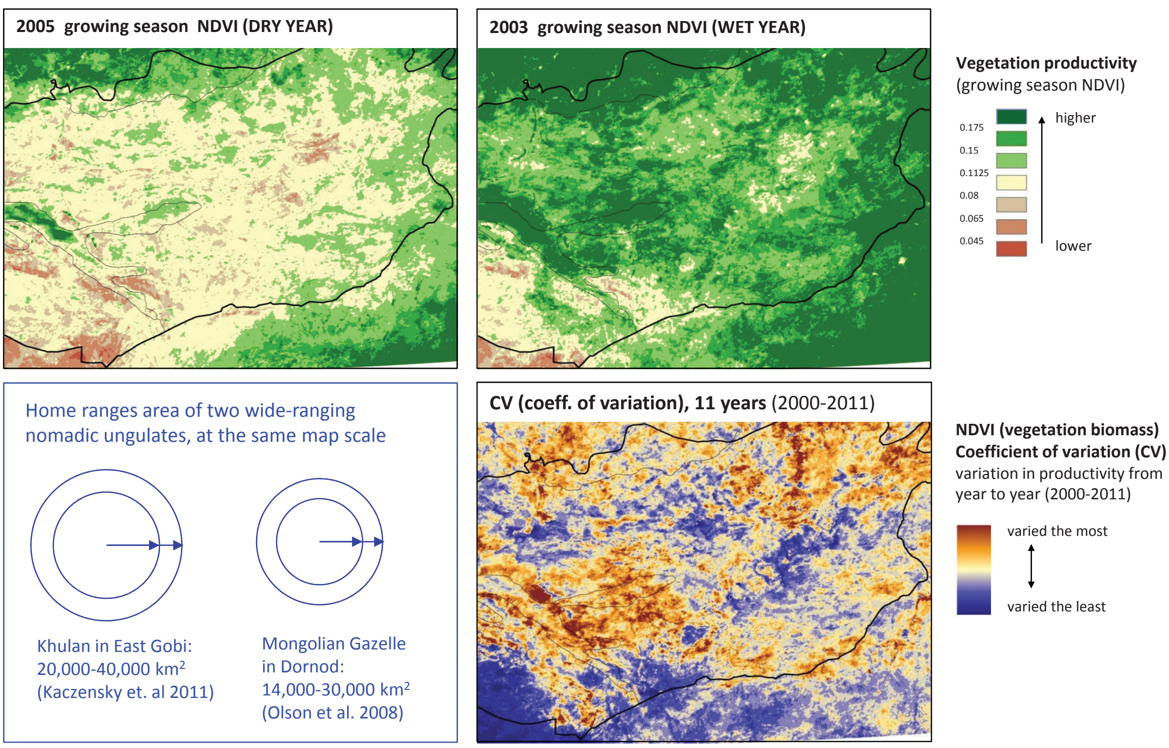


**Figure 21:** Priority conservation areas

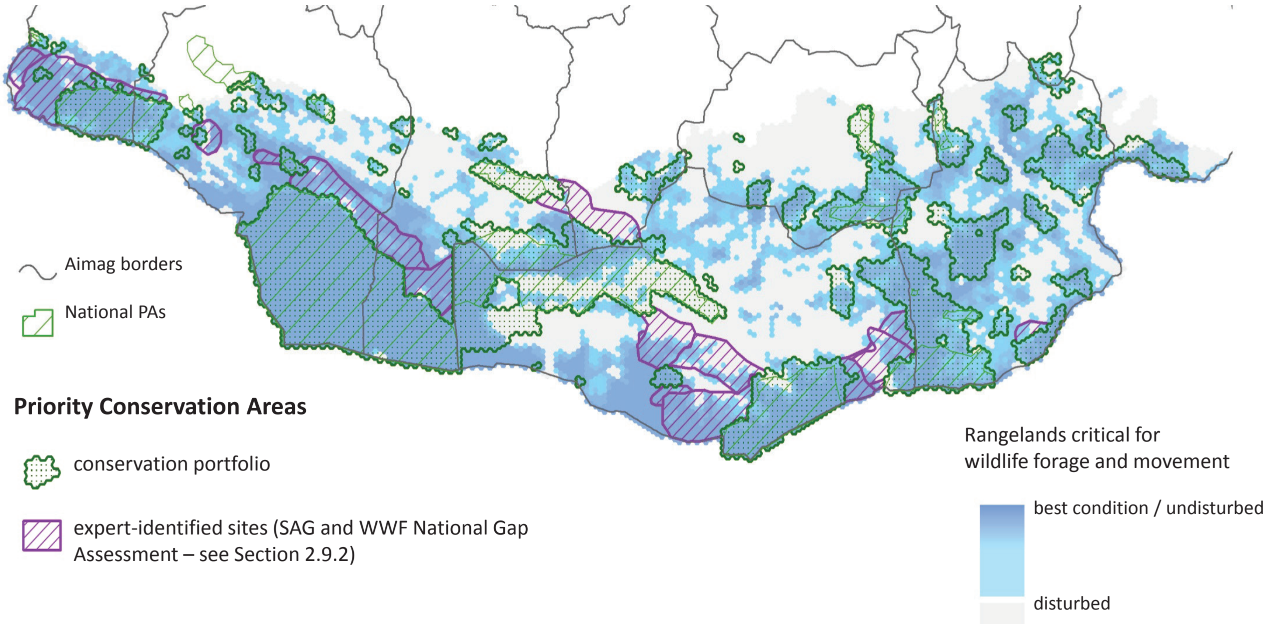



**Figure 22:** Portfolio and remaining areas of conflict with mineral development

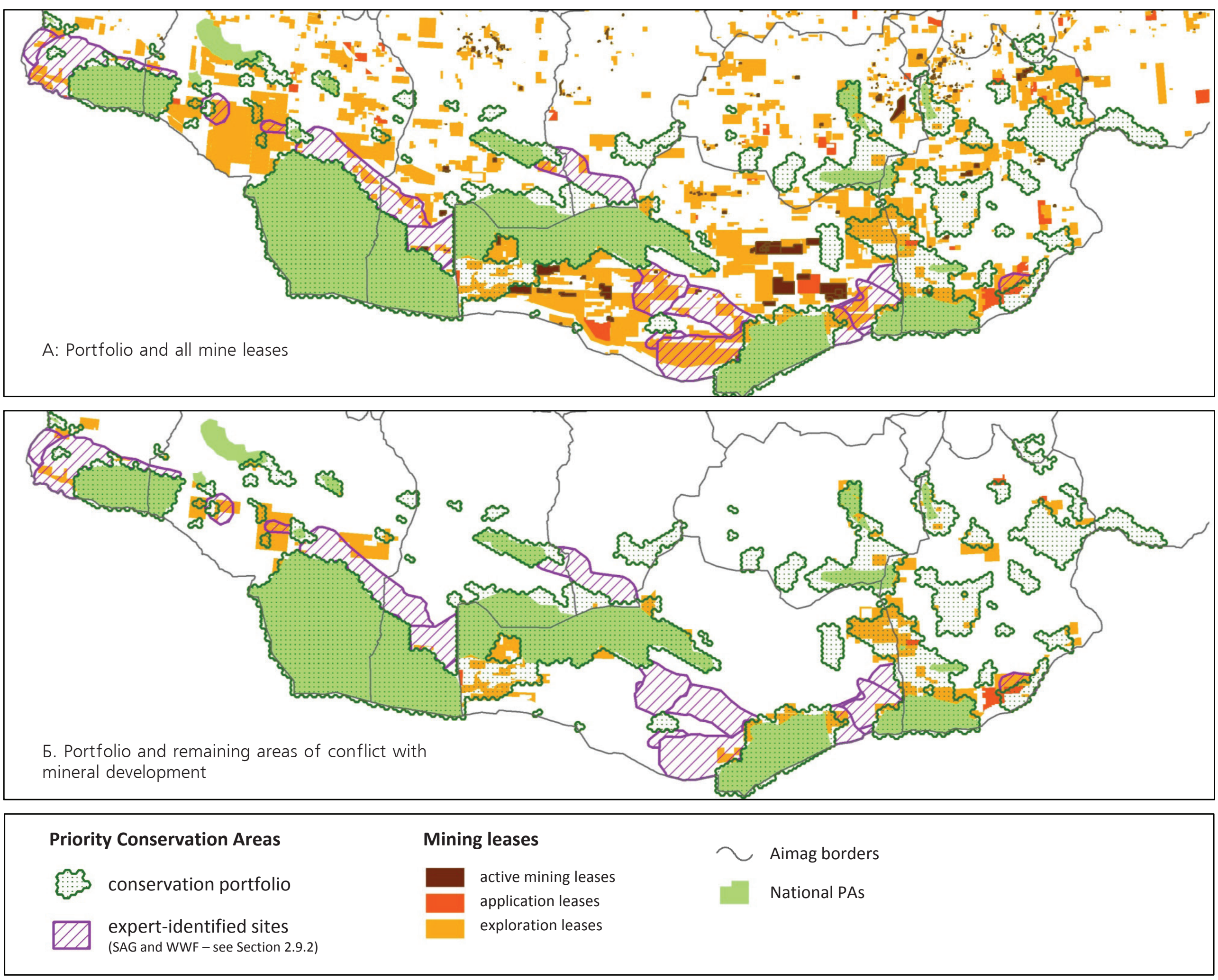
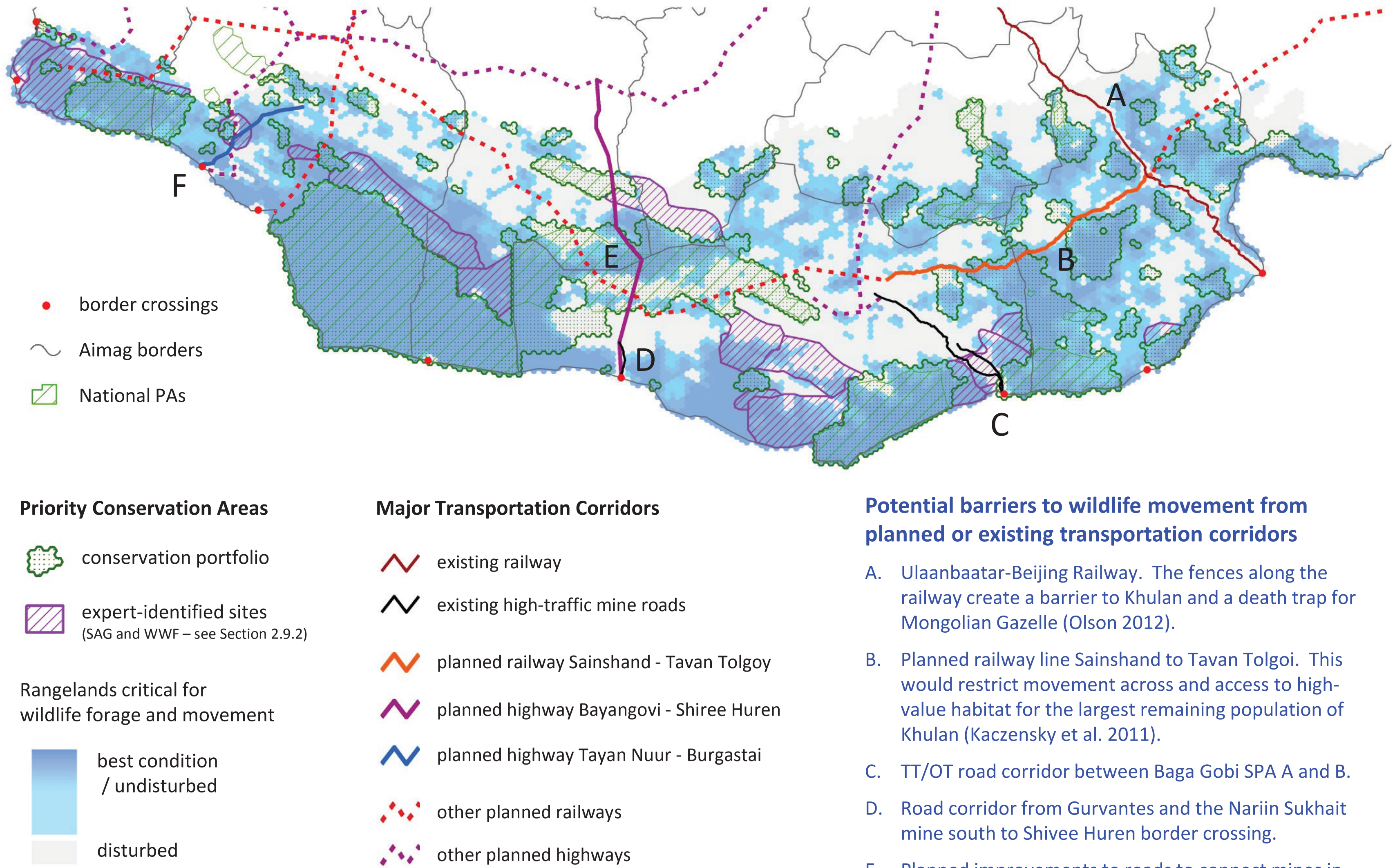


**Figure 23**: Barriers to wildlife movement from transportation corridors




**Potential barriers to wildlife movement from planned or existing transportation corridors**

A. Ulaanbaatar-Beijing Railway. The fences along the railway create a barrier to Khulan and a death trap for Mongolian Gazelle (Olson 2012).

B. Planned railway line Sainshand to Tavan Tolgoi. This would restrict movement across and access to high-value habitat for the largest remaining population of Khulan (Kaczensky et al. 2011).

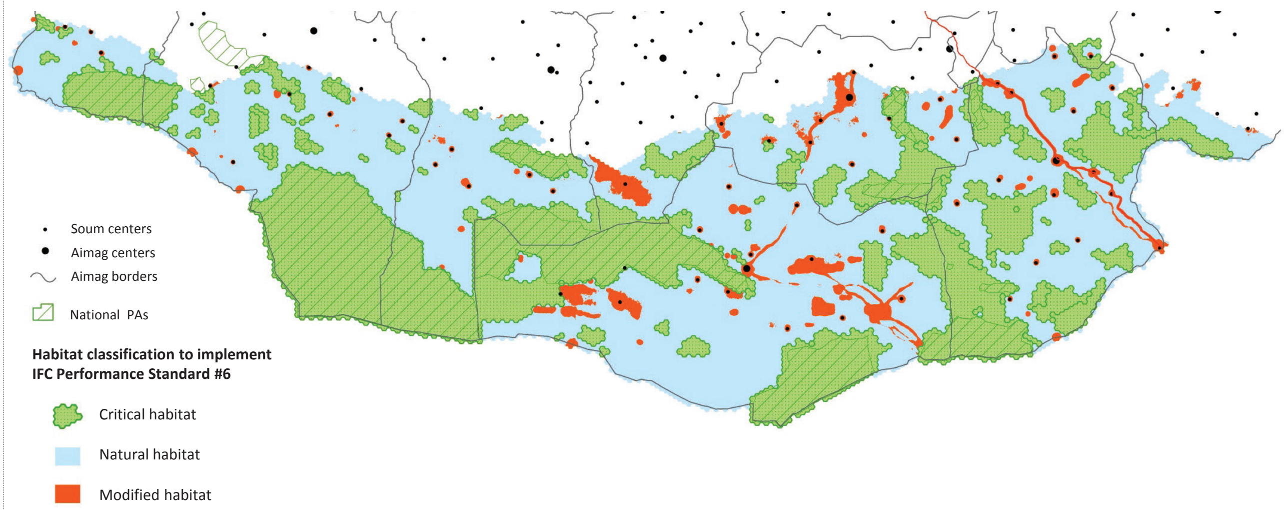
C. TT/OT road corridor between Baga Gobi SPA A and B.

D. Road corridor from Gurvantes and the Nariin Sukhait mine south to Shivee Huren border crossing.

E. Planned improvements to roads to connect mines in Bayanhongor to Shivee Huren border crossing.

F. Planned road improvement from the Tayan Nuur Iron Ore mine to Burgastai border crossing

**Figure 24:** Habitat classification to implement IFC Performance Standard #6. The results of the Gobi assessment can be used to guide the application of new performance standards (IFC 2012) as described Section 3.1.3 and shown here. For the purposes of implementation of this Performance Standard, habitats are divided into modified, natural, and critical.




## 2.10 DESIGNING BIODIVERSITY OFFSET SCENARIOS

To demonstrate how this landscape-level conservation plan, and specifically the portfolio and habitat maps, can provide the basis for designing biodiversity offsets, we developed two simple offset siting scenarios: first for a single large mine, and second, a group of aggregated offsets for all active mines in one Aimag (Dornogovi).

Although a set of offsets has great potential as a conservation tool, their establishment requires overcoming a number of conceptual and methodological challenges (Kiesecker et al. 2009). One of the key questions is how offsets should be located relative to the affected site. When on-site impacts warrant the use of offsets, there often exists tension between choosing sites as close to the impact site as possible (ensuring that benefits accrue to the same area) and choosing sites likely to provide the greatest conservation benefit (with less regard to spatial position). The conservation area portfolio and the underlying GIS can provide the basis for selecting offset sites that maximize conservation benefit.

The conservation area portfolio also supports offset designs that address residual, adverse impacts arising from more than one development project (Kiesecker et al. 2010, Kiesecker et al. 2011, Thorne et al. 2009). Aggregated offsets might be advantageous when an area is subjected to cumulative impacts from several individual developments. In this situation, aggregating offsets may provide better mitigation at lower cost, with a higher probability of success given the concentration of the management skills needed to deliver the offset and synergies in project management. Such assessments can also reduce costly delays due to protracted environmental review. A landscape approach to compensatory mitigation planning can lead to a better ecological outcome. If mitigation needs from multiple projects are pooled, then larger, less fragmented parcels can be utilized, contributing to both ecological integrity and fiscal savings.

When offsets are used, practitioners must design an approach that ensures offsets are ecologically equivalent to impact sites, will contribute to landscape-level conservation goals and provide opportunities to achieve net neutral or positive outcomes. Here we illustrate how this analysis can be conducted for individual developments or for residual impacts arising from all application and exploration leases within Dornogovi Aimag. The offset analysis consisted of two steps:

1. **Estimate development footprint:** estimate the spatial area, or footprint, affected by the development. This often includes producing both low and high estimates based on existing studies of the impacts of development on wildlife habitat use. In these simple examples, to estimate the footprint(s), we selected PUs that intersect the mine site(s) and the supporting infrastructure (roads and transmission lines).
2. **Identify potential offset sites:** we identified a set of ERA portfolio sites that contains habitat similar to the development footprint, based on the ecosystem classification using a statistical method called imputation. We used imputation to identify PUs within the conservation portfolio with similar ecosystem composition to PUs in the disturbance footprint. Imputation produces statistics that measure similarity between observations according to multiple variables (Hudak et al. 2008). In this case, the variables are the ecosystem types and the observations are the PUs. Based on the results of the imputation analysis, we identified several possible offset sites for impacts associated with one mine site (Figure 25), and 10-12 possible offset sites for impacts associated with all the application and exploration leases in Dornogovi Aimag (Figure 26).

These examples demonstrate three criteria for siting offsets: 1) align the offsets with a landscape-level plan, or maximize benefits towards regional conservation goals, 2) ecological equivalence between area of impact and offset sites and 3) locate offsets near the impact site. This approach does not consider offset accounting or impacts to wildlife movement. Developing an offset accounting framework for addressing impacts involves not just determining the approximate footprint and potential offset areas, but also identifying possible conservation actions, considering other factors such as the duration of impacts and offsets, and assessing the cost necessary to achieve offset goals. These important components of offset design are not included in the offset siting examples here.

**Figure 25:** Regional offset scenario – one mine. This map shows the approximate footprint of one mine site and a set of ecologically similar sites within the conservation portfolio. This demonstrates how a landscape-level conservation plan (conservation portfolio sites) and supporting information (habitat maps) can be used to identify offset sites that meet siting criteria of 1) align the offsets with a landscape-level plan, or maximize benefits towards regional conservation goals, 2) ecological equivalence between area of impact and offset sites and 3) locate offsets near the impact site (see discussion in Section 2.10). This analysis is not intended to estimate ratios or area necessary to meet offset accounting objectives of no-net-loss or net-positive-impact.

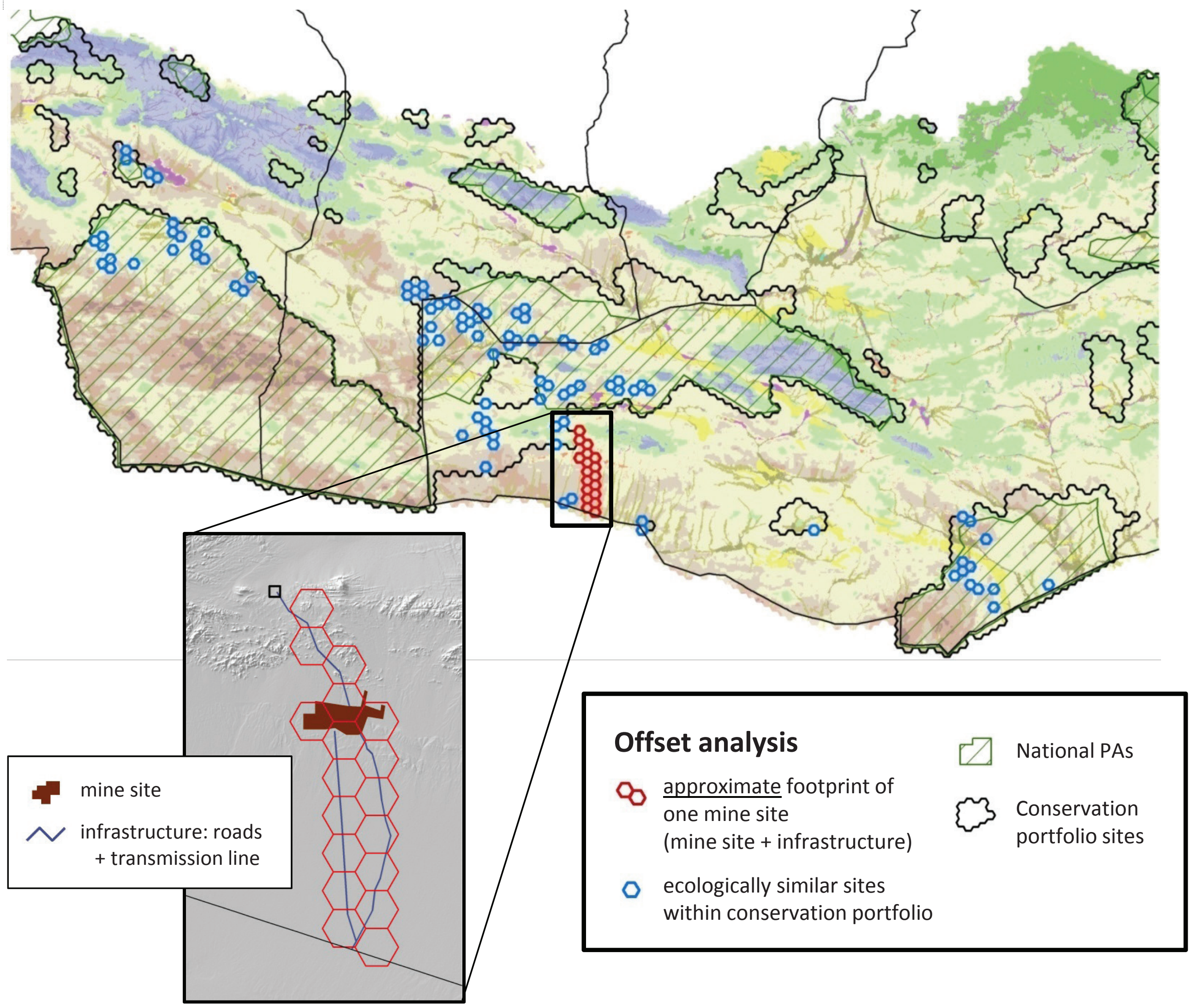


**Figure 26:** Regional offset scenario – aggregated offsets for one Aimag. This map shows the approximate footprint of all the active and application mining leases in Dornogovi Aimag and a set of ecologically similar sites within the conservation portfolio. This demonstrates how a landscape-level conservation plan (conservation portfolio sites) and supporting information (habitat maps) can be used to identify offset sites that meet siting criteria of 1) align the offsets with a landscape-level plan, or maximize benefits towards regional conservation goals, 2) ecological equivalence between area of impact and offset sites and 3) locate offsets near the impact site (see discussion in Section 2.10). This analysis is not intended to estimate ratios or area necessary to meet offset accounting objectives of no-net-loss or net-positive-impact.

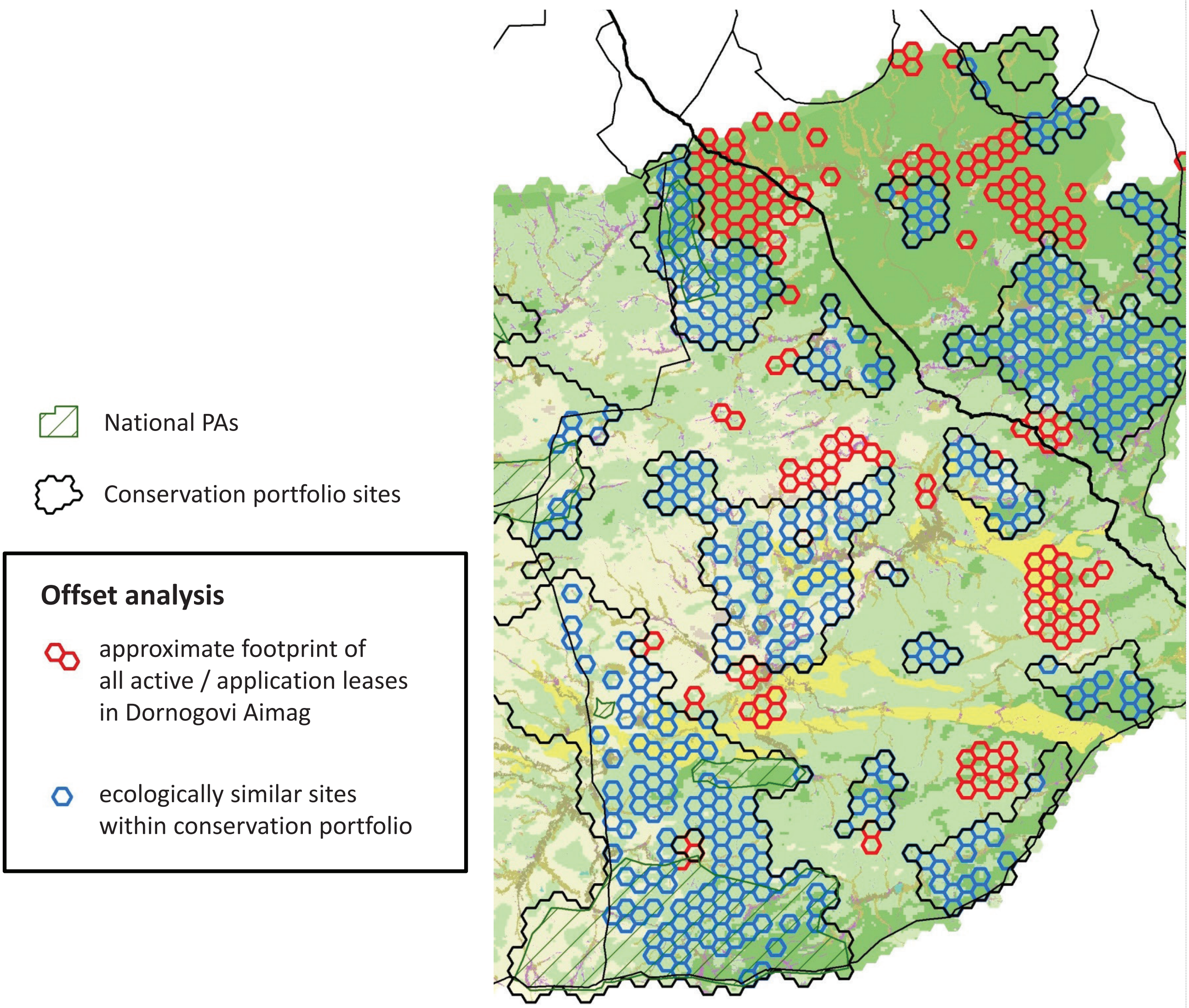


**Figure 27a:** Groundwater-dependent ecosystem types, Western Gobi

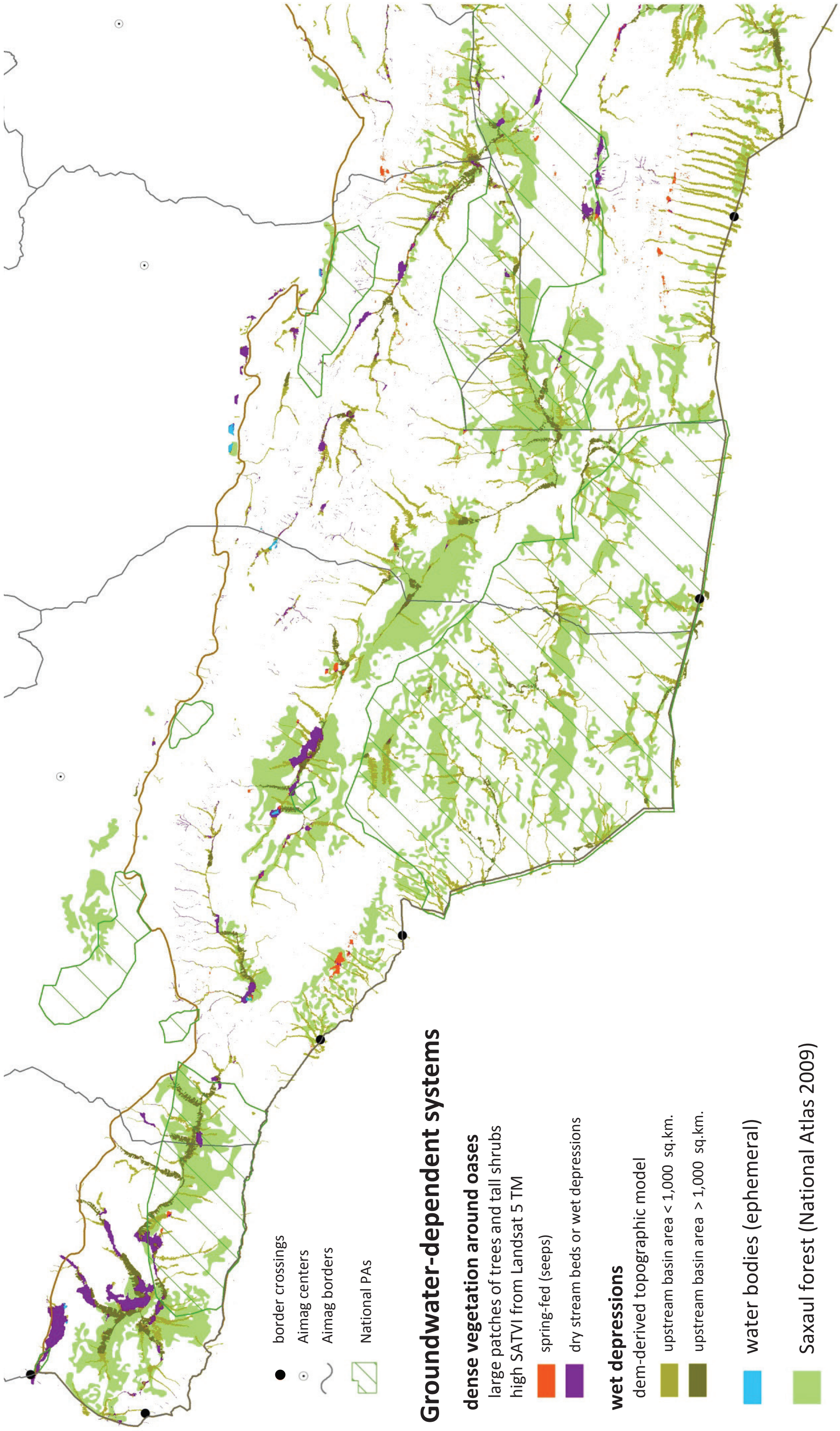
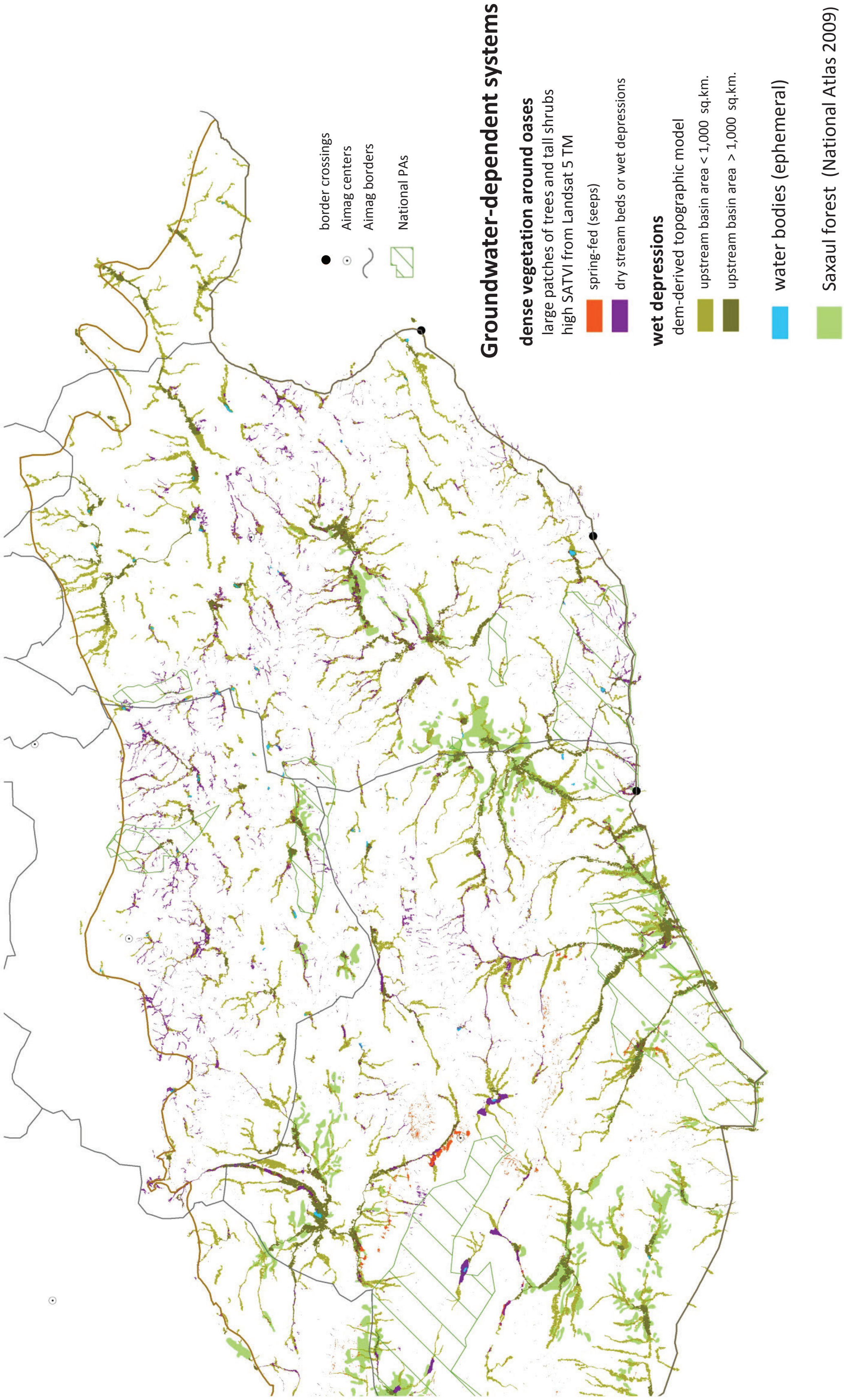


**Figure 27b:** Groundwater-dependent ecosystem types, Eastern Gobi



# 3.0 DISCUSSION

## 3.1 APPLICATIONS TO CONSERVATION AND MITIGATION

This study can support sustainable development for the Mongolian Gobi by providing a sound basis for land-use planning, balancing the needs of mineral and energy development, pastoral livelihoods, and wildlife habitat conservation. We believe the study can inform decision-making for protected areas design and management and support improvements in mitigation policy and practice.

### 3.1.1 Protected area designation and management

The results of this study can inform new protected area designations to meet the Mongolian government's goal of protecting 30% natural habitat and support the development of priorities and strategies for improving management effectiveness of existing protected areas. Resolution #13 of the Parliament of Mongolia specifies that half of the 30% protection goals will be met by local protected areas at the Aimag and Soum levels. Aimag land use agencies are primarily responsible for designing and implementing land management plans at intervals of 12-16 years (Law of Mongolia on Land, 2002).

The community managed conservation areas recently established around Ikh Nart Nature Reserve (Airag and Dalanjargalan Soums, Dornogovi) and Tost Uul (Gurvantes Soum, Omnogovi) are useful models of effective designation and management of local protected areas. Ikh Nart NR has also been chosen as one of three national demonstration sites for UNDP SPAN (Strengthening of the Protected Area Network in Mongolia) project, implemented by MEGD SPA Administration Department, which seeks to improve management effectiveness and financial sustainability (http://www.undp.mn/snrm-span.html).

### 3.1.2 Mitigation of mining and energy development

This study can support more effective decision-making for mitigating mining leases in the Mongolian Gobi. First, by identifying conservation priorities in the face of future development, the study provides an "early warning" of potential conflicts between development and conservation goals. Second, the Development by Design framework and the results of this study provide a basis for applying the mitigation hierarchy to support informed decision-making about appropriate impact mitigation practices (i.e., impact avoidance versus offsets). Areas of conflict between the conservation portfolio and proposed development may result in a "redrawing" of the portfolio to recapture habitat needed to meet biodiversity goals (Figures 18 and 19). However, if conservation goals cannot be met elsewhere within the study area, development should be avoided, or must minimize impacts to maintain biodiversity values. This provides a way to avoid conflict between potential development and areas critical for biodiversity, and provides the structure to guide decisions regarding the appropriate step in the mitigation hierarchy in response to proposed development.

It is not clear that all development will impact all biological elements, and a simple overlap between development and element occurrence does not equate with impact. Thus, translating development into impact must be done on an element by element basis. This typically involves a finer scale assessment of element distribution and development impacts. This landscape scale assessment is meant to provide a starting point to identify potential conflict and to guide where additional analyses will be required.

### 3.1.3 Lender performance standards: critical habitat

Many of the new development projects in Mongolia's Gobi Region receive financing from the International Finance Corporation (IFC) and European Bank for Reconstruction and Development (EBRD). These lending institutions adhere to the new performance standards, requirements, and guidelines (IFC 2012). The intention of the performance standards is to ensure that projects promote sustainable development practices, protecting and conserving biodiversity and sustainably managing living natural resources. The results of the Gobi assessment can guide application of the new performance standards (IFC 2012) as described below and shown in Figure 24. For the purposes of implementing IFC Performance Standard 6, habitats are divided into modified, natural, and critical.

Critical habitat includes areas important for globally or nationally Critically Endangered or Endangered species; restricted-range or

endemic species; concentrations of migratory and congregator species; highly threatened and unique ecosystems; and key evolutionary processes. These features can be built into the design of the conservation portfolio and thus serve to identify critical habitat. Areas selected as part of the conservation portfolio would be considered critical habitat. Impacts in these areas should be avoided. As described above, some of the areas selected in the initial portfolio could be removed and redesigned if minimum goals could be met elsewhere within the study area. Areas selected within the initial portfolio would still be considered critical habitat. Where development in these areas is allowed to occur, residual impacts must be offset to achieve a net gain.

Areas outside the portfolio with land cover in natural vegetation cover would be considered natural habitat. Development could proceed in these areas, but any residual impacts must be offset with a goal of no-net-loss.

We identified modified habitats here as areas with disturbance index values in the 'high disturbance' class, or the 5% most disturbed areas. The disturbance index (described in section 2.4) measures the current, cumulative human impacts or departure from historic or natural conditions. Areas within the 'high disturbance' class include population centers (Aimag centers, Soum centers or border crossings), active mines, and major transportation corridors (highways, mining traffic or railways), or support high density of herder households (more than one household per 3 $km^2$) or some combination of the above. Development could proceed in these areas using best management practices without the need to offset residual impacts to biodiversity. However, development within modified habitat can have major negative impacts on wildlife by creating barriers to movement in the form of transportation infrastructure and high traffic volume. These disjunct, indirect impacts must be mitigated.

### 3.1.4 Designing offsets

For development projects that proceed, the next step in the mitigation hierarchy and the Development by Design framework is to determine project-level impacts and identify best offset opportunities. Where development impacts occur, impacts should be minimized and areas restored in accordance with best management practices per international regulatory standards. In addition, to support a balance of development and conservation, impacts remaining after avoidance, minimization, and restoration should be quantified and offset. Applying a goal of no-net-loss to these development areas would provide a mechanism to achieve conservation goals by translating impacts in areas outside the portfolio to conservation in portfolio sites (Figure 21).

Offsets should deliver values ecologically equivalent to those lost, be located within acceptable proximity to the impact site and contribute to landscape conservation goals. Using the existing portfolio sites, offset design can meet criteria ecological equivalency and proximity to impacts sites. Because the portfolio was designed to meet landscape conservation goals, offsets directed towards areas within the portfolio would be consistent with landscape-level goals. Conservation actions for an offset should be evaluated based on potential conservation benefits, as well as risk and cost (McKenney and Kiesecker 2010, Kiesecker et al. in press).

### 3.1.5 Land use planning

The conservation portfolio and supporting information can guide land use zonation at National, Aimag and Soum levels. The regional maps of habitat types, herder household density and other land use can inform grazing management and coordination of pasture use to maintain range condition and minimize competition and conflict with wildlife, and specifically to identify and manage of pasture reserves. In grasslands, conservation areas have potential as grass banks, or reserves where grazing and hay cutting is generally excluded except following a dzud or other extreme events. A study by Leisher et al. (2010) in Omnogovi Aimag suggests that community-managed pasture reserves can provide a range of measurable benefits for pastoral households, including emergency forage or grass banks, if effectively managed for that purpose. The regional conservation portfolio may be useful for identifying candidates for grass banks based on pasture type, productivity and land use (Girvetz et al. 2012). The regional GIS may also be used to measure loss of pasture to development of mining and related infrastructure, and support planning to manage movement of people and livestock in response to mining and other major land use changes.

### 3.1.6 Basis for surveys and research

The Mongolian Gobi still supports most of its historic assemblage of native wildlife species, but many species are currently endangered and further threatened by rapid development of mineral resources and supporting infrastructure. Much of Gobi study area is unsurveyed and information on the status and ecology of most threatened and endangered species is lacking. There is an urgent need for basic research and surveys to inform conservation, mitigation, monitoring (Batsaikhan et al. 2010, Clark et. al 2006). Some remote areas support species not yet observed or recorded that are regularly discovered in field surveys. Vegetation and ecosystem maps and species habitat distribution models can inform survey designs for species or vegetation. Survey results can provide a basis for revising vegetation and ecosystem maps and species distribution models.

## 3.2 OUTSTANDING ISSUES

### 3.2.1 Remaining areas of conflict between conservation portfolio and mining leases

Through the analysis of conflicts between portfolio sites and mining leases described in section 2.8.1, we identified conflict areas covering 19,850 km$^2$ where we recommend avoiding development by either retiring or changing the boundaries of existing mining leases. This affects five application leases and many more exploration leases (Figure 22).

### 3.2.2 Barriers to wildlife movement

The Mongolian Gobi supports a large assemblage of wide-ranging species that cover large home ranges. This includes the nomadic plains ungulates – Khulan, Mongolian gazelle, and Goitered gazelle; mountain ungulates, including Ibex and endangered Argali; and carnivores, including the endangered Snow leopard. For the critically endangered Gobi bear and wild Bactrian camel, also wide-ranging species that historically ranged across the Mongolian Gobi, long-term persistence requires range expansion beyond Great Gobi A SPA. For all these species, survival requires the ability to move to reach sparse or shifting food resources and to find mates for breeding and maintain genetic fitness. Barriers from existing and planned transportation infrastructure are the most urgent threat (Kaczensky et al. 2006, Olson 2012, Lkhagvasuren et al. 2011).

The most urgent threats to wildlife movement from transportation infrastructure are listed below (Figure 23). Existing roads and railway should be priorities for mitigation though design measures (underpasses, overpasses, traffic curfews, fence removal or modification to allow wildlife passage).

A. Existing Ulaanbaatar-Beijing Railway. The fences along the railway create a nearly impermeable barrier to Khulan as well as a

potential death trap for gazelles (Olson 2012). In the Khulan range, the simplest solution is to remove fences along the track wherever feasible (away from Soum centers and where herding households are largely absent). Throughout the gazelle range, a simple change in fence design (elevated lower fence line and use of smooth wire without barbs) would allow gazelles to cross and reduce the risk of entanglement (Olson 2012).

B. Planned and funded railway line from Sainshand to Tavan Tolgoi. The largest remaining population of Khulans is currently restricted to the Eastern Gobi by the fenced UB-Beijing railway to the east and the TT road corridor to the west. This will bisect and fragment the largest remaining block of habitat (Kaczensky et al. 2011). Impacts from construction and traffic will degrade range along the railway corridor.
C. Existing Tavan Tolgoi /Oyu Tolgoi road corridor between Small Gobi SPA A and B.
D. Existing road corridor from Gurvantes and the Nariin sukhait mine south to the Shivee Huren border crossing.
E. Planned improvements to roads between Great Gobi A SPA and Gobi Gurvan Saikhan NP to connect mines in Bayanhongor to China border crossings. The most likely range expansion of wild Bactrian camel (Kaczensky et al. in prep.) and Gobi bear (Gobi Bear Project/ Harry Reynolds pers. comm.) will be the area east and northeast of Great Gobi A, which already contains one active mine and several application licenses.
F. Planned road improvement from the Tayan Nuur Iron Ore mine to Burgastai border crossing between Great Gobi B and Great Gobi A SPA.

A possible model for the protection of migratory habitat is the recent designation in the Western US of a Pronghorn (*Antilocapra americana*) Migration Corridor by a consortium of Federal and State agencies, NGOs and private land owners. This affects an area of mixed public and private lands that has experienced rapid growth of oil and gas development and related roads and fences. On Federal and State lands, the designation specifically requires that future infrastructure projects and management plans be compatible with Pronghorn migration (USFS 2008).

### 3.2.3 Protection of groundwater-dependent systems

The mapped ecosystem classification includes several groundwater-dependent types with disproportionately high biological value for wildlife, livestock, and people and that have a sparse and patchy distribution following groundwater hydrology (Figure 27). In particular, these habitat types include 1) dense vegetation around oases, which can include *Populus diversifolia* and Tamarisk, and 2) dry river beds and wet depressions that typically support Elm stands, Saxaul forests, or other tall shrub communities. These systems support high species diversity and provide distinct, irreplaceable habitat, particularly for small mammals, reptiles, and birds, and provide forage for large desert mammals such as wild Bactrian camel, Goitered gazelle, and Gobi bear. Many birds, including the endangered Houbara bustard (*Chlamydotis undulata*), Saxaul sparrow (*Passer ammodendri*), Mongolian ground jay (*Podoces hendersoni*), Short-toed snake eagle (*Ciracaetus gallicus*), and Cinereous vulture (*Aegypius monachus*) depend on Saxaul and Elms for nest sites and foraging habitat. Because these systems form a sparse, patchy network of habitat, individual patches can play important roles in connectivity within metapopulations. These systems are sensitive to groundwater changes, develop slowly over years, and may take decades to regenerate. Dry riverbeds in areas with a high ground water table provide drinking water for Khulan. In the Eastern

Gobi, Khulan dig up to 50 cm to access water close to the surface and thus also provide access for other wildlife (Kaczensky et al. 2006).

Protection and mitigation to prevent loss of these ground water dependent systems is thus critical for these irreplaceable systems and the species that depend on them. Though Saxaul forest and Oases are legally protected (Mongolian Law on Forest 2007, Mongolian Law on Water 2007), effective protection requires accurate mapping and research into the ecology and conservation of these ecological systems. In combination with local-scale mapping, such as existing 1:100,000 topographic maps or recent vegetation maps of National PAs, the maps developed for this study can provide a regional-scale template for mapping, monitoring, and protection.

3.2.4 Monitoring groundwater and impacts to people, livestock and wildlife

Water withdrawals to support mining operations could affect groundwater supplies, with impacts on wells, springs and vegetation productivity. That could cause loss of water sources and reduction in forage for livestock and wildlife, and impact the groundwater-dependent systems described above, which are habitat for many endangered species and typically support high species diversity, in particular for small mammals and reptiles.

Because current understanding of the hydrology of these systems is limited, it is difficult to estimate the effects of mining-related groundwater impacts. Given the challenges associated with understanding groundwater hydrology in the Gobi, we suggest developing a framework to detect changes in surface vegetation related to mining ground water withdrawals (see Appendix 6). The monitoring design would use the Landsat imagery and the SATVI developed for this study.

3.2.5 Cumulative impacts

Successful natural resource management requires an understanding of the synergistic effects of management actions at a variety of temporal and geographic scales. In the case of wildlife, for example, scientists suggest that managers consider effects at the population scale, and not just at the scale of individual projects or management units, to better understand effects to populations and species (Ruggiero et al., 1994).

When considering the impacts of development projects (i.e. mines and roads), it is the impacts that operate at scales beyond that of the individual project that often have the greatest effect. These cumulative impacts are changes to the environment that are caused by an action in combination with other past, present, and future

human actions. They can be difficult to define and measure within the confines of typical EIAs. Most EIAs either do not mention or insufficiently consider cumulative impacts (Cantor and Ross 2010). When mentioned, cumulative impacts are typically addressed qualitatively, without clear delineations of potential spatial and temporal effects (Burris and Cantor 1997). Given the small spatial scale of most EIAs it is often more appropriate to address cumulative impacts at a landscape scale (Joao 2010).

Our analysis and accompanying GIS can be used as a starting point for studies that assess cumulative impacts. One simple application of the GIS developed for this project is examining how future mining activities would potentially impact ecological systems and species (see Appendix 4). Ecological systems or species distributions with a high percentage of overlapping application and exploration leases can be identified for additional examination due to the higher potential for cumulative impacts. Additional studies can also use the GIS to examine potential cumulative impacts resulting from potential development. For example, transportation projects often increase accessibility of surrounding land for development or hunting. Increased accessibility may influence development in a localized area adjacent to the transportation project as well as broad-scale effects on the future impacts within a region.

The GIS assembled for this project, coupled with simulations of potential roads and rail lines, can be used to analyze and plan for the direct and indirect impacts of this kind of development.

3.2.6 Towards a National conservation portfolio: Grasslands and Gobi Ecoregional Assessments

For practical reasons related to the size of the study area, this analysis considers the Gobi region separately from other ecoregions, and separately from the Ecoregional Assessment completed for the Central and Eastern Grasslands (Heiner et al. 2010). To be effective, conservation actions and strategies must consider the landscape as a continuum, and integrate information across these study areas, especially where those ecological regions meet. Thus, the Grasslands and Gobi conservation portfolios should be considered as one (Figure 28).

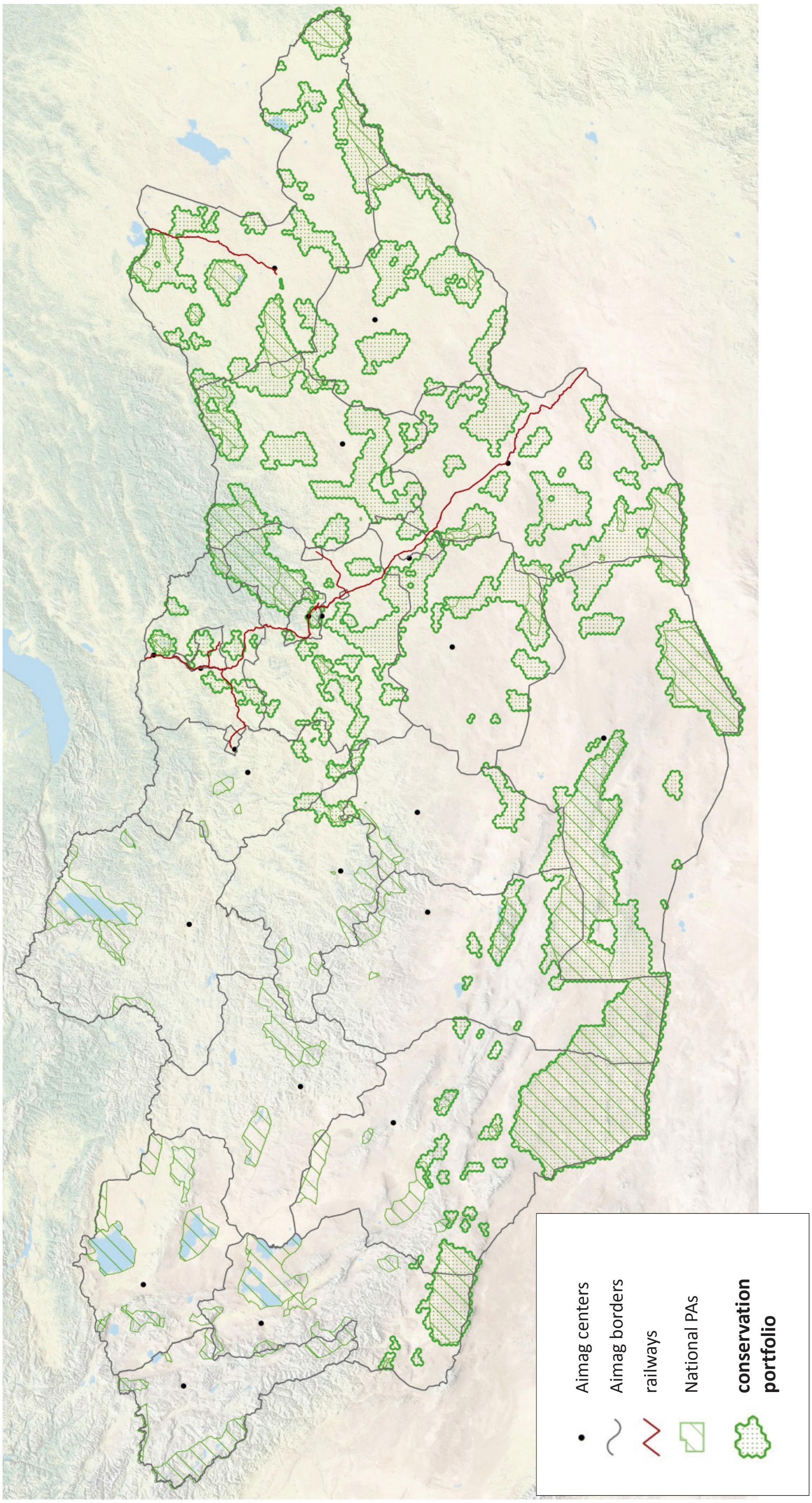



**Figure 28:** National conservation portfolio: Grasslands and Gobi

## 3.3 LIMITATIONS OF THIS STUDY AND RECOMMENDATIONS FOR IMPROVEMENT

Like all natural resource management, conservation planning must be timely, science-based, and an adaptive, iterative process of verification, data collection, and revision. There are always data gaps, and it is impossible to compile and include all existing data and information. In a landscape that remains largely undisturbed and unfragmented, with pending big changes from rapid mineral and energy development and climate change, planning must be flexible and regularly reviewed and revised, to allow managers to adapt to new threats and changes in land use, and incorporate new information.

The results of this study include both a portfolio and the underlying information system, to form a decision-making framework that describes the portfolio sites and the whole study area. The portfolio is the result of a broad, landscape-level analysis, so it is important to adjust site boundaries at the local level based on local knowledge and field surveys. Portfolio design is sensitive to the accuracy of the source data and to decisions regarding biodiversity elements, goals and measuring ecological condition. As new data becomes available and land use decisions change it will be necessary to update the portfolio and underlying GIS.

### Ecosystem classification

We used a combination of coarse-scale data (productivity, elevation, climate) to map matrix-forming systems and finer-scale data (landforms, Landsat-derived vegetation mapping) to map patch-forming systems. This is a first step in defining and mapping representative ecosystems and habitat, or coarse-filter biodiversity elements, for conservation planning. The current map can guide survey design and data collection to revise and improve this GIS model as well as other mapping efforts. The general approach and GIS methods are applicable in other temperate landscapes, such as the grasslands and forests of Mongolia.

Specific limitations:

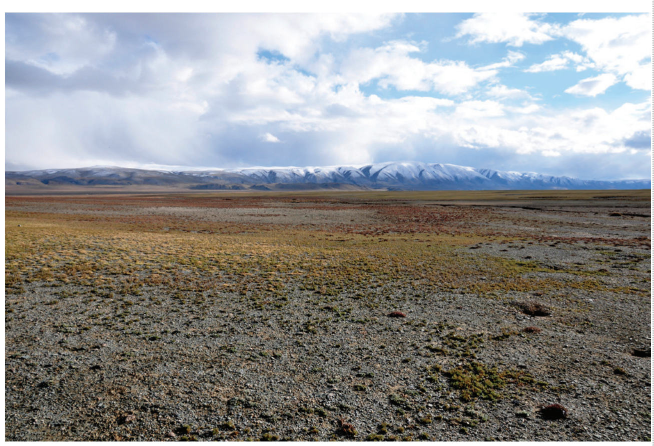
- Fine-scale features: the ecosystem map does not capture fine-scale features including small oases or springs and sandy areas. These features have been mapped in existing 1:100,000 topographic maps.
- Saxaul forests: the classification and map do not explicitly capture Saxaul forests. However, Saxaul is one of several indicator species for the broadly-mapped 'semi-desert' ecosystem type, and in the Eastern Gobi, the 'wet depression' type may be a useful predictor of Saxaul forests occurring in areas with near-surface groundwater. Saxaul forests have been delineated across Mongolia at a coarse scale (National Atlas 2009). Though this national map of Saxaul forest was not part of the ecosystem classification, 55% of the area mapped (24,720 km$^2$) is included in the portfolio, and the expert sites contain an additional 23% (10,350 km$^2$).
- Data validation: an important next step is an accuracy assessment of the ecosystem map using a combination of methods and datasets, including 1) field survey collected during summer of 2012 in Dornogovi, Omnogovi and Govi-Altai Aimags, 2) several hundred research plots established by several long-term rangeland studies, and 3) comparing the ecosystem map with existing fine-scale vegetation maps developed for smaller areas within the Gobi study area.

## Species distribution models

We used available information - range maps, descriptions of habitat and ecology in literature and available survey records - to develop deductive and inductive GIS distribution models. In many cases, particularly for small mammals and reptiles, existing knowledge and surveys remain very limited and the resulting deductive models should be regarded as working hypotheses regarding distribution and habitat selection. These models and maps can guide survey design and data collection to improve understanding of species' ecology, distributions, and status, thereby improving distribution maps. In particular, data-derived habitat models that consider annual and seasonal variation are needed. Thus, more efforts and investment is needed in systematic species inventories (e.g. camera trapping, transects) as well as long-term studies of individuals (e.g. by telemetry).

Specific limitations:

- Water sources are critical resources for wildlife, but are often small and difficult to map consistently at the coarse scale of the species distribution models.
- The water sources that are accurately represented as habitat features in the GIS models (mainly oases) are important resources for humans and livestock, and often occur in areas of relatively high human activity and disturbance. Therefore, the disturbance index may be a misleading indicator of habitat value
- The disturbance index, and specifically the herder density, is a static picture that does not consider seasonal movements of herder households and livestock. Many areas classified as high herder household density and 'moderately disturbed' by the disturbance index may be suitable for wildlife and used by wildlife after herders and livestock move for the season.
- The portfolio design considers connectivity only in terms of the size and shape of individual sites, following the reserve design principle that a few large sites are preferable to many small sites. It is possible to design or evaluate reserve systems in terms of the functional connectivity of the whole reserve network, by modeling movement and barriers



between habitat patches based on graph theory (Minor & Urban 2008; Urban & Keitt 2001; Bunn et al. 2000). For individual species or taxa with similar habitat and dispersal abilities, a graph theoretic analysis can identify critical linkages or gaps across a region to inform conservation and mitigation.

### Disturbance index

The purpose of the disturbance index is to measure cumulative human impacts as an indirect measure of ecological integrity, or departure from historic or natural conditions, and competing economic values. We used this disturbance index 1) to optimize portfolio site selection for ecosystem occurrences in good condition, 2) to classify species distribution models and identify areas where habitat may be degraded, and 3) to analyze cumulative impacts across the study area to ecosystem types and habitat, both current and projected (based on mining exploration leases).

Specific limitations:

- The disturbance index, and specifically the herder density, is a static picture that does not consider seasonal movements of herder households and livestock. Many areas classified as high herder household density and 'moderately disturbed' by the disturbance index may be suitable for wildlife and used by wildlife after herders and livestock move for the season.
- The database of seasonal herder camp locations is very useful for range of applications to land use planning and range management. Due the massive geographic extent and size (over 100,000 camp locations in the Gobi region alone) of this national survey effort, there are some gaps in the temporal and spatial coverage of the database. Because pastoral land use patterns are dynamic and continually changing, the database will require continual updates and maintenance to remain accurate.
- Most roads are dirt tracks and constantly shifting. We digitized roads from a variety of maps and a road atlas. Though incomplete, the resulting GIS is meant to represent patterns and frequent routes of vehicle traffic.
- Mining footprints and related infrastructure, as well as population centers and estimated impact areas were mapped at a coarse scale, digitized from a combination of available maps and satellite imagery (Google Earth).

This mapping will require regular updates to include changes or expansion of these features.

## 3.4 NEXT STEPS

The conservation portfolio consists of 50 sites covering 195,000 km². Approximately half of that area lies in National Protected Areas. Effective conservation will require a variety of strategies including local protection and land use zoning at the Aimag level, and effective management and sustainable funding of existing National protected areas. Therefore, essential next steps include 1) refining the portfolio according to specific threats and management actions using locally available information and 2) capacity-building to make the information system accessible.

### Refine the portfolio

This is a landscape-level assessment of critical habitat and conservation priorities. The geographic scale of the results and source data are coarse out of necessity, and it was not possible to include all the information and considerations of land use planning at the Aimag and Soum level. Therefore, some initial steps towards implementation are:

- At the national level, develop prioritization and classification of individual portfolio sites in terms of threats and conservation actions.
- At the Aimag and Soum level, revise portfolio maps based on local land use plans more detailed locally-available information.

### Capacity building

We will make the results and supporting information available to National, Aimag and Soum governments to inform land use planning, habitat protection and mitigation. Specifically, we will distribute the GIS in several forms:

1) paper maps
2) a publicly available GIS data archive
3) a web-based GIS application:
https://s3.amazonaws.com/DevByDesign-Web/MappingApps/Gobi/demo/gobi.html

# 4.0 CONCLUSION

As human populations and economies grow, pressure on natural resources will increase. Forecasts predict massive increases in investment in infrastructure, most of which will occur in developing countries (World Bank 2007). Energy development alone will result in 22 trillion USD invested in projects by 2030, again mostly in developing countries (International Energy Agency 2006). These global patterns mirror projections in Mongolia, where approximately 15% of the surface rights for mineral and petroleum exploration have been leased and an additional 26% is available for lease. To balance these growing demands with biodiversity conservation requires a shift from business-as-usual. By blending a landscape vision with the mitigation hierarchy, it is possible to move beyond the traditional project-by-project land use planning approach. By avoiding or minimizing impacts to irreplaceable occurrences of biological elements, using the best international standards to ensure that impacts are restored on site, and finally offsetting any remaining residual impacts, development can find a path that is truly consistent with sustainable development (Bartelmus 1997, Pritchard 1993).

A biodiversity vision is essential because it serves as a touchstone to ensure that biologically and ecologically important features remain the core conservation elements over time. Without a vision, we lose sight of the overarching conservation goals, we have difficulty establishing priorities, and we waste scarce resources. Determining appropriate areas to preserve as part of a conservation vision is a challenging exercise, but in reality, this is the easy part. The real challenge is finding funding mechanisms to underwrite the conservation of these areas. The framework outlined here not only balances development with conservation goals, it provides a structure to fund conservation commensurate with impacts from development.

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## APPENDIX 1: Ecosystem classification: descriptions of ecosystem types

The terrestrial ecosystem classification (section 2.2.1) is organized as a hierarchy of biogeographic zones, terrestrial ecosystems based on vegetation and geomorphology, and landforms. Ecosystems are defined and mapped at two levels or spatial scales: matrix-forming and patch forming (Table 2). These ecosystem types are mapped across 5 biogeographic zones: Djungarian Gobi, Trans-Altai Gobi, Gobi-Altay, Southern Gobi, Eastern Gobi. Five of the matrix-forming types (extreme arid desert, true desert, semi-desert, desert steppe, dry steppe) are stratified by landforms.

### Matrix-forming types

Matrix-forming systems cover most of the land area and follow broad patterns of climate and precipitation. These include desert, semi-desert, desert steppe, dry steppe and mountain steppe as described in existing literature (Hilbig 1995, von Wehrden et al. 2006, von Wehrden et al. 2007, Wesche et al. 2005). In the Gobi region, precipitation, vegetation productivity, and the spatial pattern of plant communities are highly correlated (von Wehrden and Wesche 2007). Based on this strong relationship, we developed a predictive model of the distribution of general steppe and desert types based on annual productivity, annual precipitation, and elevation of 1,145 survey records of diagnostic plant communities collected by von Wehrden et al. (2009) and Wesche et al. (2005). In this case, productivity is represented by the 11-year (2000-2011) mean Normalized Difference Vegetation Index (NDVI) during the growing season (June through September), derived from MODIS satellite imagery (NASA 2011a). Based on the results (Figure 5, Table 3), we chose NDVI thresholds to map the predicted distribution of the following vegetation types.

| ecosystem type | barren |
|---|---|
| dominant vegetation | virtually no vegetation |
| principal habitat characteristics | Often low depression, with no water surplus, sometimes also clay depressions |
| soil types | Sealed stone-nets or clay soils |
| typical features | vegetationless |
| characteristic plant species | Only annuals might occur in extremely wet years, in clay depressions salt adapted plants might occur in rainy years. |
| characteristic animal species | Wild camels might pass these regions, and some species such as Allactaga were found even at lowest depressions |
| mapping method | NDVI < 0.045 |

| ecosystem type | extreme arid desert |
|---|---|
| dominant vegetation | *Illjinnia regelii* (diagnostic species for NDVI classification), annuals such as *Bassia dasyphylla* and *Peganum nigellastrum* |
| principal habitat characteristics | Within lower depressions there might be microsites with a slight water surplus, where in a low abundance plant species might still grow. Within moist years annuals might add up to higher cover values. |
| soil types | Stone net soils, undeveloped and often with a high salt content |
| typical features | Almost vegetationsless deserts, at some spots desert scrubs (mainly Chenopodiaceae) might occur |
| characteristic plant species | *Illjinnia regelii* |
| characteristic animal species | Wild camels might pass these regions, and some species such as Allactaga were found even at lowest depressions |
| mapping method | NDVI between 0.045 and 0.065 |

| **ecosystem type** | **true desert** |
|---|---|
| dominant vegetation | characteristic desert shrubs, Haloxylon and Reaumaria, dominate |
| principal habitat characteristics | Rather sparsely growing scrub vegetation with a rather low vegetation cover. |
| soil types | Stone nets or sandy soils |
| typical features | Low-growing scrubs (<0.5 meters), at microsites with some watersurplus scrubs might occasionally grow higher |
| characteristic plant species | *Haloxylon ammodendron, Reaumuria songarica* |
| characteristic animal species | Wild camels and Lhulans might occur in these habitats, and higher scrubs are important for many bird species |
| mapping method | NDVI between 0.065 and 0.08 |

| **ecosystem type** | **semi-desert** |
|---|---|
| dominant vegetation | grasses appear, mixed with desert shrubs (Anabasis, Haloxylon, Ephedra, Reaumaria) |
| principal habitat characteristics | Typical desert scrubs with occasional grasses (e.g. Stipa glareosa) and some wild onions (e.g. Allium mongolicum) |
| soil types | Below Anabasis soils are typically stone nets with blown out fine soil. While Haloxylon tolerates these habitats as well, it is usually found at more uneven and sandy habitats. Salt contents are variable, yet can be locally high. |
| typical features | Desert scrubs with occasional herbs and grasses |
| characteristic plant species | *Haloxylon* and *Anabasis* |
| characteristic animal species | Wild camels, Khulan, occasional P-Horses, gazelle, Wheater, Kestrel, Mongolian ground Jay, Shrikes |
| mapping method | NDVI between 0.08 and 0.1125 |

| **ecosystem type** | **desert steppe** |
|---|---|
| dominant vegetation | Stipa grasses dominate, desert shrubs become less abundant |
| principal habitat characteristics | Grasses and herbals become dominant, according to current climate with partly high cover values |
| soil types | Typically limy soils, often with a stone net due to wind erosion. |
| typical features | Higher diversity, with Stipa and Allium widely dominating the vegetation. |
| characteristic plant species | *Stipa glareosa, Stipa gobica, Allium mongolicum, Allium polyrrhizum, Caragana leucophloea, Ephedra, Eurotia ceratoides* |
| characteristic animal species | Khulan, P-Horse, Gazella, yet livestock is becoming increasingly abundant (sheep, goat) |
| mapping method | NDVI between 0.1125 and 0.15 |

| **ecosystem type** | **dry steppe** |
|---|---|
| dominant vegetation | Stipa and Allium |
| principal habitat characteristics | Highly productive pediment vegetation, almost no scrubs, some elements of montane vegetation occur |
| soil types | Typically limy soils, often with a stone net due to wind erosion. |
| typical features | Typical plants of pediments are mixed with montane elements, and these regions represent important pastures in the region. This community occurs typically in hilly regions and at upper pediments |
| characteristic plant species | *Stipa gobica, Allium polyrrhizum, Caragana leucophloea,* |
| characteristic animal species | Gazella and Khulan sometimes occur in the regions, and this is the lowest altitude where Ibex and Argali occur |
| mapping method | • East Gobi AND mean NDVI > 0.15 AND elevation > 1400m<br>• NDVI > 0.15 AND elevation < 1400m AND growing season precip. > 75mm |

| ecosystem type | mountain steppe |
|---|---|
| dominant vegetation | Comparably dense mountain steppes which are widely dominated by herbs and grasses, yet at some locations patchy scrubs may occur |
| principal habitat characteristics | Highest productivity of all matrix forming vegetation types, and also the highest biodiversity |
| soil types | Stony and undeveloped soils, often with rocky spots. At northern slopes some soil development might befound. |
| typical features | Grass and herb dominated matrix with scrub patches in between, highly productive and diverse vegetation, rich in appearance and physiognomy |
| characteristic plant species | Stipa krylovii, Artemisia frigida, Agropyron christatum, Festuca, Juniperus, Artemisia santolinifolia, Kobresia |
| characteristic animal species | Ibex, Argali, Pica |
| mapping method | mean NDVI > 0.15 AND elevation > 1400m AND landforms= hills or flat |

| ecosystem type | mountains steep terrain |
|---|---|
| dominant vegetation | *Festuca, Kobresia, Betula* forests, Juniper patches |
| principal habitat characteristics | Highly heterogenous vegetation, with numerous species being restricted to small sites with water surplus, e.g. screes and rocky sites |
| soil types | Initial soils on rocks |
| typical features | Extremly heterognous terrain at high mountain sites |
| characteristic plant species | *Festuca* and *Kobresia* (on northern slopes), many species are restricted to these high mountain sites |
| characteristic animal species | Ibex and Argali, birds of prey |
| mapping method | mean NDVI > 0.15 AND elevation > 1400m AND landforms=rough terrain |

**Patch-forming types**

Patch-forming systems include five general types and set of mapping methods. All of these are groundwater-dependent systems that have disproportionately high biological value for wildlife, livestock and people, with sparse and patchy distribution following groundwater hydrology. These systems support high species diversity and provide critical habitat, particularly for small mammals, reptiles and birds, and provide valuable forage for large desert mammals.

| ecosystem type | wet depressions |
|---|---|
| dominant vegetation | |
| principal habitat characteristics | dry river beds or salty depressions with shallow water table following broad drainage patterns. These areas typically support distinct vegetation types (including Saxaul forests in the whole regions, Elm in the Eastern Gobi and Poplar in the western Gobi) and contain physically diverse soil types due to near-surface groundwater and hydrology. |
| soil types | Either clay soils or sandy soils occur frequently, at river beds often intermingled with stones |
| typical features | Highly productive ecosystems, covering extreme features in physiognomy including oases forests |
| characteristic plant species | Populus, Ulmus, Haloxylon, Tamarix |
| characteristic animal species | Because of the relatively high productivity and structural diversity of vegetation and soils, these areas also often support high diversity of small mammals and reptiles (N.Batsaikhan pers. comm.). |
| mapping method | We mapped these features using a GIS topographic model that delineates potential riverine wetlands based on regional flow accumulation and local topography of the stream channel, as derived from a digital elevation model (Lehner et al. 2008) at 3-second (77m) resolution. |

| ecosystem type | dense vegetation around oases – springs or seeps |
|---|---|
| dominant vegetation | large patches of closely-spaced tall shrubs and trees, typically near oases, including tamarisk, Populus, Elm and Saxaul. |
| principal habitat characteristics | Highly productive salt meadows |
| soil types | Clay or sand soils, often with very high salt contents |
| typical features | Vegetation contrasts everything else known in the Gobi due to its unique features, species and physiognomy |
| characteristic plant species | *Blysmus, Triglochin* |
| characteristic animal species | Gobi bear, Shorebirds, many other birds species on trees |
| mapping method | We mapped these features with a vegetation index derived from satellite imagery. First, we compiled and processed 54 Landsat TM5 satellite scenes to cover the study area (NASA 2011b). The acquisition date for most scenes was between June 15 and September 28, 2011. For six scenes, the best available image was acquired in 2010. Pre-processing included an atmospheric correction algorithm, tasseled cap transformation (ERDAS 1999) and calculation of the Soil-adjusted total vegetation index (SATVI; Marsett et al 2006). The SATVI was developed specifically to measure biomass of aridlands vegetation. Dense vegetation in an arid desert setting produces distinct high SATVI values (Figure 6). We classified areas with high SATVI values as dense vegetation. Finally, we separated the result by likely water source or hydrology into patches occurring in either a) dry stream beds and wet depression (described above), or b) spring-fed seeps (remainder). |

| ecosystem type | dense vegetation around oases–in dry river beds |
|---|---|
| dominant vegetation | large patches of closely-spaced tall shrubs and trees, typically near oases, including tamarisk, Populus, Elm and Saxaul. |
| principal habitat characteristics | Large scrubs, up to 2 meters in height or even more |
| soil types | Clay or sand soils, often with very high salt contents |
| typical features | Vegetation contrasts everything else known in the Gobi due to its unique features, species and physiognomy |
| characteristic plant species | *Tamarix, Populus, Ulmus* |
| characteristic animal species | Gobi bear, Shorebirds, many other birds species on trees |
| mapping method | We mapped these features with a vegetation index derived from satellite imagery. First, we compiled and processed 54 Landsat TM5 satellite scenes to cover the study area (NASA 2011b). The acquisition date for most scenes was between June 15 and September 28, 2011. For six scenes, the best available image was acquired in 2010. Pre-processing included an atmospheric correction algorithm, tasseled cap transformation (ERDAS 1999) and calculation of the Soil-adjusted total vegetation index (SATVI; Marsett et al 2006). The SATVI was developed specifically to measure biomass of aridlands vegetation. Dense vegetation in an arid desert setting produces distinct high SATVI values (Figure 6). We classified areas with high SATVI values as dense vegetation. Finally, we separated the result by likely water source or hydrology into patches occurring in either a) dry stream beds and wet depression (described above), or b) spring-fed seeps (remainder). |

| ecosystem type | ephemeral waterbodies |
|---|---|
| dominant vegetation | *Chenopodiaceae* |
| principal habitat characteristics | Highly variable habitats, either dry clay depressions or muddy water bodies |
| soil types | Pure clay |
| typical features | water |
| characteristic plant species | *Salicornia, Crypsis* |
| characteristic animal species | Shorebirds, Ducks |
| mapping method | we digitized the boundaries and point locations of water bodies through manual interpretation of the 2011 Landsat TM5 satellite imagery described above. The tasseled cap transformation produces a 3-band image that improves the contrast between bare ground, water, and vegetation. The resulting image is useful for classification and manual interpretation of landscape features. Using the transformed images, we digitized over 1,200 waterbodies on-screen at 1:200,000. Because precipitation was relatively high during the summer of 2011, many water bodies had surface water and were more visible in the Landsat imagery. |

| ecosystem type | sand massives |
|---|---|
| dominant vegetation | Nitraria patches on small dunes and Psamochloa on sandy soils |
| principal habitat characteristics | large areas of sand dunes |
| soil types | sand |
| typical features | sand dunes |
| characteristic plant species | The unique hydrology of sand dunes often creates small wetlands that support distinct plant communities and habitat with high species diversity. These small wetlands would be classified as salt meadows described above: dense vegetation around oases fed by springs and seeps (tes_patch_ed = 91). |
| characteristic animal species | |
| mapping method | digitized manually from 1:200,000 topographic maps |

| ecosystem type | mountain valleys |
|---|---|
| dominant vegetation | Moutain steppes and woody patches |
| principal habitat characteristics | Rocky valleys |
| soil types | Stony |
| typical features | Steep slopes |
| characteristic plant species | Many species are restricted to these sites |
| characteristic animal species | Ibex and Argali |
| mapping method | mapped as valley bottoms, per the landform classification (below), in mountain steppe or rugged mountain vegetation, per the matrix-forming ecosystem classification |

## APPENDIX 2a: Terrestrial Ecosystem Classification - Composition of the Study Area and the Portfolio

This table lists the composition of the study area and portfolio in terms of ecosystem types defined and mapped by the ecosystem classification described in Section 2.2.1, which is organized in a hierarchy of biogeographic zones, ecosystems based on vegetation, and landforms.

| ECOSYSTEM TYPE | | area distribution ($km^2$) | | | | area distribution (% study area) | | |
|---|---|---|---|---|---|---|---|---|
| ecosystem | landform | study area | National PAs | portfolio | expert sites | National PAs | portfolio | expert sites |
| | | (a) | (b) | (c)* | (d) | (b)/(a) | (c)/(a) | (d)/(a) |
| **Dzungarian Gobi** | | | | | | | | |
| barren | - | 201 | 0 | 61 | 137 | - | 30 | 68 |
| extreme arid | rough steep N-facing | 9 | 0 | 4 | 3 | 1 | 46 | 32 |
| extreme arid | hills N-facing | 66 | 1 | 35 | 28 | 1 | 54 | 42 |
| extreme arid | hills S-facing | 131 | 2 | 46 | 69 | 2 | 35 | 53 |
| extreme arid | rough S-facing | 22 | 0 | 8 | 6 | 1 | 36 | 25 |
| extreme arid | upland | 244 | 5 | 87 | 146 | 2 | 36 | 60 |
| extreme arid | low flat | 209 | 3 | 75 | 127 | 1 | 36 | 61 |
| extreme arid | depression | 101 | 1 | 36 | 63 | 1 | 35 | 62 |
| extreme arid | valleys water tracks | 21 | 0 | 8 | 13 | 2 | 37 | 62 |
| true desert | rough steep N-facing | 48 | 7 | 16 | 17 | 14 | 32 | 35 |
| true desert | hills N-facing | 201 | 33 | 60 | 94 | 17 | 30 | 47 |
| true desert | hills S-facing | 221 | 34 | 63 | 111 | 15 | 28 | 50 |
| true desert | rough S-facing | 64 | 9 | 21 | 18 | 14 | 32 | 28 |
| true desert | upland | 897 | 173 | 288 | 481 | 19 | 32 | 54 |
| true desert | low flat | 929 | 139 | 285 | 510 | 15 | 31 | 55 |
| true desert | depression | 446 | 61 | 134 | 248 | 14 | 30 | 56 |
| true desert | valleys water tracks | 113 | 16 | 37 | 60 | 14 | 32 | 53 |
| semi desert | rough steep N-facing | 451 | 92 | 156 | 121 | 20 | 35 | 27 |
| semi desert | hills N-facing | 1,158 | 424 | 496 | 305 | 37 | 43 | 26 |
| semi desert | hills S-facing | 1,113 | 295 | 360 | 238 | 26 | 32 | 21 |
| semi desert | rough S-facing | 588 | 137 | 220 | 119 | 23 | 37 | 20 |
| semi desert | upland | 4,075 | 1,944 | 2091 | 1,078 | 48 | 51 | 26 |
| semi desert | low flat | 3,815 | 1,831 | 1981 | 1,078 | 48 | 52 | 28 |
| semi desert | depression | 1,838 | 901 | 977 | 510 | 49 | 53 | 28 |
| semi desert | valleys water tracks | 485 | 259 | 279 | 124 | 53 | 57 | 26 |
| desert steppe | rough steep N-facing | 478 | 112 | 184 | 58 | 24 | 38 | 12 |
| desert steppe | hills N-facing | 922 | 287 | 367 | 117 | 31 | 40 | 13 |
| desert steppe | hills S-facing | 826 | 186 | 266 | 68 | 23 | 32 | 8 |
| desert steppe | rough S-facing | 661 | 90 | 202 | 65 | 14 | 31 | 10 |
| desert steppe | upland | 1,357 | 292 | 414 | 274 | 22 | 30 | 20 |
| desert steppe | low flat | 916 | 227 | 302 | 192 | 25 | 33 | 21 |
| desert steppe | depression | 439 | 115 | 151 | 83 | 26 | 34 | 19 |
| desert steppe | valleys water tracks | 92 | 22 | 29 | 17 | 24 | 32 | 19 |
| wet dep., small basins | - | 1,018 | 398 | 437 | 429 | 39 | 43 | 42 |
| wet dep., large basins | - | 1,114 | 473 | 507 | 507 | 43 | 46 | 46 |
| mountain steppe | - | 495 | 33 | 156 | 62 | 7 | 31 | 12 |
| steep mountains | - | 600 | 127 | 197 | 133 | 21 | 33 | 22 |
| ephemeral waterbodies | - | 7 | 0 | 7 | 0 | 1 | 93 | 3 |
| dense veg.- seeps | - | 19 | 14 | 14 | 4 | 70 | 73 | 21 |
| dense veg. – dry river | - | 1,118 | 182 | 365 | 595 | 16 | 33 | 53 |
| mountain valleys | - | 38 | 4 | 13 | 8 | 11 | 35 | 20 |
| sand massives | - | 373 | 111 | 123 | 203 | 30 | 33 | 54 |

* NOTE: column (c) includes column (b) National PAs. The portfolio sites selected to meet the 30% representation goal for ecosystems include all National PAs. Expert sites (column d) were selected separately and do not include the portfolio sites in column (c).

## APPENDIX 2a (continued)

| ECOSYSTEM TYPE | | area distribution (km²) | | | | area distribution (% study area) | | |
|---|---|---|---|---|---|---|---|---|
| ecosystem | landform | study area | National PAs | portfolio | expert sites | National PAs | portfolio | expert sites |
| | | (a) | (b) | (c)* | (d) | (b)/(a) | (c)/(a) | (d)/(a) |
| **Southern Gobi-Altay** | | | | | | | | |
| barren | - | 161 | 149 | 151 | 11 | 92 | 93 | 7 |
| extreme arid | rough steep N-facing | 3 | 2 | 3 | 1 | 77 | 81 | 19 |
| extreme arid | hills N-facing | 153 | 106 | 120 | 11 | 70 | 78 | 7 |
| extreme arid | hills S-facing | 221 | 161 | 173 | 19 | 73 | 78 | 9 |
| extreme arid | rough S-facing | 2 | 1 | 1 | 1 | 39 | 39 | 60 |
| extreme arid | upland | 1,836 | 805 | 942 | 278 | 44 | 51 | 15 |
| extreme arid | low flat | 1,526 | 536 | 651 | 255 | 35 | 43 | 17 |
| extreme arid | depression | 784 | 269 | 329 | 130 | 34 | 42 | 17 |
| extreme arid | valleys water tracks | 225 | 70 | 87 | 40 | 31 | 39 | 18 |
| true desert | rough steep N-facing | 51 | 24 | 25 | 7 | 47 | 48 | 14 |
| true desert | hills N-facing | 610 | 224 | 272 | 142 | 37 | 45 | 23 |
| true desert | hills S-facing | 753 | 274 | 323 | 213 | 36 | 43 | 28 |
| true desert | rough S-facing | 43 | 20 | 21 | 5 | 46 | 48 | 11 |
| true desert | upland | 8,460 | 1,939 | 2771 | 1,974 | 23 | 33 | 23 |
| true desert | low flat | 7,494 | 1,592 | 2327 | 1,671 | 21 | 31 | 22 |
| true desert | depression | 3,847 | 815 | 1192 | 816 | 21 | 31 | 21 |
| true desert | valleys water tracks | 1,048 | 209 | 316 | 218 | 20 | 30 | 21 |
| semi desert | rough steep N-facing | 431 | 147 | 190 | 100 | 34 | 44 | 23 |
| semi desert | hills N-facing | 3,497 | 847 | 1257 | 1,098 | 24 | 36 | 31 |
| semi desert | hills S-facing | 3,817 | 1,017 | 1396 | 1,121 | 27 | 37 | 29 |
| semi desert | rough S-facing | 529 | 188 | 249 | 103 | 36 | 47 | 20 |
| semi desert | upland | 22,527 | 5,379 | 6971 | 6,626 | 24 | 31 | 29 |
| semi desert | low flat | 16,482 | 3,973 | 5172 | 4,591 | 24 | 31 | 28 |
| semi desert | depression | 7,964 | 1,930 | 2512 | 2,219 | 24 | 32 | 28 |
| semi desert | valleys water tracks | 2,008 | 463 | 599 | 580 | 23 | 30 | 29 |
| desert steppe | rough steep N-facing | 496 | 151 | 261 | 34 | 30 | 53 | 7 |
| desert steppe | hills N-facing | 937 | 188 | 403 | 177 | 20 | 43 | 19 |
| desert steppe | hills S-facing | 979 | 188 | 381 | 176 | 19 | 39 | 18 |
| desert steppe | rough S-facing | 751 | 170 | 361 | 48 | 23 | 48 | 6 |
| desert steppe | upland | 1,110 | 222 | 349 | 318 | 20 | 31 | 29 |
| desert steppe | low flat | 713 | 139 | 234 | 191 | 19 | 33 | 27 |
| desert steppe | depression | 358 | 66 | 116 | 88 | 18 | 32 | 25 |
| desert steppe | valleys water tracks | 84 | 17 | 27 | 18 | 21 | 32 | 21 |
| wet dep., small basins | - | 5,492 | 1,090 | 1597 | 1,158 | 20 | 29 | 21 |
| wet dep., large basins | - | 1,459 | 307 | 423 | 714 | 21 | 29 | 49 |
| mountain steppe | - | 89 | 25 | 29 | 7 | 28 | 33 | 8 |
| steep mountains | - | 375 | 189 | 220 | 3 | 50 | 59 | 1 |
| ephemeral waterbodies | - | 21 | 0 | 9 | 3 | 0 | 44 | 15 |
| dense veg.- seeps | - | 394 | 71 | 112 | 62 | 18 | 28 | 16 |
| dense veg. – dry river | - | 739 | 201 | 258 | 245 | 27 | 35 | 33 |
| mountain valleys | - | 5 | 1 | 1 | 0 | 21 | 31 | - |
| sand massives | - | 3,147 | 817 | 967 | 925 | 26 | 31 | 29 |

* NOTE: column (c) includes column (b) National PAs. The portfolio sites selected to meet the 30% representation goal for ecosystems include all National PAs. Expert sites (column d) were selected separately and do not include the portfolio sites in column (c).

## APPENDIX 2a (continued)

| ECOSYSTEM TYPE | | area distribution ($km^2$) | | | | area distribution (% study area) | | |
|---|---|---|---|---|---|---|---|---|
| **ecosystem** | **landform** | **study area** | **National PAs** | **portfolio** | **expert sites** | **National PAs** | **portfolio** | **expert sites** |
| | | (a) | (b) | (c)* | (d) | (b)/(a) | (c)/(a) | (d)/(a) |
| **Trans Altai Gobi** | | | | | | | | |
| barren | - | 2,451 | 2,228 | 2233 | 17 | 91 | 91 | 1 |
| extreme arid | rough steep N-facing | 69 | 60 | 62 | 3 | 86 | 89 | 4 |
| extreme arid | hills N-facing | 887 | 711 | 732 | 50 | 80 | 83 | 6 |
| extreme arid | hills S-facing | 844 | 664 | 672 | 43 | 79 | 80 | 5 |
| extreme arid | rough S-facing | 41 | 27 | 29 | 2 | 67 | 71 | 6 |
| extreme arid | upland | 5,176 | 3,986 | 4065 | 221 | 77 | 79 | 4 |
| extreme arid | low flat | 3,947 | 3,041 | 3094 | 193 | 77 | 78 | 5 |
| extreme arid | depression | 1,938 | 1,501 | 1526 | 88 | 77 | 79 | 5 |
| extreme arid | valleys water tracks | 431 | 334 | 340 | 18 | 77 | 79 | 4 |
| true desert | rough steep N-facing | 133 | 120 | 125 | 4 | 90 | 94 | 3 |
| true desert | hills N-facing | 1,159 | 966 | 1016 | 51 | 83 | 88 | 4 |
| true desert | hills S-facing | 962 | 763 | 793 | 51 | 79 | 82 | 5 |
| true desert | rough S-facing | 91 | 73 | 79 | 6 | 80 | 86 | 7 |
| true desert | upland | 7,301 | 5,640 | 5853 | 436 | 77 | 80 | 6 |
| true desert | low flat | 5,334 | 4,184 | 4336 | 286 | 78 | 81 | 5 |
| true desert | depression | 2,531 | 1,994 | 2061 | 128 | 79 | 81 | 5 |
| true desert | valleys water tracks | 636 | 502 | 519 | 31 | 79 | 82 | 5 |
| semi desert | rough steep N-facing | 296 | 285 | 292 | 1 | 96 | 99 | 0 |
| semi desert | hills N-facing | 1,498 | 1,349 | 1436 | 28 | 90 | 96 | 2 |
| semi desert | hills S-facing | 1,415 | 1,271 | 1339 | 24 | 90 | 95 | 2 |
| semi desert | rough S-facing | 337 | 320 | 323 | 1 | 95 | 96 | 0 |
| semi desert | upland | 5,205 | 4,235 | 4611 | 312 | 81 | 89 | 6 |
| semi desert | low flat | 3,479 | 2,817 | 3072 | 219 | 81 | 88 | 6 |
| semi desert | depression | 1,645 | 1,352 | 1459 | 98 | 82 | 89 | 6 |
| semi desert | valleys water tracks | 428 | 354 | 380 | 25 | 83 | 89 | 6 |
| desert steppe | - | 697 | 690 | 693 | 0 | 99 | 99 | - |
| wet dep., small basins | - | 2,811 | 2,109 | 2230 | 113 | 75 | 79 | 4 |
| wet dep., large basins | - | 703 | 461 | 480 | 134 | 66 | 68 | 19 |
| mountain steppe | - | 3 | 3 | 3 | 0 | 100 | 100 | - |
| steep mountains | - | 18 | 18 | 18 | 0 | 100 | 100 | - |
| ephemeral waterbodies | - | 3 | 3 | 3 | 0 | 100 | 100 | - |
| dense veg.- seeps | - | 94 | 42 | 43 | 1 | 45 | 45 | 1 |
| dense veg. – dry river | - | 12 | 8 | 8 | 0 | 65 | 68 | 0 |
| sand massives | - | 90 | 74 | 83 | 5 | 82 | 93 | 6 |

* NOTE: column (c) includes column (b) National PAs. The portfolio sites selected to meet the 30% representation goal for ecosystems include all National PAs. Expert sites (column d) were selected separately and do not include the portfolio sites in column (c).

## APPENDIX 2a (continued)

| ECOSYSTEM TYPE | | area distribution ($km^2$) | | | | area distribution (% study area) | | |
|---|---|---|---|---|---|---|---|---|
| ecosystem | landform | study area | National PAs | portfolio | expert sites | National PAs | portfolio | expert sites |
| | | (a) | (b) | (c)* | (d) | (b)/(a) | (c)/(a) | (d)/(a) |
| **Gobi-Altay** | | | | | | | | |
| barren | - | 95 | 0 | 61 | 34 | - | 64 | 36 |
| extreme arid | rough steep N-facing | 6 | 0 | 2 | 3 | - | 34 | 51 |
| extreme arid | hills N-facing | 31 | 1 | 10 | 11 | 2 | 33 | 34 |
| extreme arid | hills S-facing | 22 | 1 | 7 | 6 | 6 | 32 | 27 |
| extreme arid | rough S-facing | 5 | 0 | 2 | 2 | - | 40 | 51 |
| extreme arid | upland | 283 | 7 | 90 | 93 | 3 | 32 | 33 |
| extreme arid | low flat | 289 | 5 | 93 | 100 | 2 | 32 | 35 |
| extreme arid | depression | 150 | 3 | 48 | 54 | 2 | 32 | 36 |
| extreme arid | valleys water tracks | 36 | 1 | 12 | 13 | 2 | 34 | 36 |
| true desert | rough steep N-facing | 29 | 3 | 9 | 9 | 10 | 30 | 33 |
| true desert | hills N-facing | 191 | 38 | 66 | 44 | 20 | 34 | 23 |
| true desert | hills S-facing | 293 | 45 | 105 | 31 | 15 | 36 | 11 |
| true desert | rough S-facing | 22 | 1 | 8 | 7 | 6 | 36 | 31 |
| true desert | upland | 1,922 | 238 | 614 | 275 | 12 | 32 | 14 |
| true desert | low flat | 1,637 | 149 | 483 | 239 | 9 | 29 | 15 |
| true desert | depression | 816 | 73 | 239 | 117 | 9 | 29 | 14 |
| true desert | valleys water tracks | 201 | 17 | 61 | 26 | 8 | 31 | 13 |
| semi desert | rough steep N-facing | 398 | 57 | 127 | 31 | 14 | 32 | 8 |
| semi desert | hills N-facing | 2,338 | 335 | 710 | 155 | 14 | 30 | 7 |
| semi desert | hills S-facing | 2,705 | 384 | 807 | 299 | 14 | 30 | 11 |
| semi desert | rough S-facing | 450 | 51 | 130 | 34 | 11 | 29 | 7 |
| semi desert | upland | 10,188 | 1,673 | 3058 | 1,009 | 16 | 30 | 10 |
| semi desert | low flat | 7,397 | 1,144 | 2213 | 656 | 15 | 30 | 9 |
| semi desert | depression | 3,477 | 530 | 1041 | 324 | 15 | 30 | 9 |
| semi desert | valleys water tracks | 760 | 120 | 239 | 67 | 16 | 31 | 9 |
| desert steppe | rough steep N-facing | 1,198 | 161 | 378 | 32 | 13 | 32 | 3 |
| desert steppe | hills N-facing | 3,812 | 510 | 1147 | 160 | 13 | 30 | 4 |
| desert steppe | hills S-facing | 3,617 | 468 | 1092 | 315 | 13 | 30 | 9 |
| desert steppe | rough S-facing | 1,567 | 196 | 473 | 30 | 13 | 30 | 2 |
| desert steppe | upland | 6,359 | 753 | 1918 | 403 | 12 | 30 | 6 |
| desert steppe | low flat | 3,886 | 506 | 1178 | 255 | 13 | 30 | 7 |
| desert steppe | depression | 1,818 | 235 | 557 | 121 | 13 | 31 | 7 |
| desert steppe | valleys water tracks | 342 | 42 | 107 | 15 | 12 | 31 | 4 |
| dry steppe | - | 24 | 0 | 9 | 0 | - | 36 | - |
| wet dep., small basins | - | 2,066 | 243 | 699 | 127 | 12 | 34 | 6 |
| wet dep., large basins | - | 653 | 71 | 207 | 66 | 11 | 32 | 10 |
| mountain steppe | - | 12,470 | 3,179 | 3939 | 830 | 25 | 32 | 7 |
| steep mountains | - | 9,810 | 2,324 | 2953 | 927 | 24 | 30 | 9 |
| ephemeral waterbodies | - | 64 | 0 | 43 | 0 | - | 67 | 0 |
| dense veg.- seeps | - | 206 | 27 | 50 | 61 | 13 | 24 | 29 |
| dense veg. – dry river | - | 866 | 92 | 285 | 16 | 11 | 33 | 2 |
| mountain valleys | - | 1,062 | 229 | 319 | 46 | 22 | 30 | 4 |
| sand massives | - | 689 | 567 | 578 | 6 | 82 | 84 | 1 |

* NOTE: column (c) includes column (b) National PAs. The portfolio sites selected to meet the 30% representation goal for ecosystems include all National PAs. Expert sites (column d) were selected separately and do not include the portfolio sites in column (c).

## APPENDIX 2a (continued)

| ECOSYSTEM TYPE | | area distribution ($km^2$) | | | | area distribution (% study area) | | |
|---|---|---|---|---|---|---|---|---|
| ecosystem | landform | study area | National PAs | portfolio | expert sites | National PAs | portfolio | expert sites |
| | | (a) | (b) | (c)* | (d) | (b)/(a) | (c)/(a) | (d)/(a) |
| **Eastern Gobi** | | | | | | | | |
| extreme arid | - | 224 | 75 | 166 | 3 | 34 | 74 | 1 |
| true desert | - | 1,943 | 413 | 817 | 31 | 21 | 42 | 2 |
| semi desert | rough steep N-facing | 48 | 6 | 18 | 1 | 13 | 37 | 2 |
| semi desert | hills N-facing | 1,750 | 172 | 542 | 32 | 10 | 31 | 2 |
| semi desert | hills S-facing | 1,668 | 125 | 503 | 35 | 7 | 30 | 2 |
| semi desert | rough S-facing | 17 | 3 | 6 | 0 | 15 | 32 | 1 |
| semi desert | upland | 28,986 | 2,448 | 8682 | 1,816 | 8 | 30 | 6 |
| semi desert | low flat | 20,038 | 1,743 | 5996 | 1,525 | 9 | 30 | 8 |
| semi desert | depression | 8,894 | 783 | 2673 | 648 | 9 | 30 | 7 |
| semi desert | valleys water tracks | 2,415 | 207 | 722 | 182 | 9 | 30 | 8 |
| desert steppe | rough steep N-facing | 55 | 6 | 19 | 3 | 11 | 35 | 5 |
| desert steppe | hills N-facing | 3,152 | 320 | 945 | 77 | 10 | 30 | 2 |
| desert steppe | hills S-facing | 2,496 | 189 | 747 | 63 | 8 | 30 | 3 |
| desert steppe | rough S-facing | 24 | 2 | 8 | 1 | 10 | 34 | 3 |
| desert steppe | upland | 44,938 | 3,441 | 13448 | 1,064 | 8 | 30 | 2 |
| desert steppe | low flat | 28,152 | 2,027 | 8516 | 677 | 7 | 30 | 2 |
| desert steppe | depression | 12,322 | 914 | 3722 | 293 | 7 | 30 | 2 |
| desert steppe | valleys water tracks | 3,099 | 227 | 931 | 82 | 7 | 30 | 3 |
| dry steppe | rough steep N-facing | 68 | 11 | 20 | 28 | 16 | 30 | 41 |
| dry steppe | hills N-facing | 1,981 | 231 | 624 | 56 | 12 | 31 | 3 |
| dry steppe | hills S-facing | 1,451 | 134 | 423 | 17 | 9 | 29 | 1 |
| dry steppe | rough S-facing | 32 | 6 | 11 | 12 | 19 | 36 | 37 |
| dry steppe | upland | 26,766 | 1,461 | 7980 | 76 | 5 | 30 | 0 |
| dry steppe | low flat | 17,397 | 743 | 5236 | 53 | 4 | 30 | 0 |
| dry steppe | depression | 7,555 | 333 | 2272 | 24 | 4 | 30 | 0 |
| dry steppe | valleys water tracks | 1,897 | 75 | 573 | 3 | 4 | 30 | 0 |
| wet dep., small basins | - | 12,138 | 806 | 3686 | 607 | 7 | 30 | 5 |
| wet dep., large basins | - | 5,216 | 646 | 1624 | 577 | 12 | 31 | 11 |
| ephemeral waterbodies | - | 228 | 14 | 72 | 13 | 6 | 32 | 6 |
| dense veg.- seeps | - | 311 | 7 | 92 | 6 | 2 | 30 | 2 |
| dense veg. – dry river | - | 4,178 | 420 | 1260 | 86 | 10 | 30 | 2 |
| sand massives | - | 7,654 | 450 | 2310 | 1 | 6 | 30 | 0 |

* NOTE: column (c) includes column (b) National PAs. The portfolio sites selected to meet the 30% representation goal for ecosystems include all National PAs. Expert sites (column d) were selected separately and do not include the portfolio sites in column (c).

## APPENDIX 2b: Species Habitat Models - Composition of the Study Area and the Portfolio

This table lists the composition of the study area and portfolio in terms of species habitat distributions defined and mapped by GIS models described in Appendix 3.

| Species name | area distribution ($km^2$) | | | | area distribution (% study area) | | | |
|---|---|---|---|---|---|---|---|---|
| | study area | National PAs | portfolio | expert sites | study area | National PAs | portfolio | expert sites |
| | (a) | (b) | (c)* | (d) | | (b)/(a) | (c)/(a) | (d)/(a) |
| LARGE MAMMALS | | | | | | | | |
| Asiatic wild ass (Equus hemionus) - current | 233,202 | 73,382 | 113,457 | 31,875 | 100 | 31 | 49 | 14 |
| Asiatic wild ass (Equus hemionus) - potential | 460,956 | 84,548 | 160,943 | 47,076 | 100 | 18 | 35 | 10 |
| Goitered gazelle (Gazella subgutturosa) | 487,795 | 100,189 | 177,968 | 49,690 | 100 | 21 | 36 | 10 |
| Mongolian gazelle (Procapra gutturosa) | 329,601 | 45,381 | 111,187 | 22,346 | 100 | 14 | 34 | 7 |
| Argali (Ovis ammon) | 47,196 | 9,374 | 16,000 | 4,936 | 100 | 20 | 34 | 10 |
| Siberian ibex (Capra sibirica) | 47,005 | 11,070 | 17,089 | 5,585 | 100 | 24 | 36 | 12 |
| Snow leopard (Panthera uncia) | 9,018 | 2,392 | 3,431 | 952 | 100 | 27 | 38 | 11 |
| Bactrian camel (Camelus bactrianus ferus) | most of known range occurs inside Ikh Gobi SPA | | | | | | | |
| Gobi bear (Ursus arctos gobiensis) | entire known range occurs inside Ikh Gobi SPA | | | | | | | |
| SMALL MAMMALS | | | | | | | | |
| Alashan ground squirrel (Spermophilus alashanicus) | 11,906 | 5,788 | 6,526 | 2,425 | 100 | 49 | 55 | 20 |
| Forest dormouse (Dryomys nitedula) | 342 | 36 | 203 | 108 | 100 | 11 | 59 | 31 |
| Gobi jerboa (Allactaga bullata) | 409,043 | 91,819 | 153,959 | 42,657 | 100 | 22 | 38 | 10 |
| Small five-toed jerboa (Allactaga elater) | 21,044 | 7,542 | 9,114 | 7,288 | 100 | 36 | 43 | 35 |
| Five-toed pygmy jerboa (Cardiocranius paradoxus) | 415,382 | 95,384 | 157,928 | 43,237 | 100 | 23 | 38 | 10 |
| Long-eared jerboa (Euchoreutes naso) | 141,018 | 60,309 | 70,732 | 22,990 | 100 | 43 | 50 | 16 |
| Thick-tailed pygmy jerboa (Salpingotus crassicauda) | 211,969 | 49,216 | 79,272 | 34,139 | 100 | 23 | 37 | 16 |
| Kozlov's pygmy jerboa (Salpingotus kozlovi) | 193,060 | 78,497 | 100,705 | 28,858 | 100 | 41 | 52 | 15 |
| Mongolian three-toed jerboa (Stylodipus sungorus) | 26,272 | 8,867 | 10,852 | 8,148 | 100 | 34 | 41 | 31 |
| Grey hamster (Cricetulus migratorius) | 208,166 | 47,611 | 83,459 | 29,750 | 100 | 23 | 40 | 14 |
| Tamarisk gerbil (Meriones tamariscinus) | 3,687 | 1,178 | 1,449 | 1,735 | 100 | 32 | 39 | 47 |

* NOTE: column (c) includes column (b) National PAs. The portfolio sites selected to meet the 30% representation goal for ecosystems include all National PAs. Expert sites (column d) were selected separately and do not include the portfolio sites in column (c).

## APPENDIX 2b: (continued)

| Species name | area distribution (km²) | | | | area distribution (% study area) | | | |
|---|---|---|---|---|---|---|---|---|
| | study area | National PAs | portfolio | expert sites | study area | National PAs | portfolio | expert sites |
| | (a) | (b) | (c)* | (d) | | (b)/(a) | (c)/(a) | (d)/(a) |
| AMPHIBIANS & REPTILES | | | | | | | | |
| Pewzow's toad (Bufo pewzowi) | 1,195 | 36 | 203 | 752 | 100 | 3 | 17 | 63 |
| Gobi naked-toed gecko (Cyrtopodion elongatus) | 38,655 | 21,496 | 25,556 | 4,677 | 100 | 56 | 66 | 12 |
| Przewalski's wonder gecko (Teratoscincus przewalskii) | 185,930 | 70,263 | 86,750 | 28,252 | 100 | 38 | 47 | 15 |
| Mongolian agama (Laudakia stoliczkana) | 66,530 | 29,207 | 37,280 | 8,294 | 100 | 44 | 56 | 12 |
| Tatar sand boa (Eryx tataricus) | 138,201 | 45,304 | 57,998 | 25,836 | 100 | 33 | 42 | 19 |
| Slender racer (Coluber spinalis) | 296,327 | 57,116 | 107,055 | 33,220 | 100 | 19 | 36 | 11 |
| BIRDS | | | | | | | | |
| Houbara Bustard (Chlamydotis undulata) | 429,428 | 85,245 | 154,722 | 42,932 | 100 | 20 | 36 | 10 |
| Short-toed Snake-eagle (Ciracaetus gallicus) | 194,617 | 22,383 | 57,334 | 25,710 | 100 | 12 | 29 | 13 |
| Saker Falcon (Falco cherrug) | 438,731 | 70,894 | 145,463 | 40,492 | 100 | 16 | 33 | 9 |
| Lammergeier, Bearded Vulture (Gypaetus barbatus) | 438,731 | 70,894 | 145,463 | 40,492 | 100 | 16 | 33 | 9 |
| Saxaul Sparrow (Passer ammodendri) | 432,717 | 99,815 | 163,887 | 50,368 | 100 | 23 | 38 | 12 |
| Mongolian Ground-jay (Podoces hendersoni) | 523,725 | 109,123 | 190,143 | 52,652 | 100 | 21 | 36 | 10 |
| Altai Snowcock (Tetraogallus altaicus) | 24,179 | 5,896 | 7,510 | 1,961 | 100 | 24 | 31 | 8 |
| Cinereous Vulture (Aegypius monachus) | 523,709 | 109,123 | 190,143 | 52,652 | 100 | 21 | 36 | 10 |

* NOTE: column (c) includes column (b) National PAs. The portfolio sites selected to meet the 30% representation goal for ecosystems include all National PAs. Expert sites (column d) were selected separately and do not include the portfolio sites in column (c).

## APPENDIX 3: Focal Species Habitat Distribution Maps

To assess the distribution and protection of rare and endangered species, or fine-filter biodiversity elements, we developed GIS models of habitat distribution for 33 species of mammals, herptiles and birds selected based on threatened status in the National Red Lists, listed in Table 4 (Clark et al. 2006, Terbish et al. 2006, Gombobataar et al. 2012). Most of the habitat models are deductive models based on habitat descriptions in literature and map units in the ecosystem and landform classifications. Three are inductive (data-driven statistical) models based on analysis of survey records and habitat selection.

For most all of these species, existing data and knowledge regarding distribution and ecology is limited, and there is an urgent for basic research, surveys and monitoring. The goal of this mapping effort was to combine and map available information about range, distribution and habitat in order to estimate current levels of protection, ecological condition and threat from future mining development (Appendix 2b and Appendix 4). We did not include the modeled focal species habitat directly in portfolio design for reasons explained in Section 2.3, but we measured representation of modeled habitat in the portfolio and expert sites (Appendix 2b). In all but one case (Pewzow's Toad), the portfolio site selection included more than 30% of the modeled distribution of each focal species. These models and maps can guide survey design and data collection to improve understanding of species' ecology, distributions and status, and improve the distribution maps.

Developing each habitat model followed these general steps.

1. establish species range, based on literature and existing survey records.
2. develop GIS habitat distribution model. Most are deductive models based on habitat descriptions in literature and applied with map units in the ecosystem and landform classifications. Three are inductive models based on analysis of survey records and habitat selection.
3. classify distribution according to disturbance, based on the disturbance index (Section 2.4).

# LARGE MAMMALS

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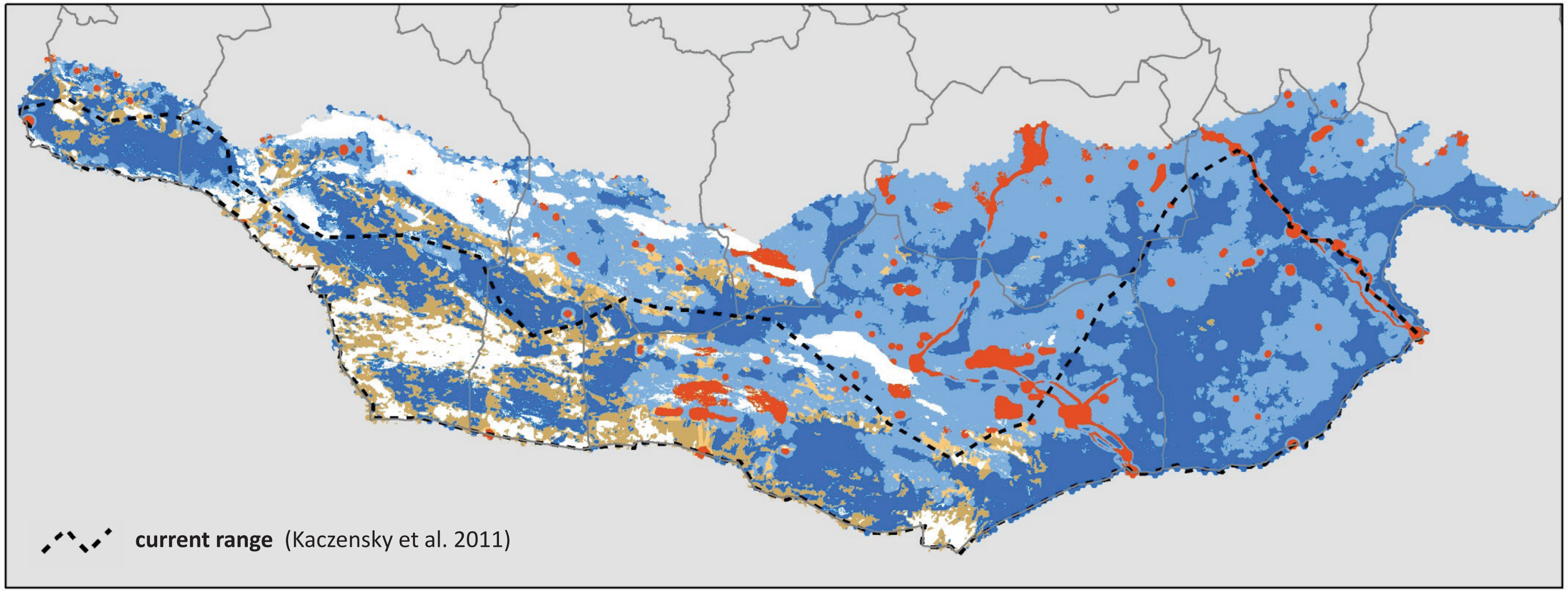
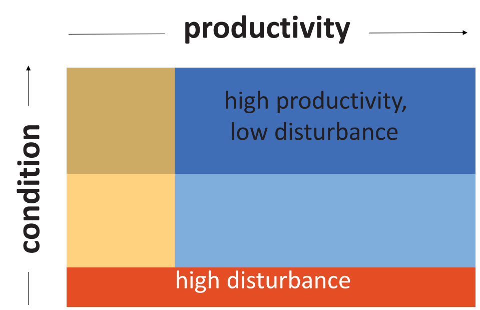


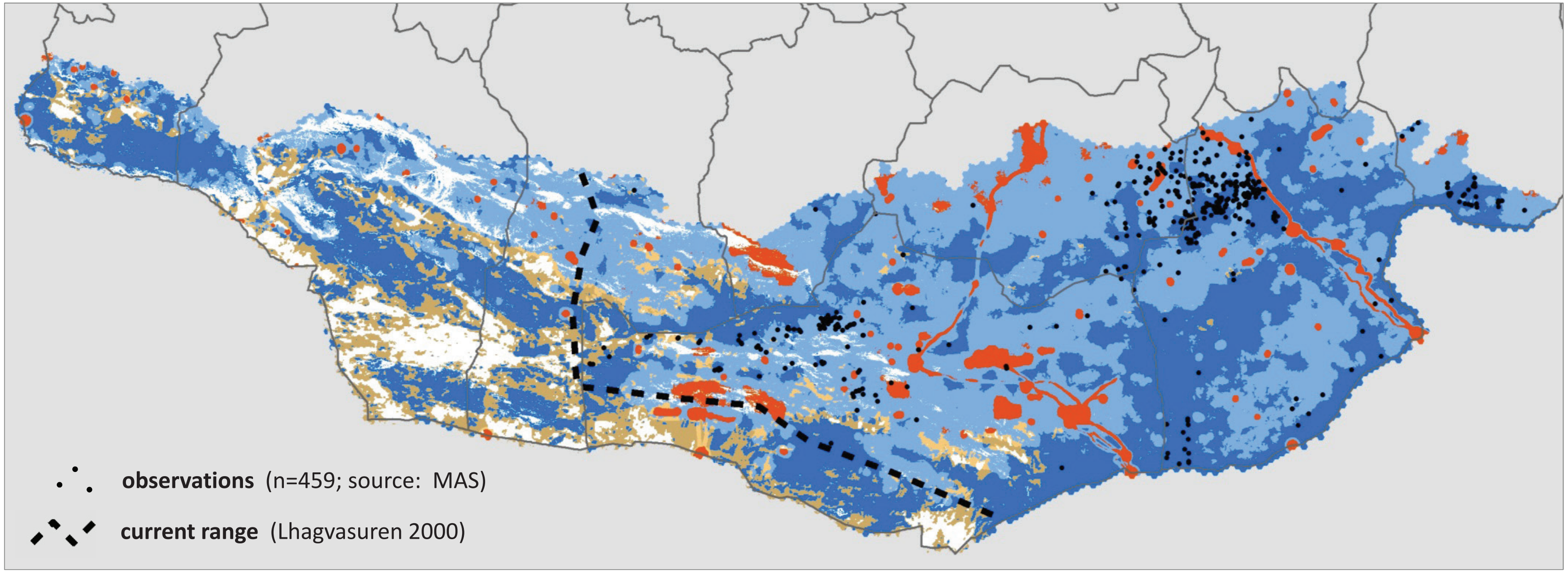

## Khulan (*Equus hemionus*) habitat model

1. **range:** map shows current (Kaczensky et al. 2011) and potential range.
2. **classify habitat:** based on Kaczensky et al. (2011), who assessed habitat and connectivity and mapped suitable habitat according to biomass production and terrain (excluding mountains).
    - high: semi-desert and desert steppe [1]
    - low: true desert [1]
    - exclude extreme arid desert [1]
    - exclude hills, rugged terrain [2]
3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%



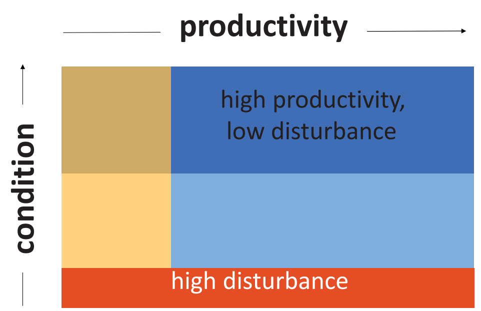

white: not habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)



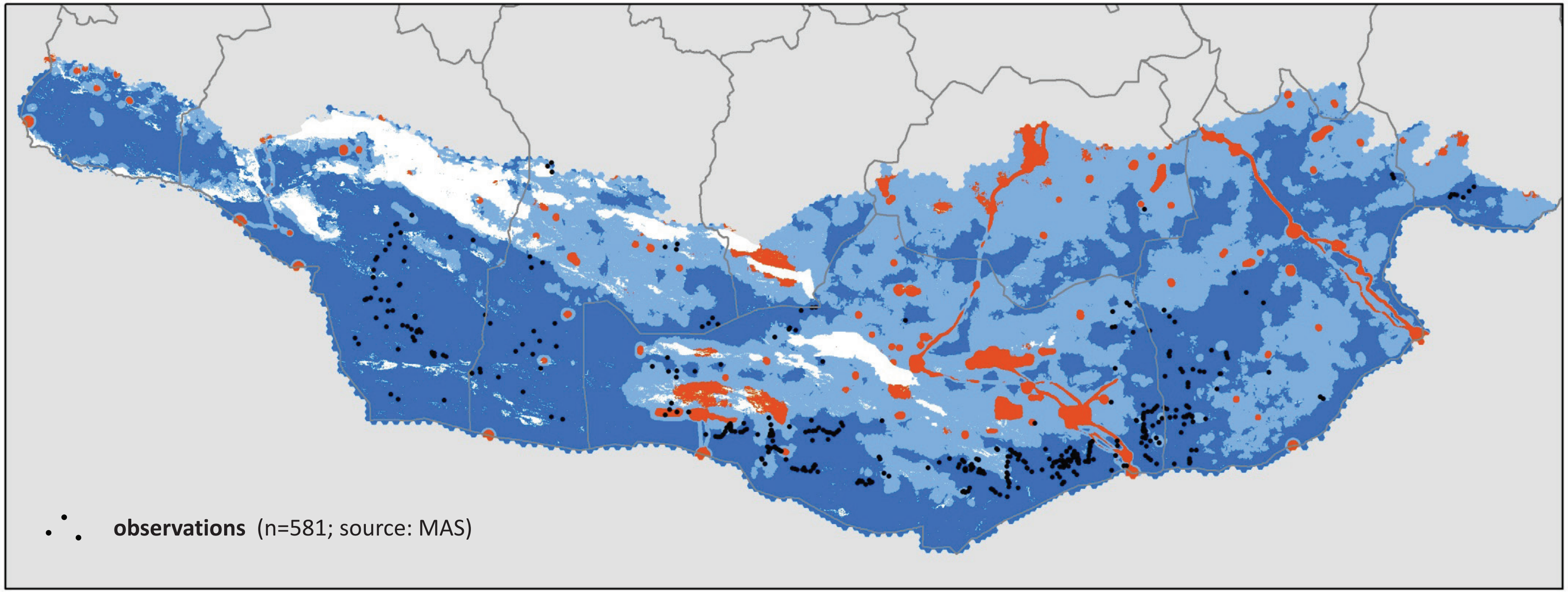

## Mongolian Gazelle (*Procapra gutturosa*) habitat model

1. **range:** map shows current (Lhagvasuren 2000) and potential range.
2. **classify habitat:** rolling plains, steppe or semi-desert (Mallon 2008, Heptner 1961). Avoid irregular terrain, narrow valleys (Heptner 1961). Common forage is steppe plants: *Stipa, Allium, Artemisia* spp. (Olson 2008, Lhagvasuren 1997).
   - high: semi-desert and steppe [1]
   - low: true desert [1]
   - exclude hills, rugged terrain [2]
   - exclude extreme arid desert [1]
3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




white: not habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)




## Black-Tailed Gazelle (*Gazella subgutturosa*) habitat model

1. **range:** (Batsaikhan et al. 2010)
2. **classify habitat:** wide range of semi-desert and shrub desert (Mallon 2008, Kingswood 1996, Heptner 1961). Prefer plains or gently rolling or terraced deserts (Heptner 1961) .
    - exclude mountains [1]
    - exclude hills, rugged terrain [2]
3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%

**condition**

low disturbance

moderate disturbance

high disturbance

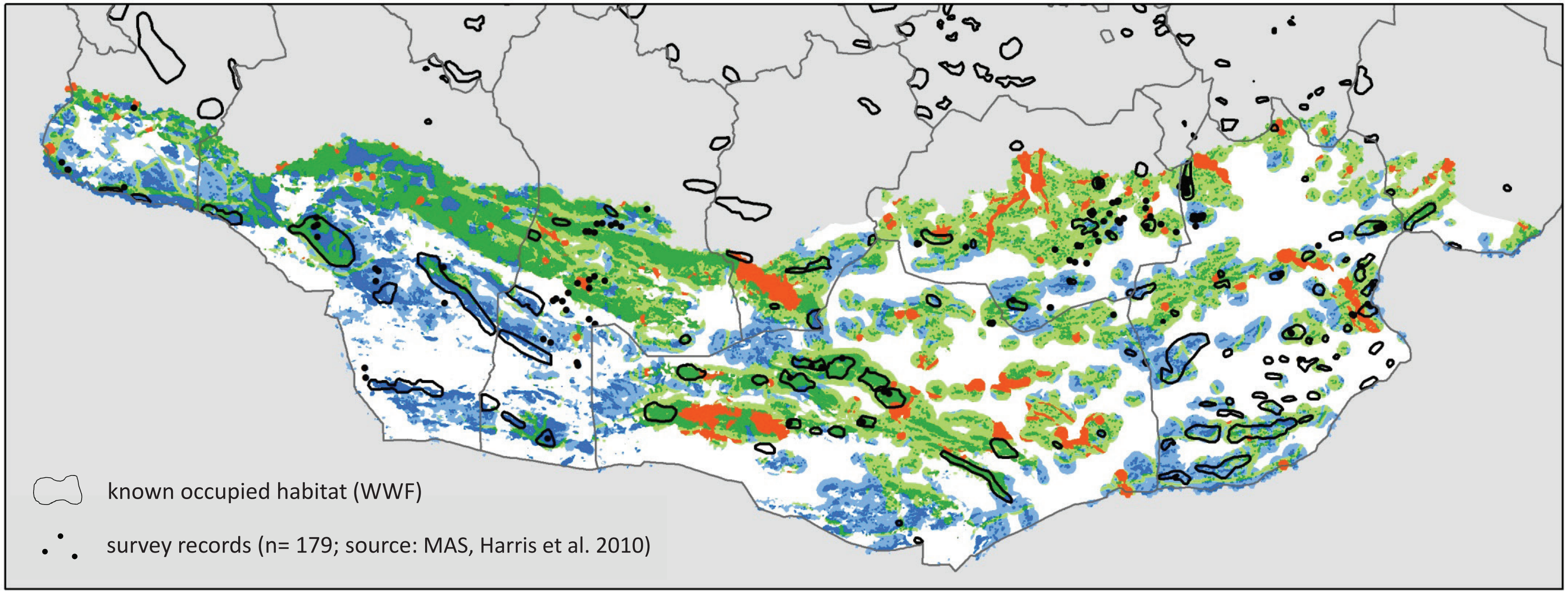
white: not habitat

gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)

[2] landform classification map (section 2.2.1, Figure 8)

[3] disturbance index (section 2.4)



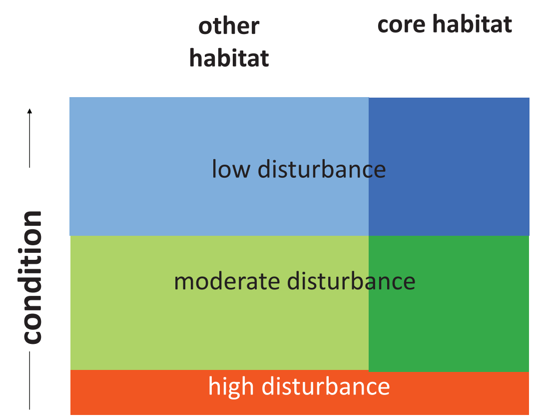

## Argali (*Ovis ammon*) habitat model

**1. habitat envelope model based on survey records to define:**

- **core habitat** (escape terrain, lambing habitat) based on Vector Ruggedness Measure (VRM, Sappington 2007), patch size and landscape metrics.
- **other habitat** based on distance from escape terrain

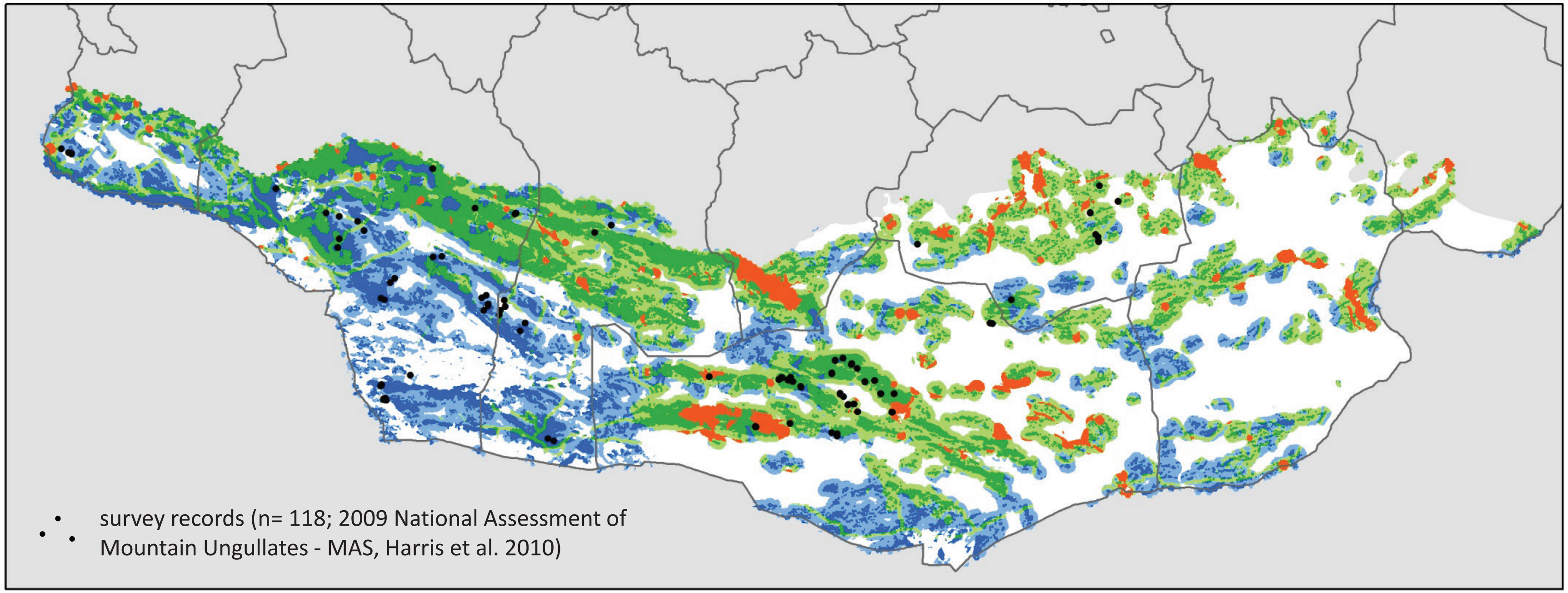
**2. classify by condition / disturbance** [3]

- unsuitable: most disturbed 5% of study area
- moderate: remaining 45%
- best: least disturbed 50%



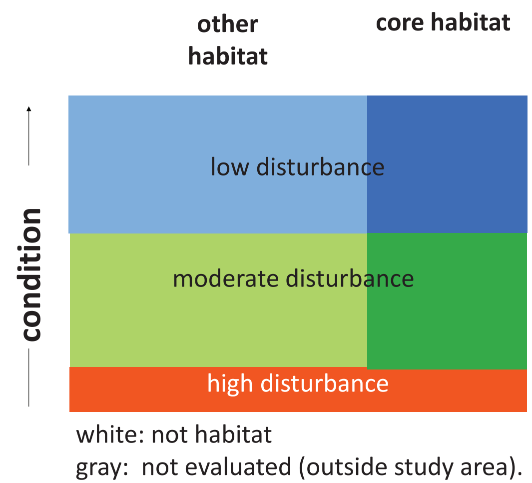

white: not habitat
gray: not evaluated (outside study area).

[3] disturbance index (section 2.4)

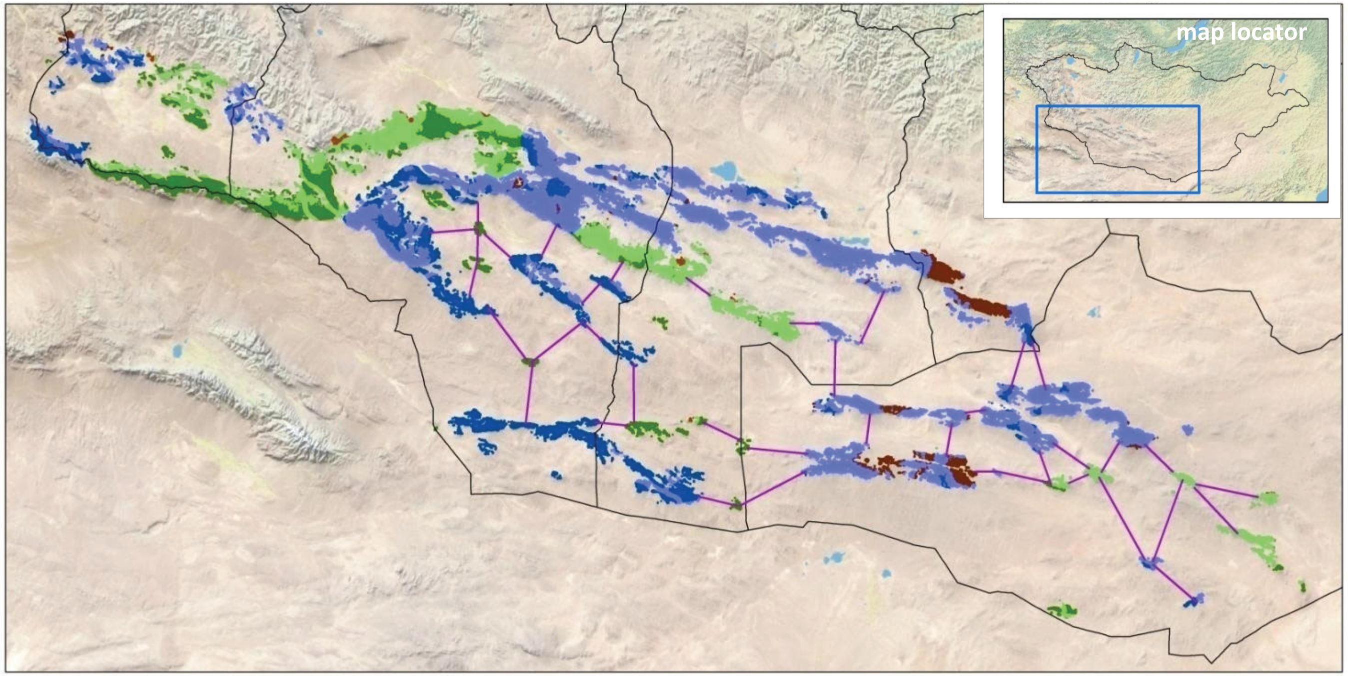



## Siberian Ibex (*Capra sibirica*) habitat model

1. **habitat envelope model based on survey records to define:**
   - **core habitat** (escape terrain, lambing habitat) based on Vector Ruggedness Measure (VRM, Sappington 2007), patch size and landscape metrics.
   - **other habitat** based on distance from escape terrain
2. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%

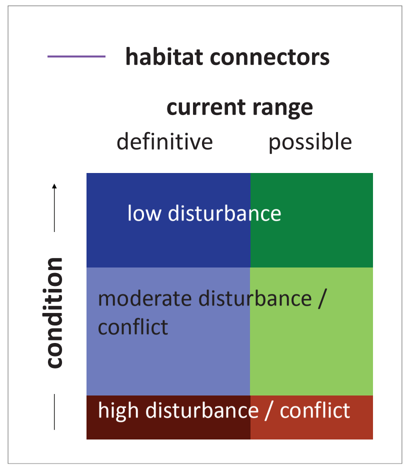



[3] disturbance index (section 2.4)



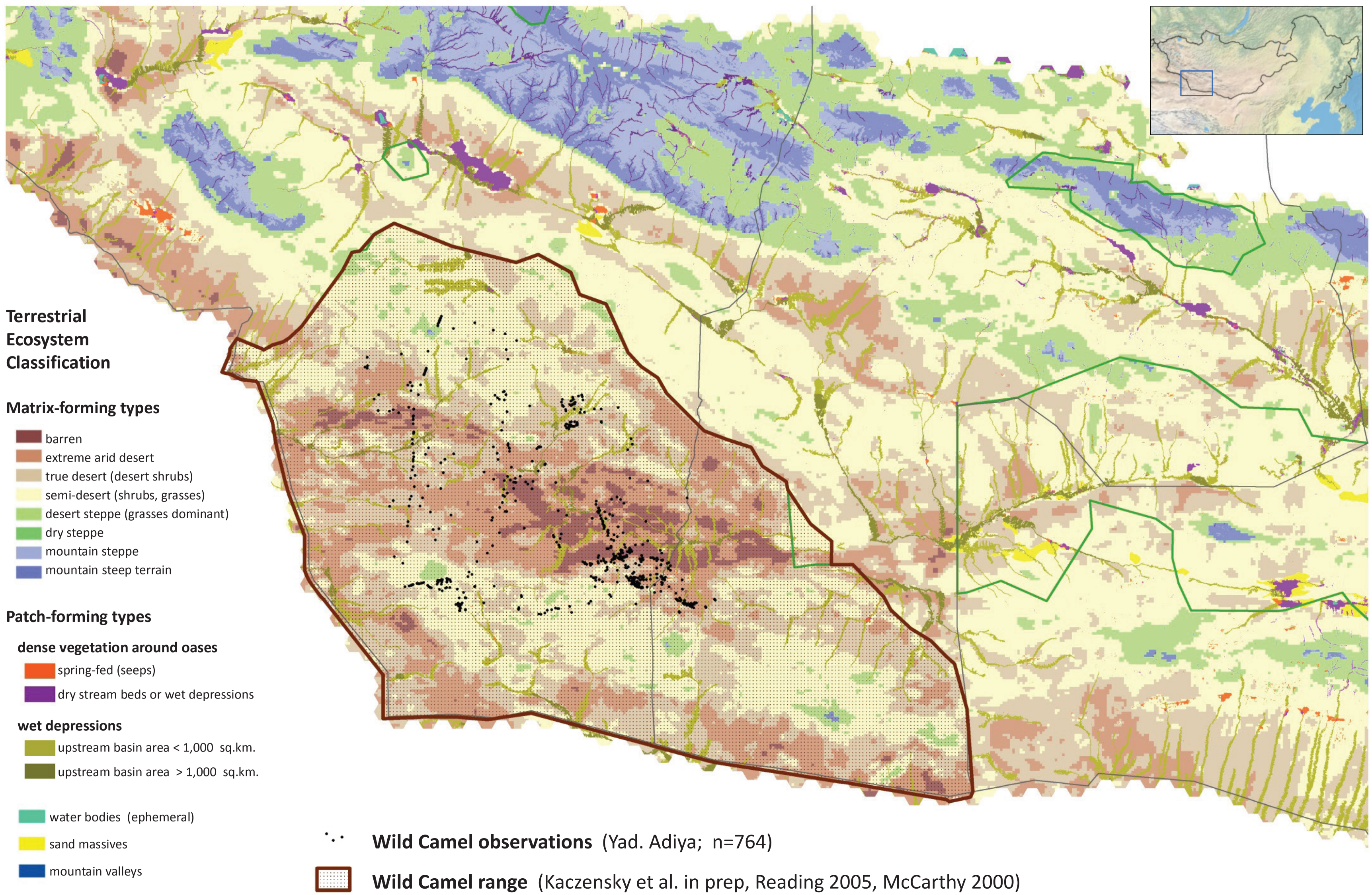

## Snow Leopard (*Panthera uncia*) habitat model

1. **habitat envelope model based on observation records [1] to define:**
   - **escape terrain** (core habitat) based on Vector Ruggedness Measure (VRM, Sappington 2007), patch size and landscape metrics.
   - **other habitat** based on distance from escape terrain
2. **classify habitat as occupied**: definitive / possible [1]
3. **classify by disturbance / conflict** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%

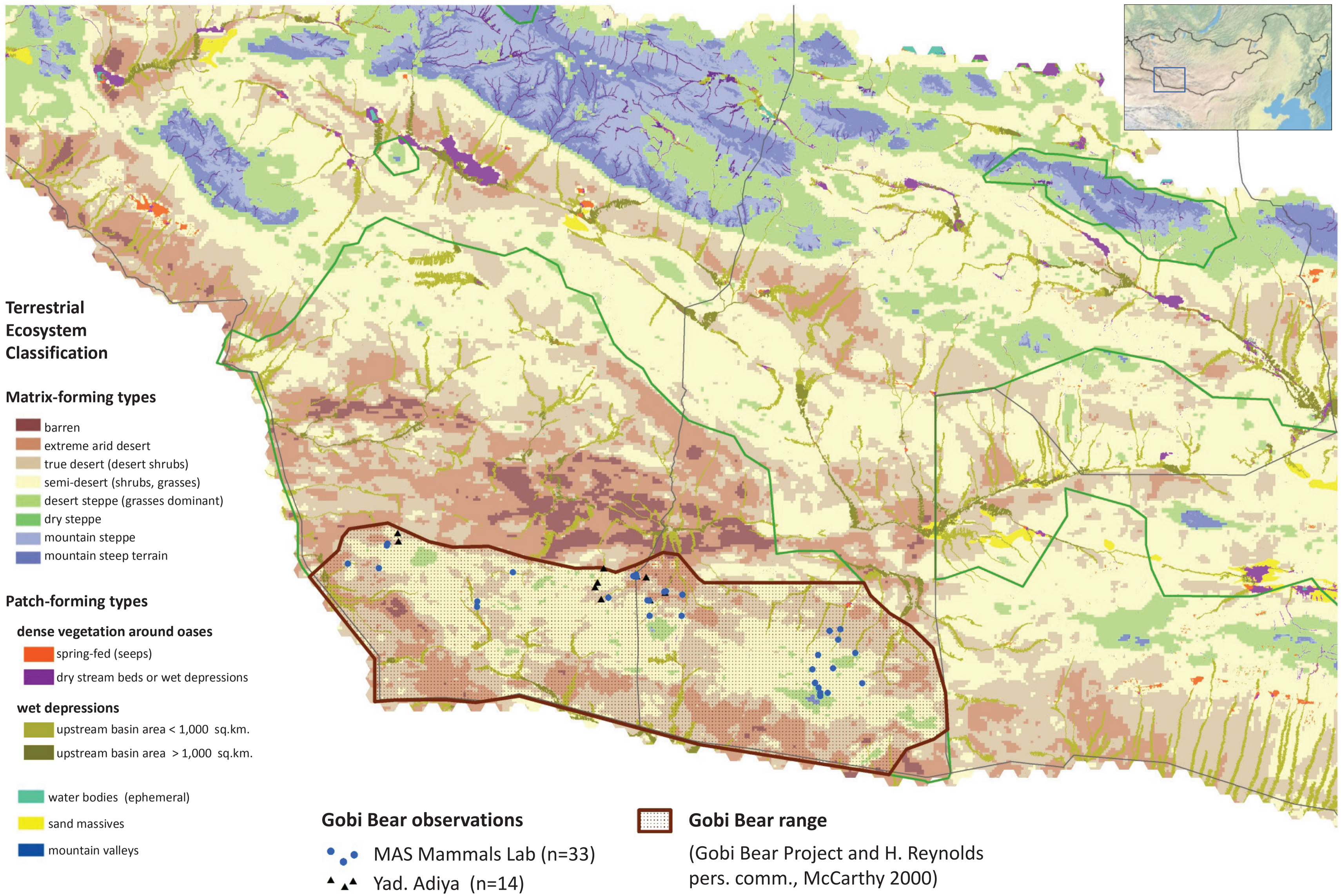



[1] compiled at the 2008 International Snow Leopard conference in Beijing, provided by Panthera.
[3] disturbance index (section 2.4)

## Wild Bactrian Camel (*Camelus bactrianus ferus*) known range



## Gobi Brown Bear (*Ursus arctos Isabellinus*) known range



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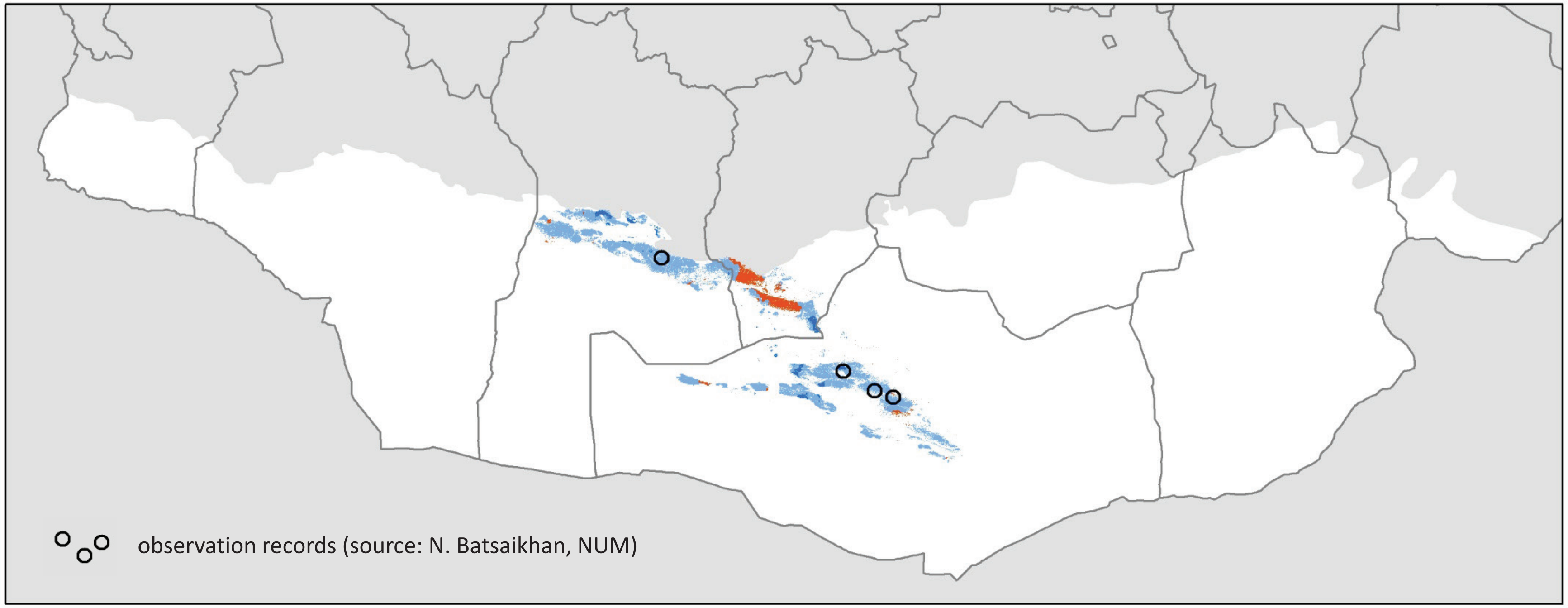
**Survey records provided by N. Batsaikhan, NUM**

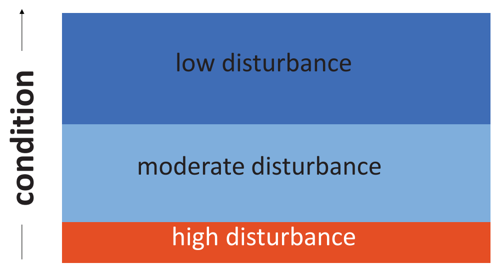



## Alashan Ground Squirrel (*Spermophilus alashanicus*) habitat model

1. **range** based on Batsaikhan et al. (2010) and observation records (n=4).

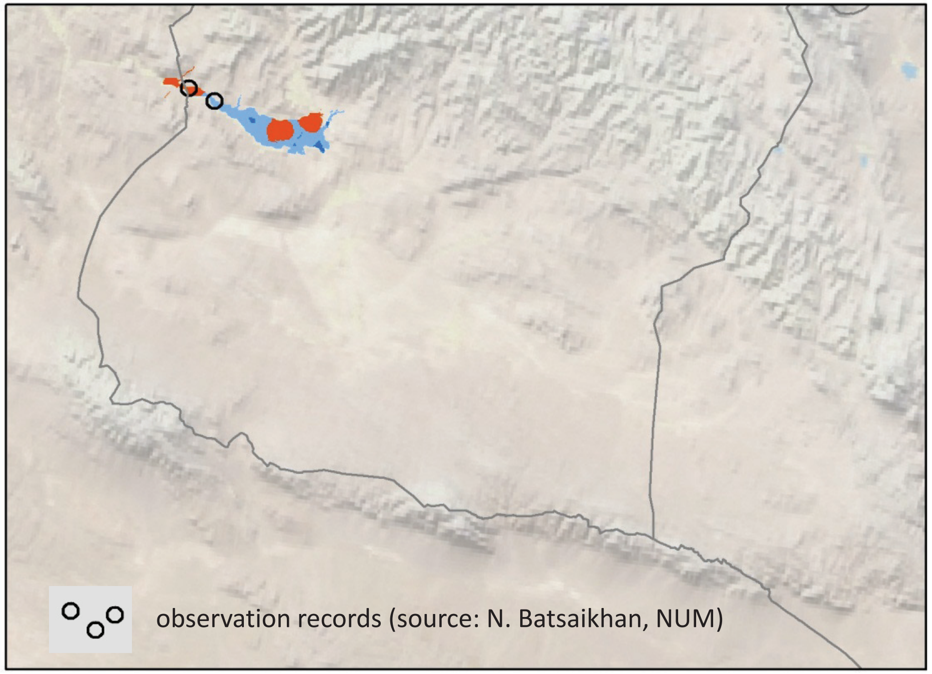
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
    - mountains and mountain steppe foothills [1]

3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%




white: not habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

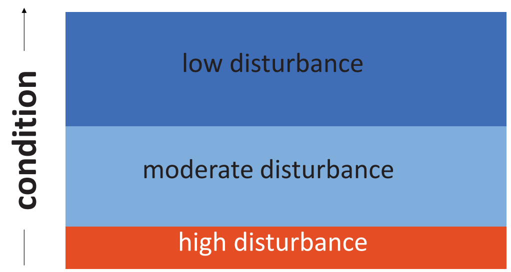



## Forest Doormouse (*Dryomys nitedula*) habitat model

1. **range** based on Batsaikhan et al. (2010) and observation records (n=2); boundary follows Bulgan River valley.

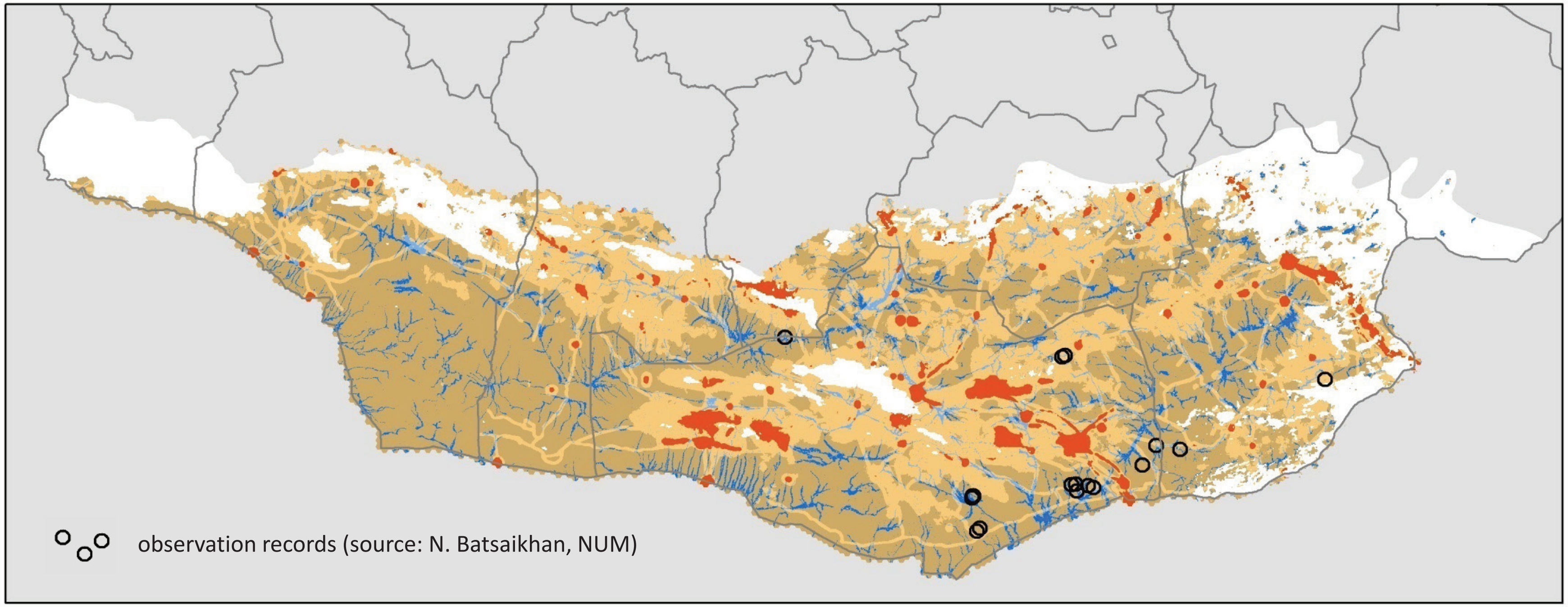
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
    - dense vegetation along river valley [1]

3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%




white: not habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

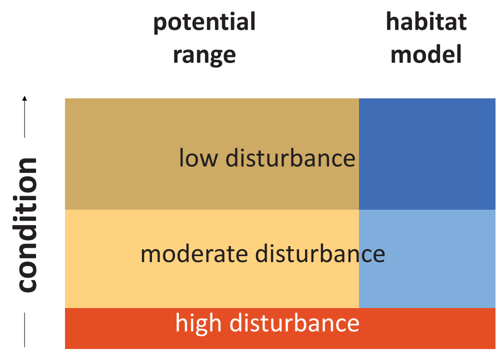



## Gobi Jerboa (*Allactaga bullata*) habitat model

1. **range** based on Batsaikhan et al. (2010) and observation records (n=24).
    - desert, semi-desert and desert steppe [1]

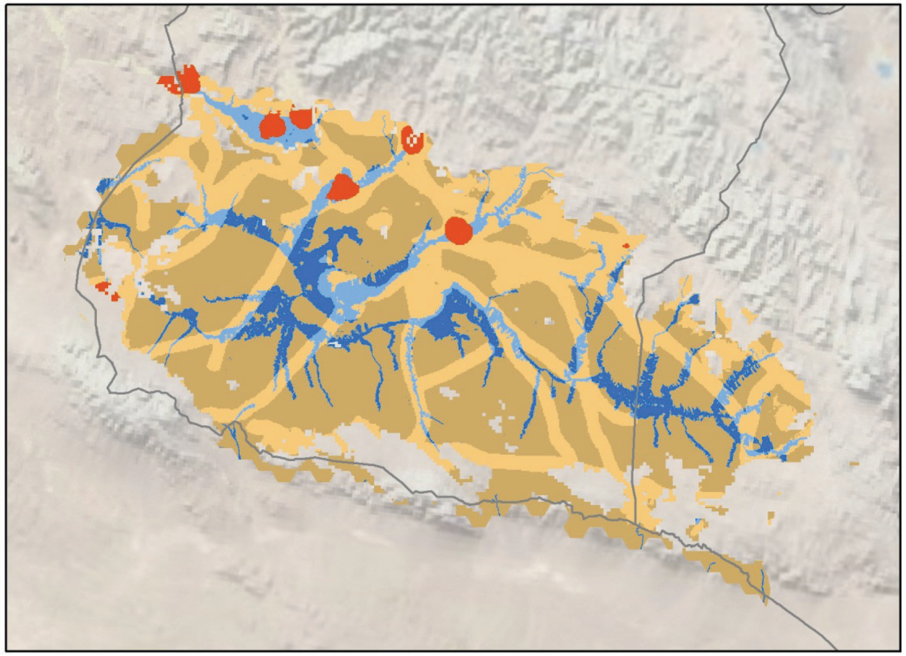
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
    - dense vegetation around oases [1]
    - salty depressions/dry river beds [1]

3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

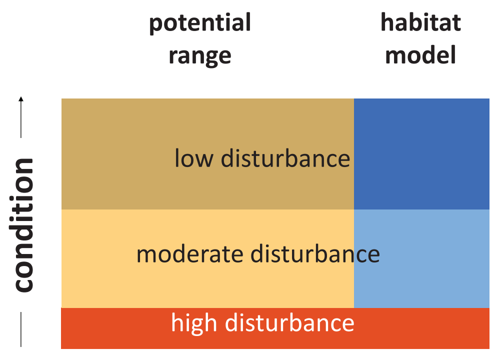


## Small Five-toed Jerboa (*Allactaga elater*) habitat model

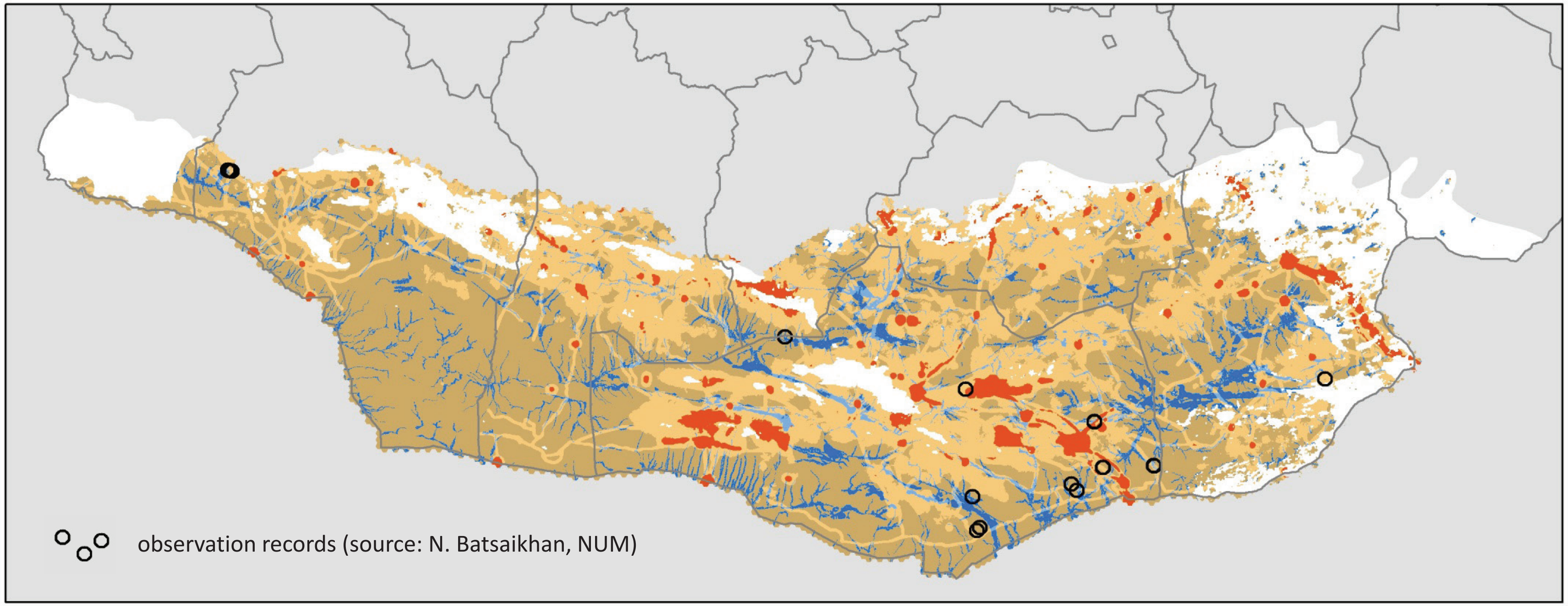
1. **species range** based on Batsaikhan et al. (2010).
   - desert and semi-desert [1]

2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
   - dense vegetation around oases [1]
   - salty depressions/dry river beds [1]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%

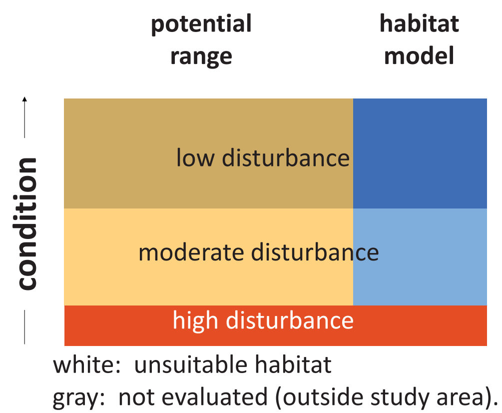



[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

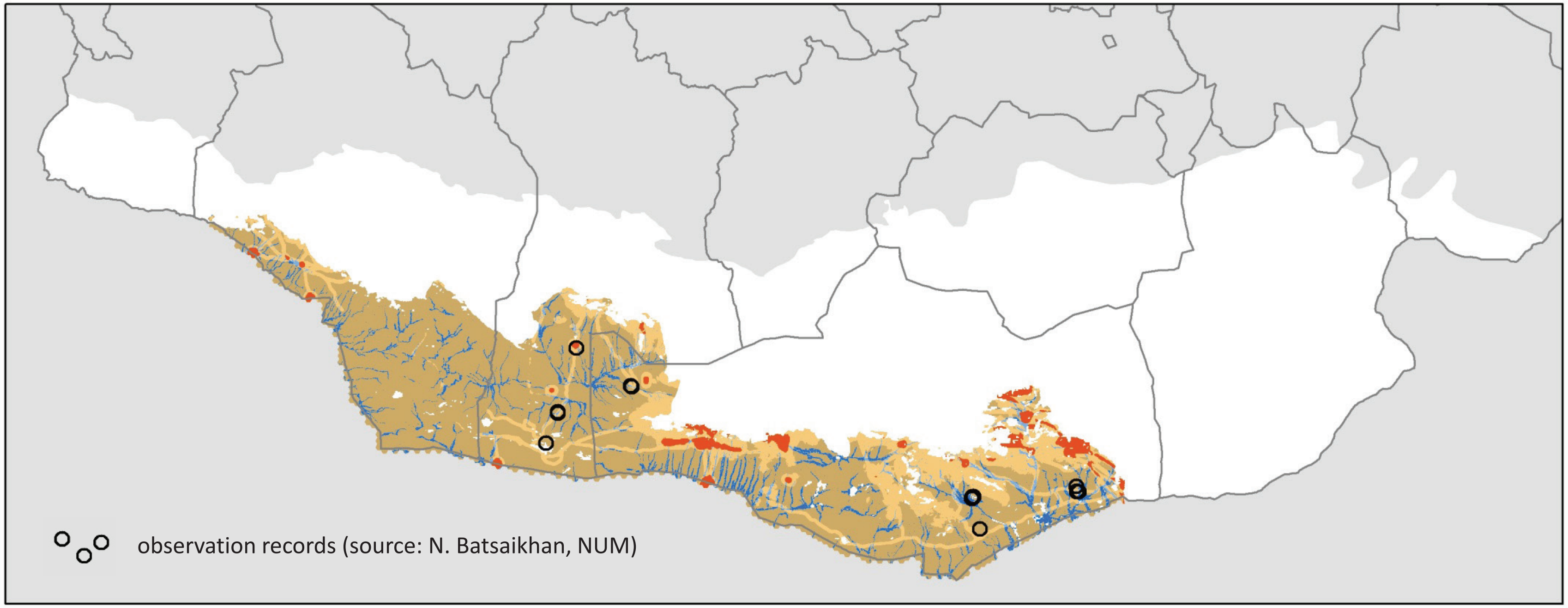



## Five-toed Pygmy Jerboa (*Cardiocranius paradoxus*) habitat model

1. **species range** based on Batsaikhan et al. (2010) and observation records (n=20).
    - desert, semi-desert and desert steppe [1]
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
    - sand massives [1]
    - salty depressions/dry river beds [1]
3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%

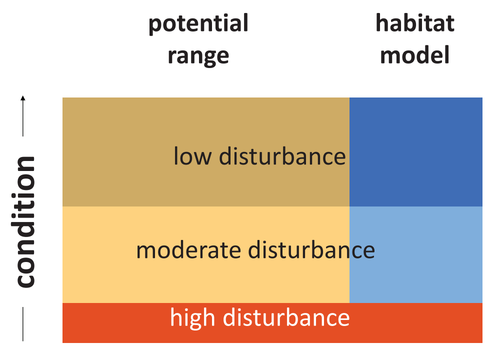



[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)



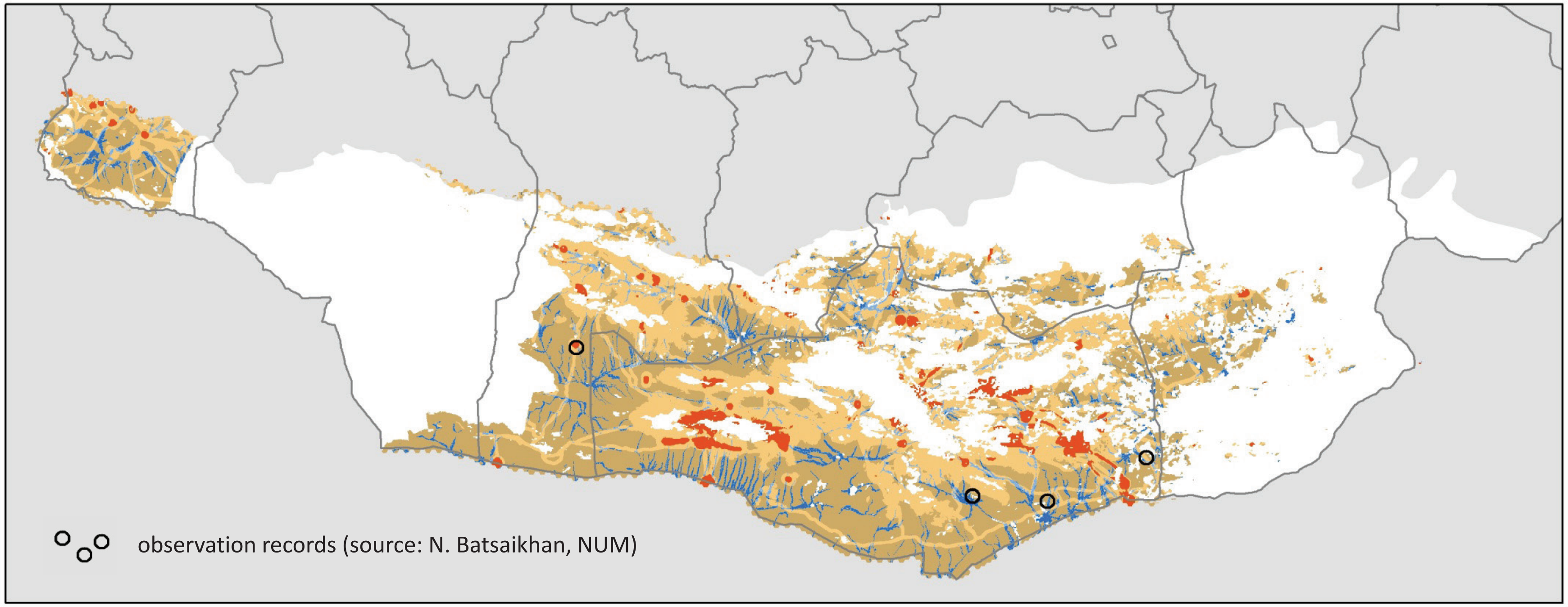

## Long-eared Jerboa (*Euchoreutes Naso*) habitat model

1. **species range** based on Batsaikhan et al. (2010) and observation records (n=16).
   - desert and semi-desert [1]
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
   - salty depressions/dry river beds [1]
3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

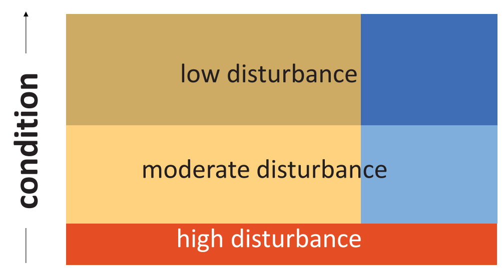
[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)




## Thick-tailed Pygmy Jerboa (*Salpingotus crassicauda*) habitat model

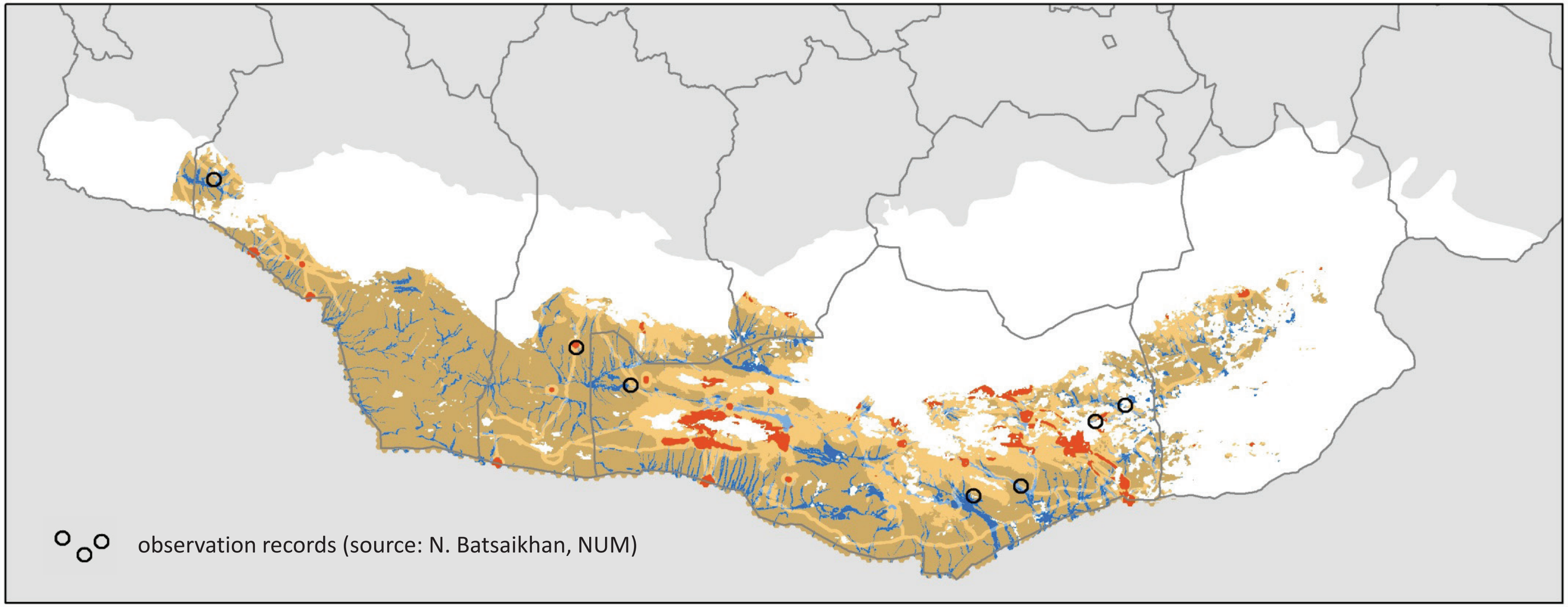
1. **species range** based on Batsaikhan et al. (2010) and observation records (n=4).
   - desert and semi-desert [1]
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
   - salty depressions/dry river beds [1]
3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%

**potential range** **habitat model**




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

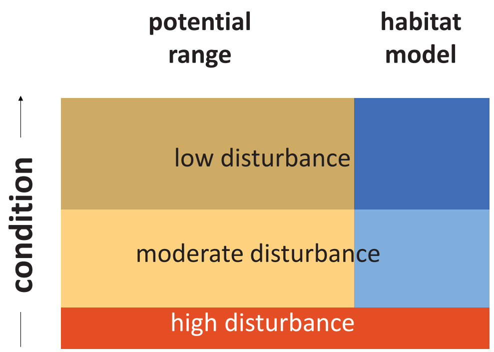



## Kozlov’s Pygmy Jerboa (*Salpingotus kozlovi*) habitat model

1. **species range** based on Batsaikhan et al. (2010) and observation records (n=7).
   - desert and semi-desert [1]

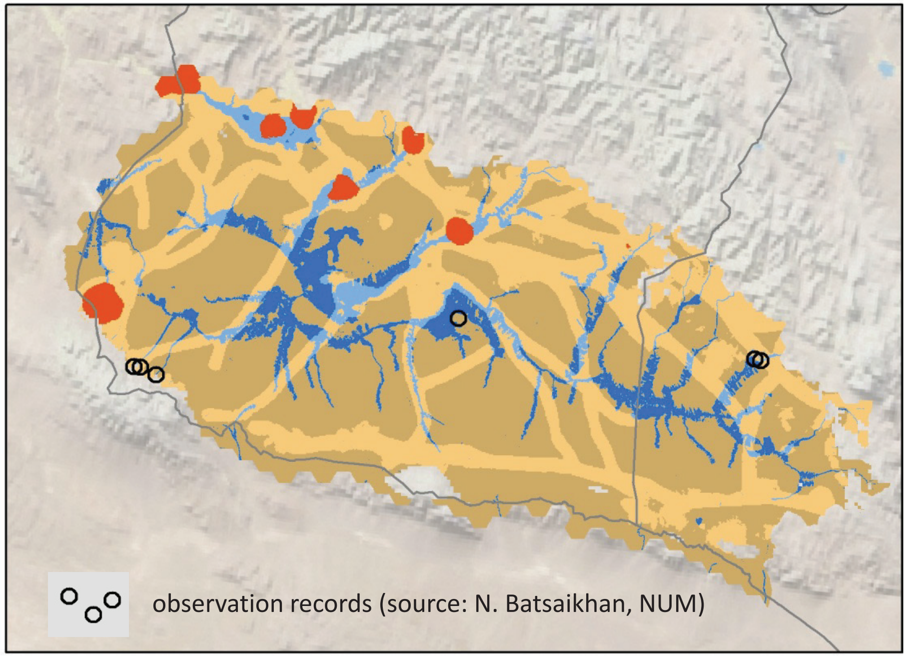
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
   - sand massives [1]
   - salty depressions/dry river beds [1]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%



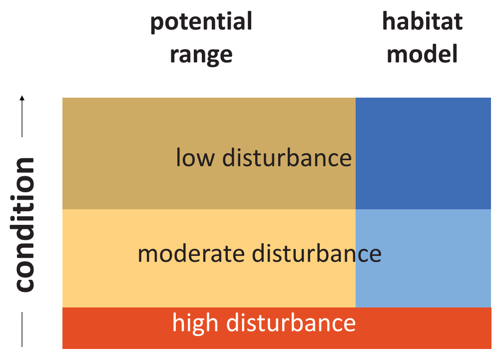

white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

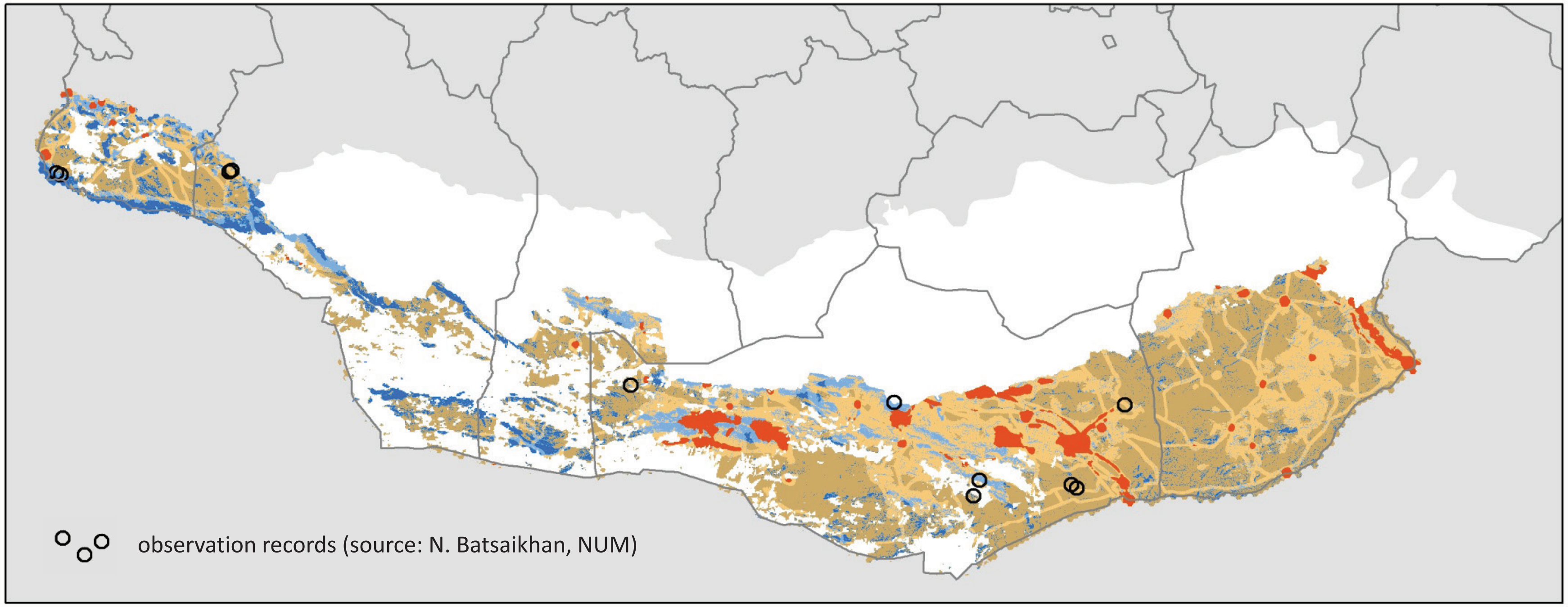



## Mongolian Three-toed Jerboa (*Stylodipus sungorus*) habitat model

1. **species range** based on Batsaikhan et al. (2010) and observation records (n=6).
    - desert and semi-desert [1]
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
    - dense vegetation around oases [1]
    - salty depressions/dry river beds [1]
3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%




[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

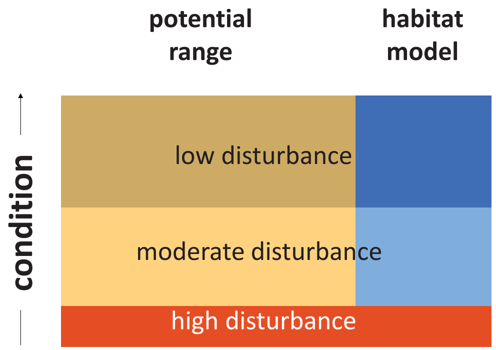



## Grey Hamster (*Cricetulus migratorius*) habitat model

1. **species range** based on Batsaikhan et al. (2010) and observation records (n=12).
   - semi-desert and desert steppe [1]

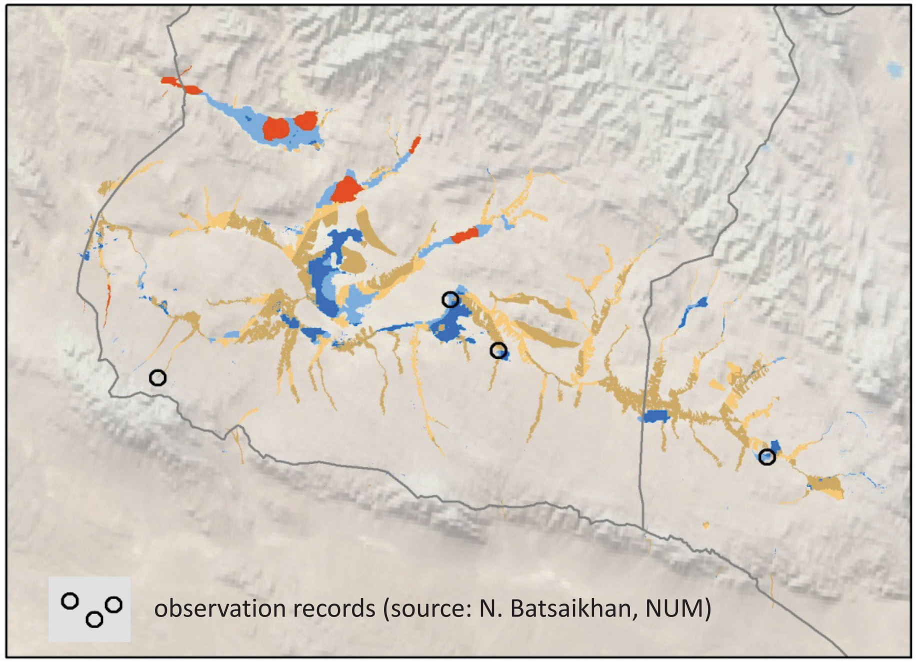
2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
   - dense vegetation around oases [1]
   - hills and rugged terrain [2]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)

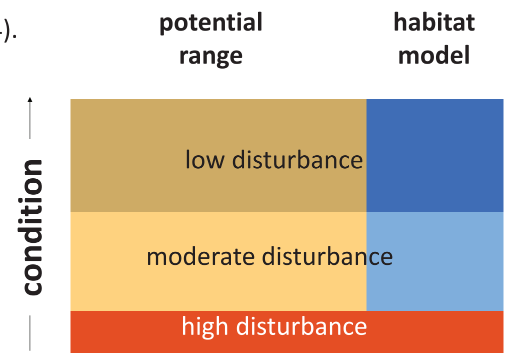



## Tamarisk Gerbil (*Meriones tamariscinus*) habitat model

1. **species range** based on Batsaikhan et al. (2010) and observation records (n=4).
   - riparian zone, wet depressions, salt marshes [1]

2. **habitat model** (Batsaikhan et al. 2010, Batsaikhan unpub. report)
   - dense vegetation in riparian zone [1]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

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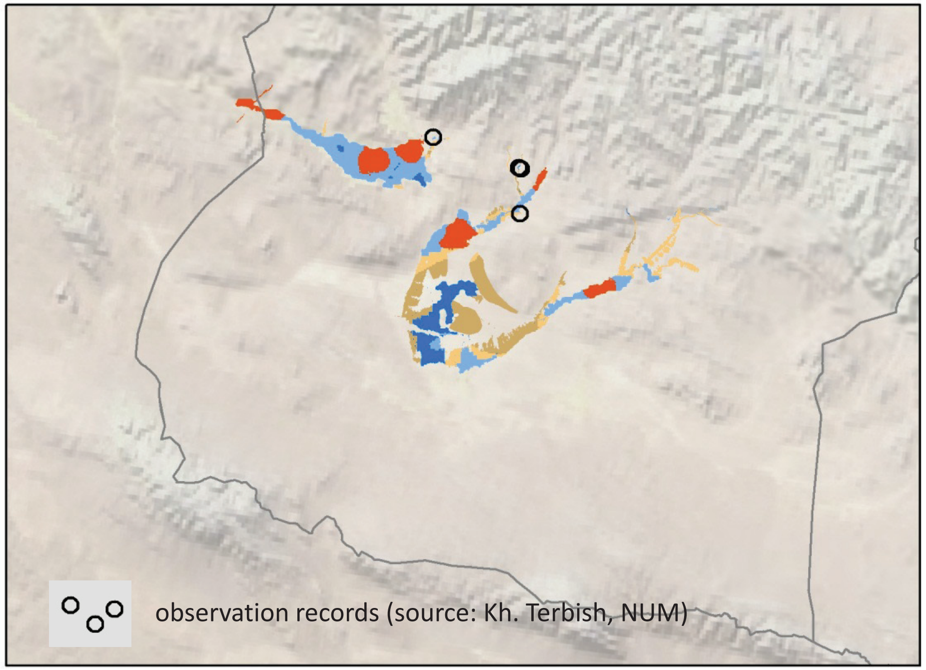
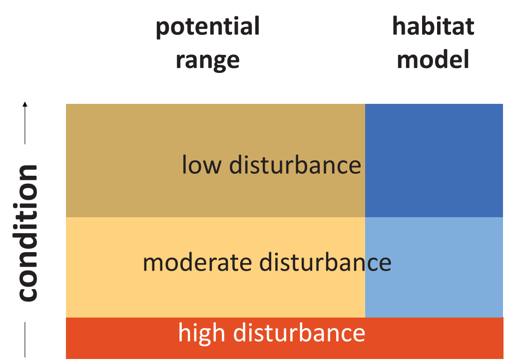
**Survey records provided by Kh. Terbish, NUM**

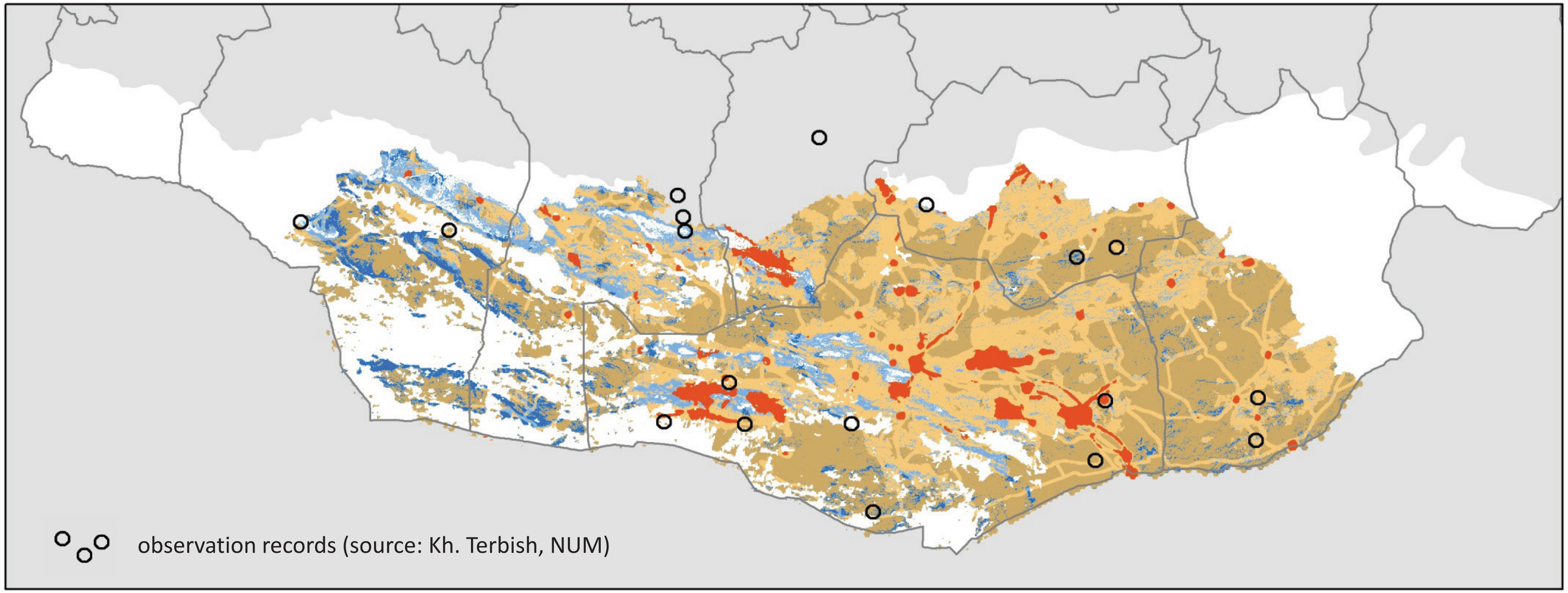



## Pewzow's Toad (*Bufo pewzowi*) habitat model

1. **species range** based on Terbish et al. (2006) and observation records (n=4).
   - riparian zone, wet depressions [1]
2. **habitat model** (Terbish et al. 2006, Terbish unpub. report 2012)
   - water bodies [1]
   - dense vegetation in riparian zone [1]
3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

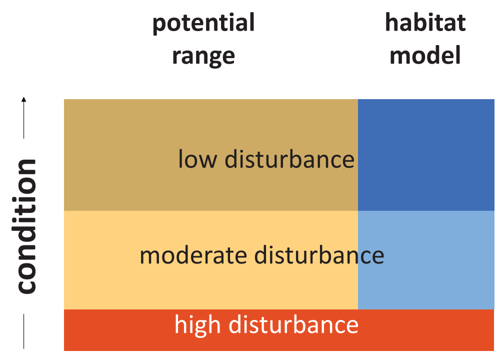



## Slender racer (*Coluber spinalis*) habitat model

1. **species range** based on Terbish et al. (2006) and observation records (n=21).
   - semi-desert and steppe [1]

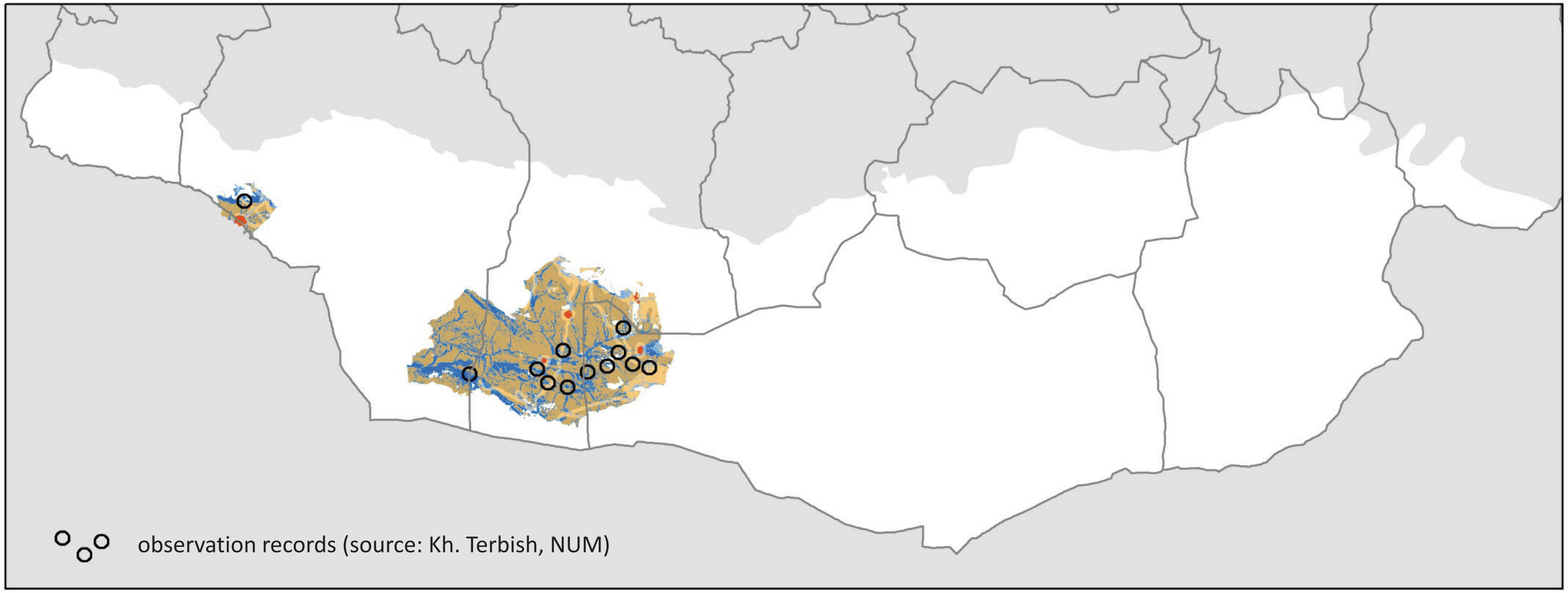
2. **habitat model** (Terbish et al. 2006, Terbish unpub. report 2012)
   - hills, lower slopes of mountains [2]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%



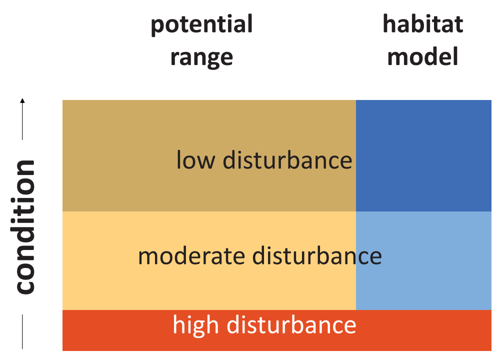

white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)



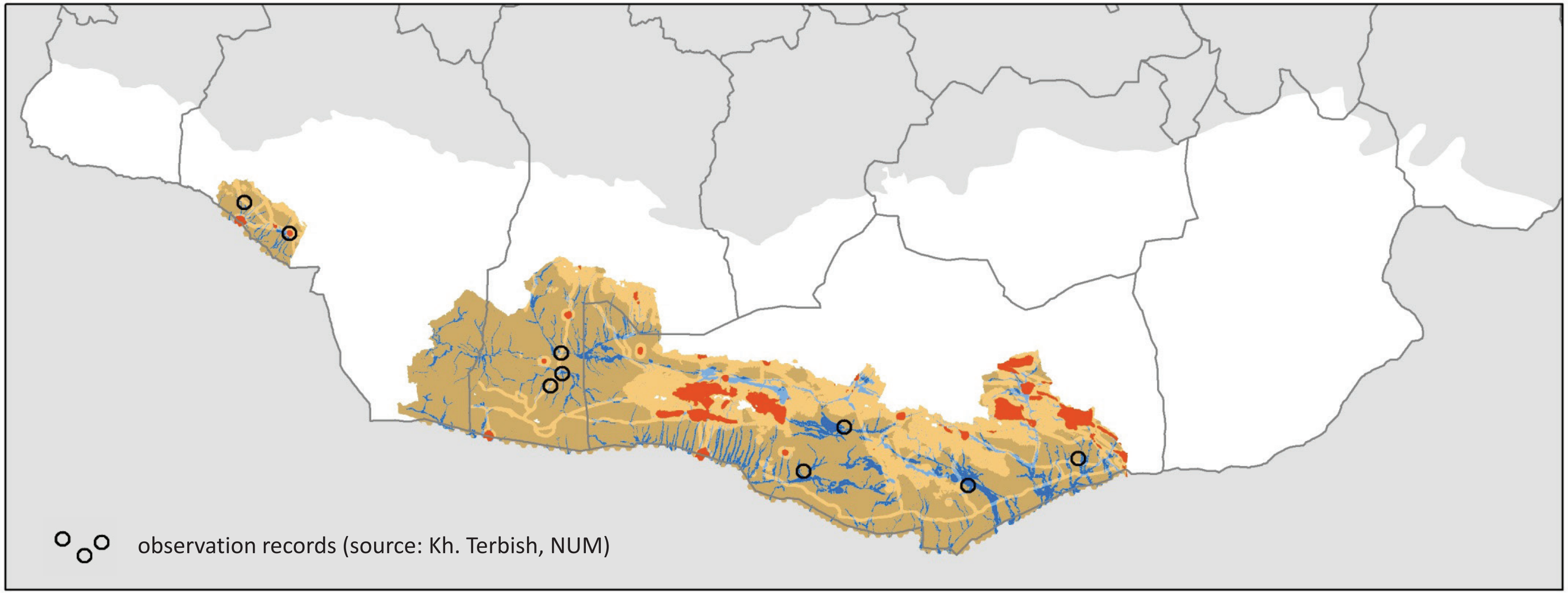

## Gobi naked-toed gecko (*Cyrtopodion elongatus*) habitat model

1. **species range** based on Terbish et al. (2006) and observation records (n=12).
   - true desert [1]
2. **habitat model** (Terbish et al. 2006, Terbish unpub. report 2012)
   - salty depressions/dry river beds [1]
   - oases [1]
   - hills [2]
3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

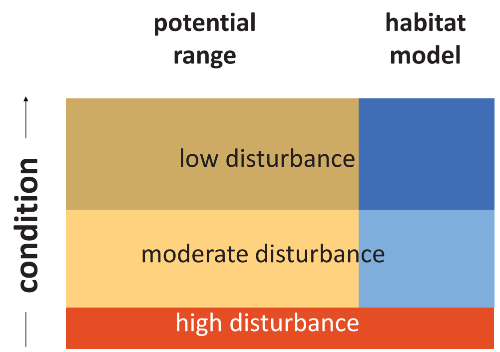



## Tatary sand boa (*Eryx tataricus*) habitat model

1. **species range** based on Terbish et al. (2006) and observation records (n=9).
   - desert and desert steppe [1]

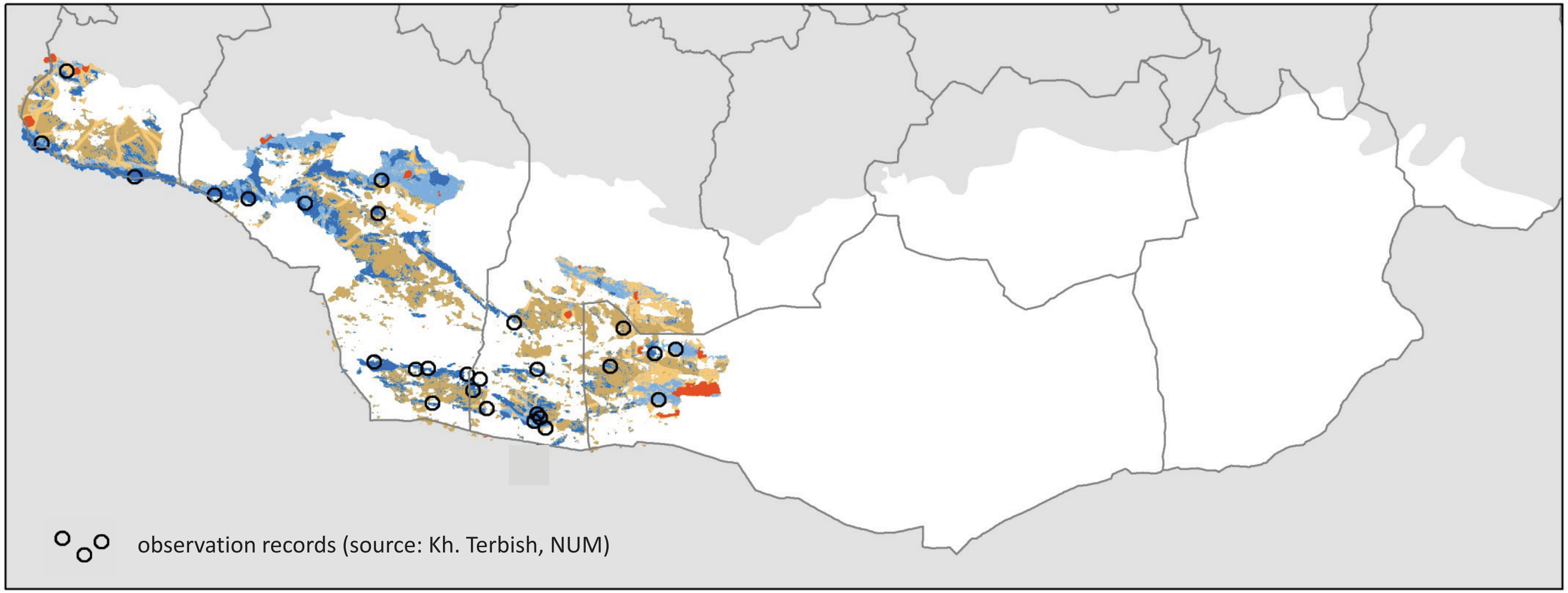
2. **habitat model** (Terbish et al. 2006, Terbish unpub. report 2012)
   - sand dunes [1]
   - salty depressions/dry river beds [1]
   - dense vegetation around oases [1]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

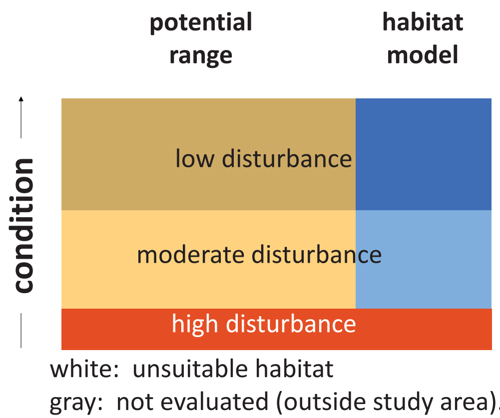



## Mongolian agama (*Laudakia stoliczkana*) habitat model

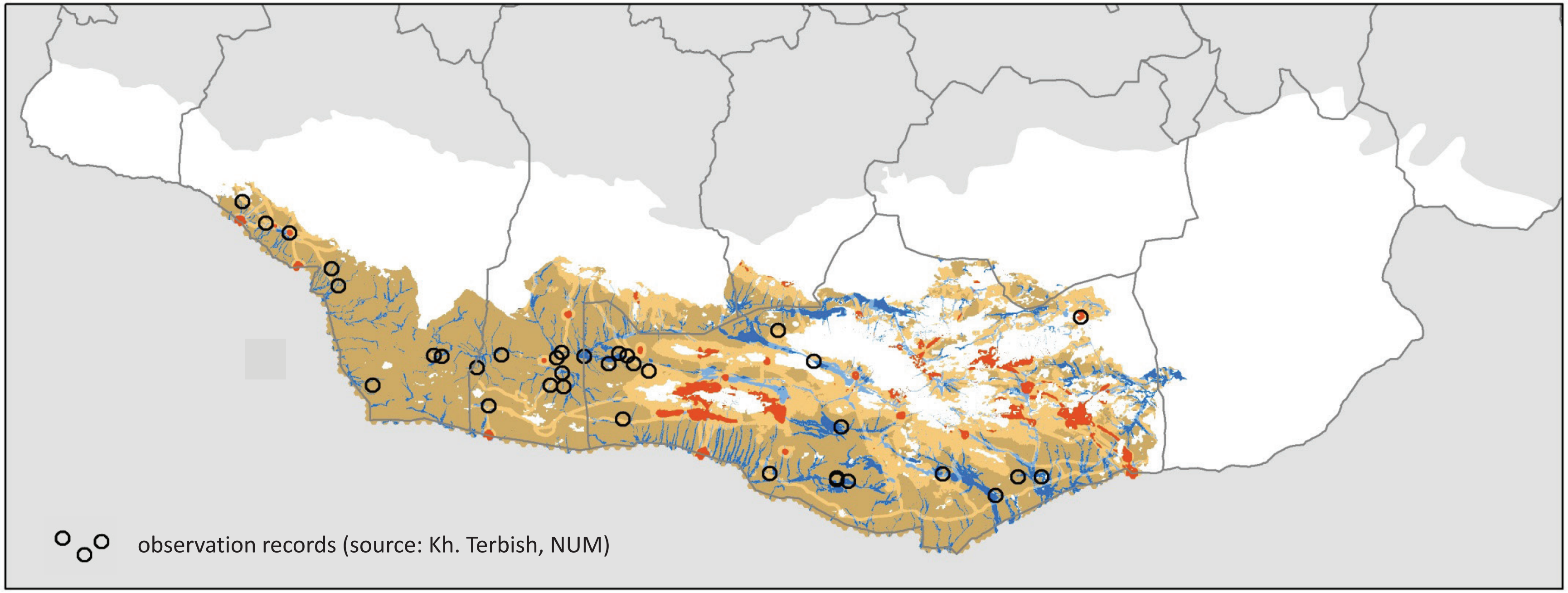
1. **species range** based on Terbish et al. (2006) and observation records (n=28).
   - semi-desert and desert steppe [1]

2. **habitat model** (Terbish et al. 2006, Terbish unpub. report 2012)
   - rocky hills and mountains [2]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)

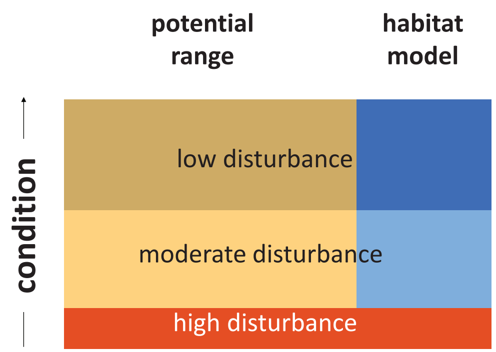



## Przewalski's wonder gecko (*Teratoscincus przewalskii*) habitat model

1. **species range** based on Terbish et al. (2006) and observation records (n=36).
   - desert and semi-desert [1]

2. **habitat model** (Terbish et al. 2006, Terbish unpub. report 2012)
   - sand massives [1]
   - salty depressions/dry river beds [1]
   - dense vegetation around oases [1]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)

# BIRDS

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Nyambayar B, Bayarjargal B, Stacey J and Braunlich A. 2011. Key endangered species in Galba Gobi: status and provisional impact assessments of regional development scenarios. Wildlife Science and Conservation Center of Mongolia and BirdLife International.

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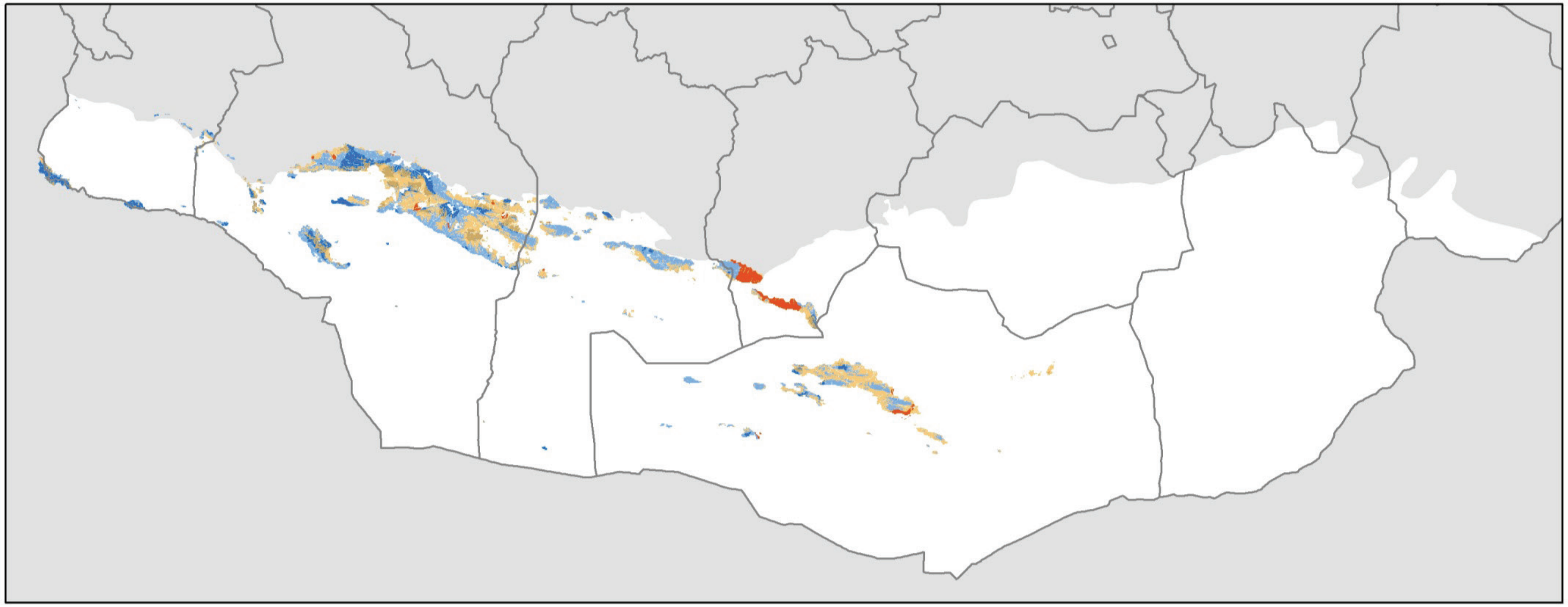
**Survey records provided by N. Batsaikhan**

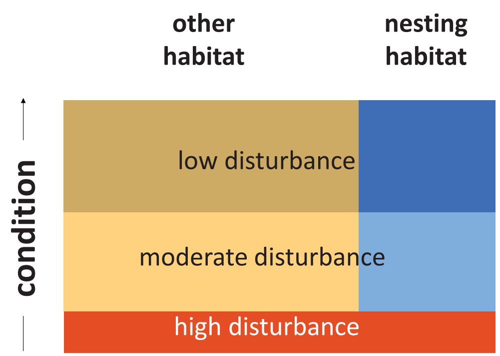


## Altai Snowcock (*Tetraogallus altaicus*) habitat model

1. **species range** based on Gombobataar et al. (2011).
   - mountains [1]

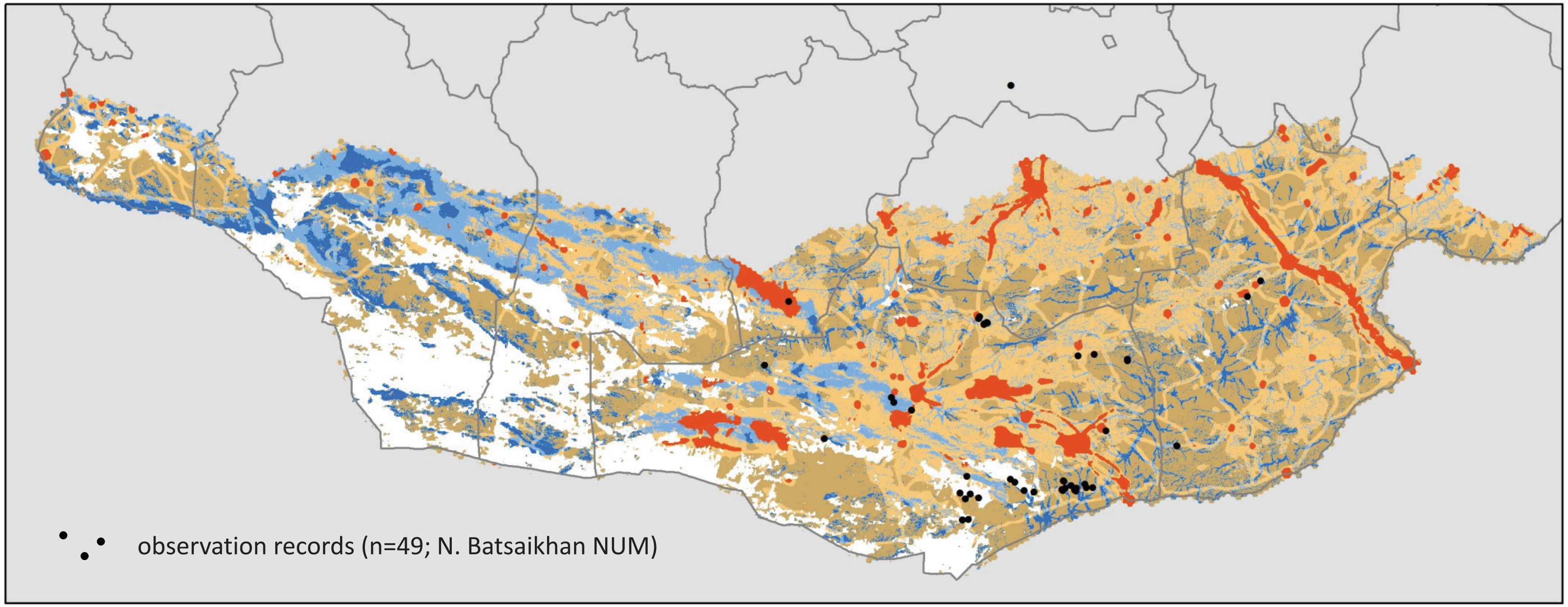
2. **habitat model** (Gombobaatar et al. 2011, Tseweenmyadag unpub. report 2012)
   - rocky slopes [2]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%



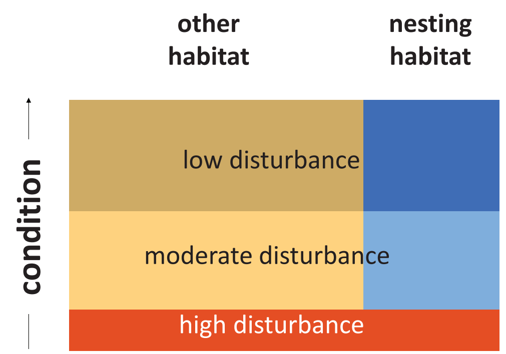

white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)



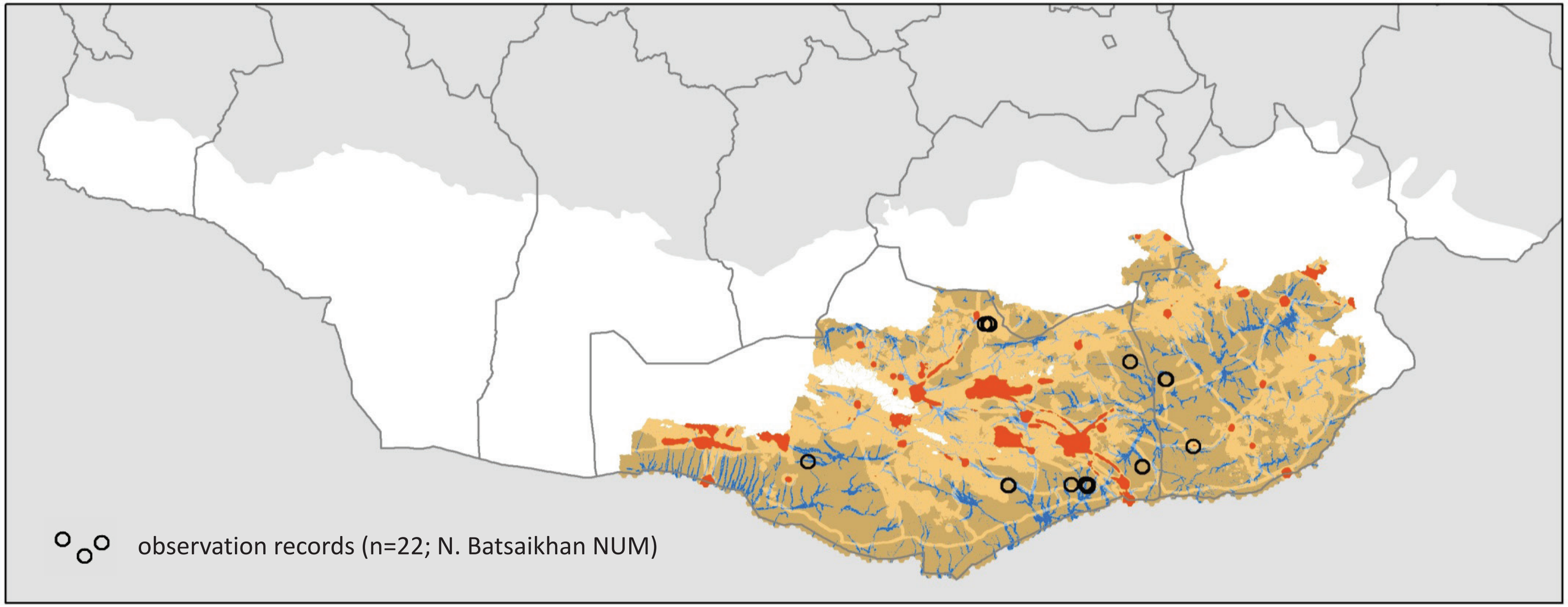

## Saker Falcon (*Falco cherrug*) habitat model

1. **species range** based on Gombobataar et al. (2011) and observation records (n=49).
   - semi-desert, desert steppe and mountains [1]
2. **habitat model** (Gombobaatar et al. 2011, Tseweenmyadag unpub. report 2012)
   - rocky hills and mountains [1]
   - in Eastern Gobi [4], elms in dry river beds [1]
3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)
[4] biogeographic regions (Chimed-Ochir et a. 2010)

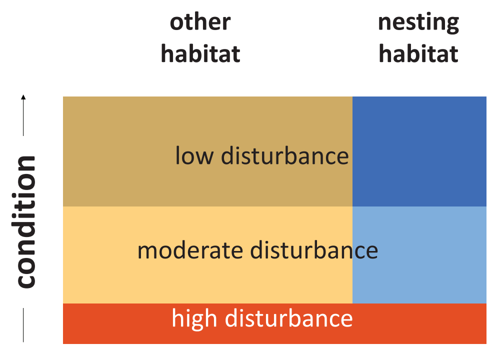



## Short-toed Snake-eagle (*Ciracaetus gallicus*) habitat model

1. **species range** based on Gombobataar et al. (2011) and observation records (n=22).
    - desert, semi-desert and desert steppe [1]

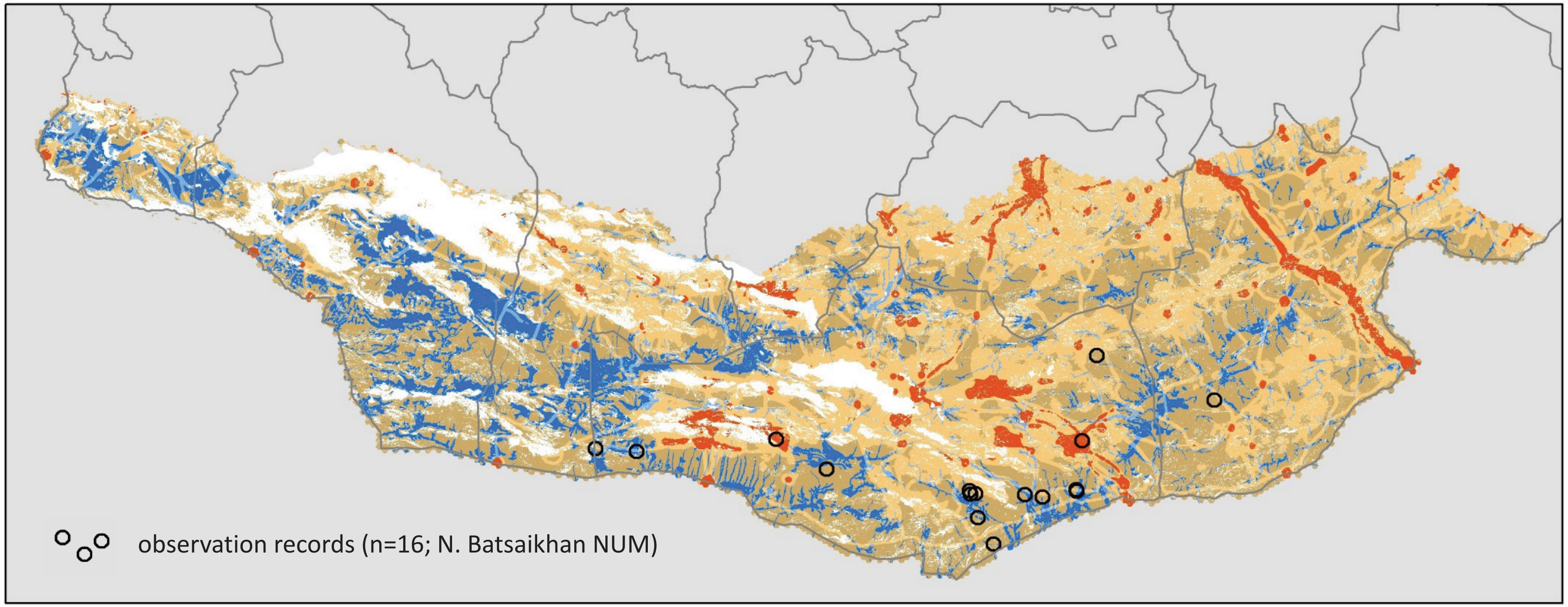
2. **habitat model** (Gombobaatar et al. 2011, Tseweenmyadag unpub. report 2012)
    - rocky hills and mountains [1]
    - in Eastern Gobi [4], elms in dry river beds [1]

3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%




white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)
[4] biogeographic regions (Chimed-Ochir et a. 2010)

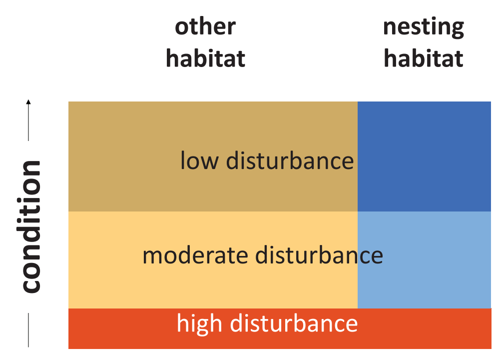



## Houbara Bustard (*Chlamydotis undulata*) habitat model

1. **species range** based on Gombobataar et al. (2011) and observation records (n=16).
    - desert, semi-desert and desert steppe [1]
    - flat terrain [2]

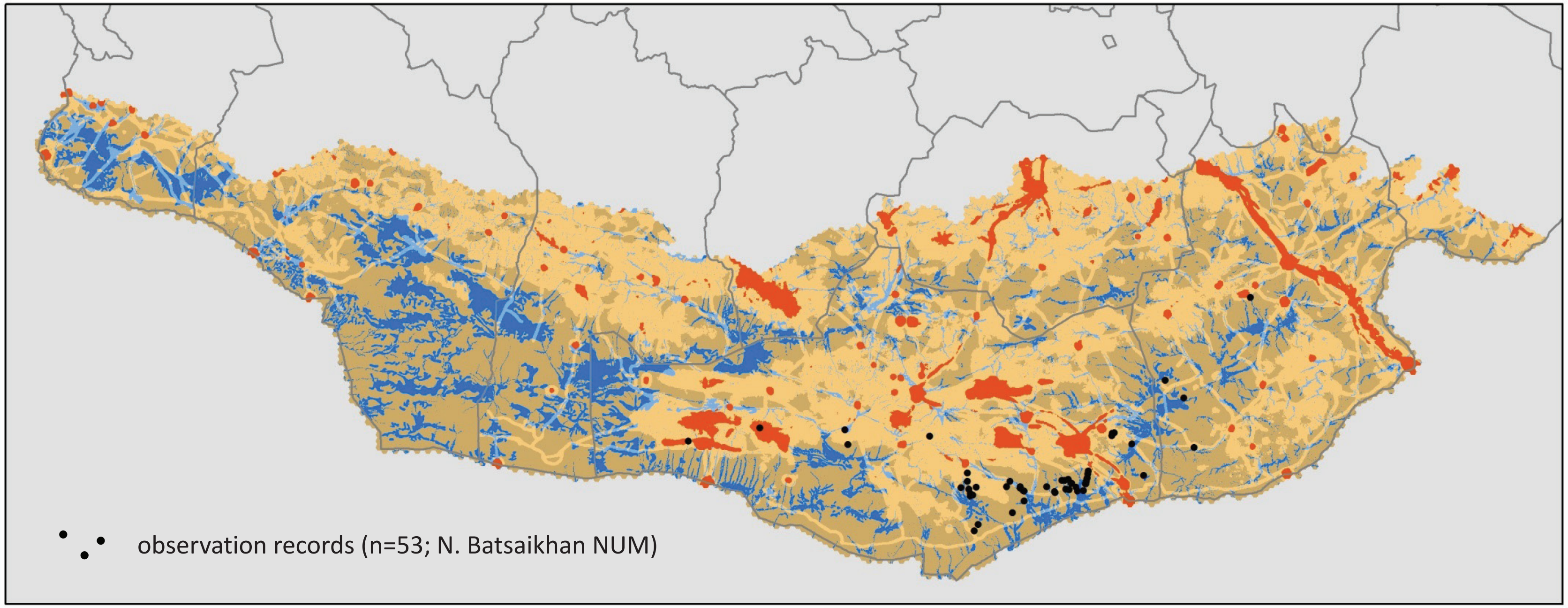
2. **habitat model** (Nyambayar et al. 2011)
    - Saxaul forest [5]
    - dry river beds [1]

3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%

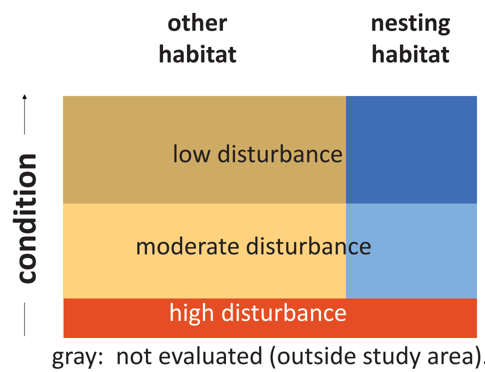



white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[3] disturbance index (section 2.4)
[5] Saxaul forest map (National Atlas 2009)




## Mongolian Ground-jay (*Podoces hendersoni*) habitat model

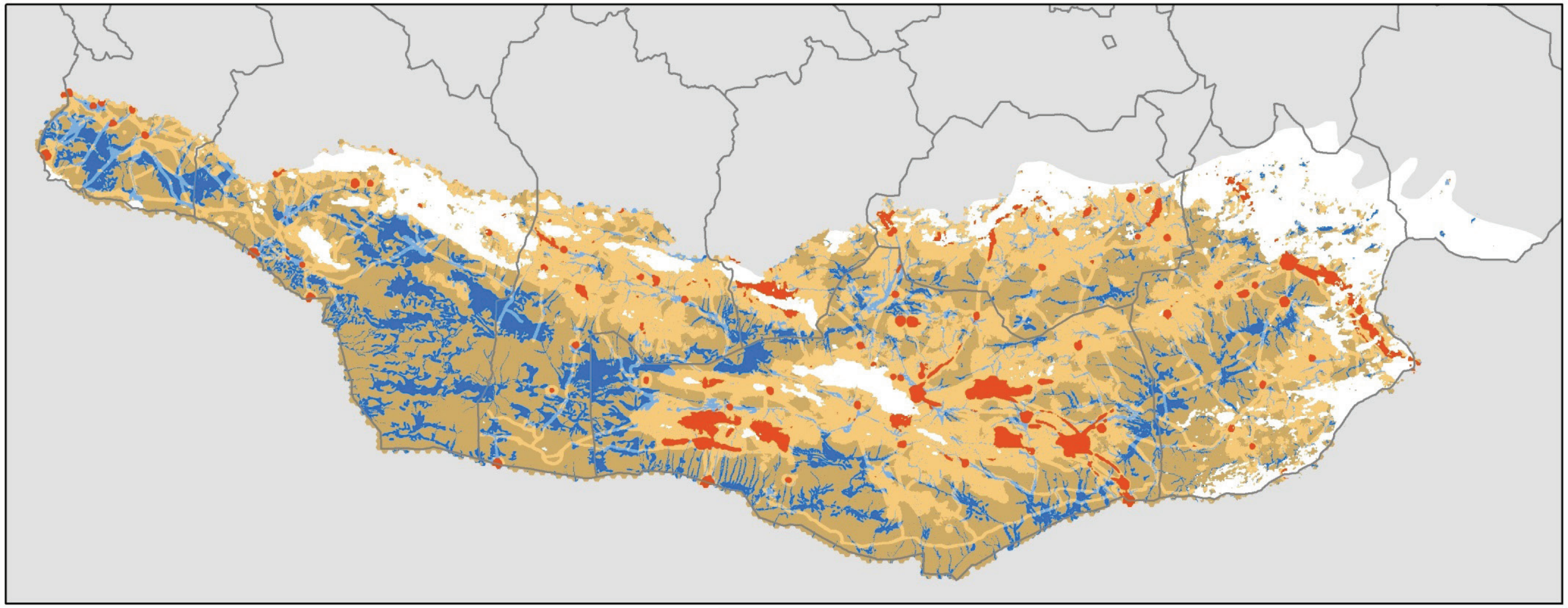



1. **species range** based on Gombobataar et al. (2011) and observation records (n=53).
   ( covers entire study area )

2. **habitat model** (Gombobaatar et al. 2011, Tseweenmyadag unpub. report 2012)
   - Saxaul forest [5]
   - shrubs in dry river beds [1]
   - dense vegetation around oases [1]
   - mountain valleys [1, 2]

3. **classify by condition / disturbance** [3]
   - unsuitable: most disturbed 5% of study area
   - moderate: remaining 45%
   - best: least disturbed 50%

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)
[5] Saxaul forest map (National Atlas 2009)



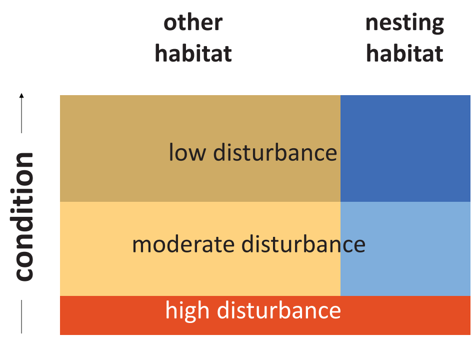
## Saxaul Sparrow (*Passer ammodendri*) habitat model

1. **species range** based on Gombobataar et al. (2011).
    - desert, semi-desert and desert steppe

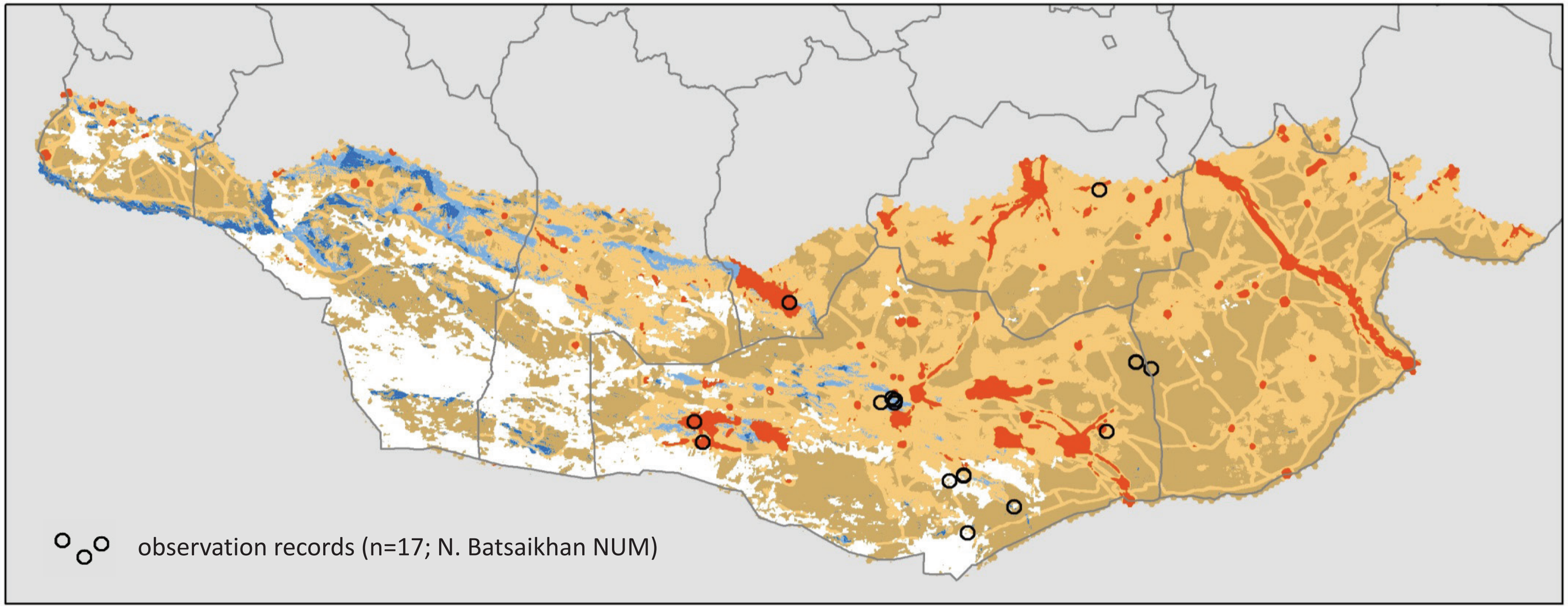
2. **habitat model** (Gombobaatar et al. 2011, Tseweenmyadag unpub. report 2012)
    - Saxaul forest [5]
    - shrubs in dry river beds [1]
    - dense vegetation around oases [1]
    - mountain valleys [1, 2]

3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)
[5] Saxaul forest map (National Atlas 2009)




white: unsuitable habitat
gray: not evaluated (outside study area).



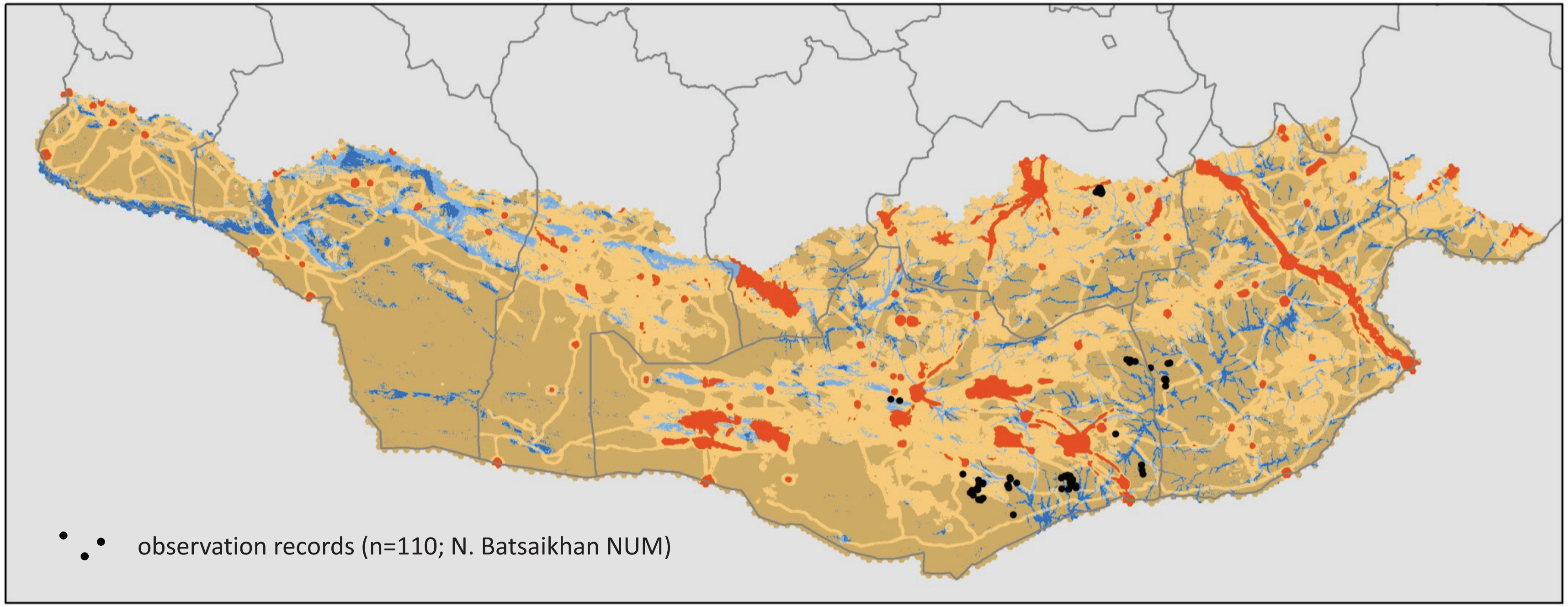

## Lammergeier (*Gypaetus barbatus*) habitat model

1. **species range** based on Gombobataar et al. (2011) and observation records (n=17).
    - semi-desert, steppe and moutains [1]
2. **habitat model** (Gombobaatar et al. 2011, Tseweenmyadag unpub. report 2012)
    - steep terrain in mountains [1, 2]
3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%

| condition | other habitat | nesting habitat |
|---|---|---|
| ↑ | low disturbance | |
| | moderate disturbance | |
| | high disturbance | |

white: unsuitable habitat
gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)

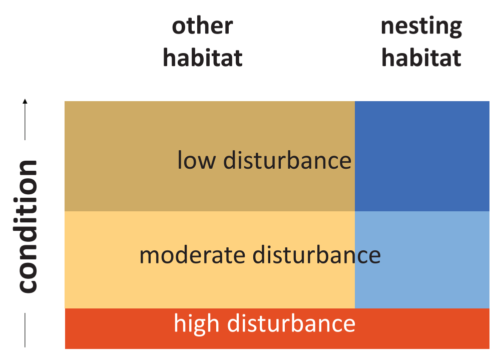



## Cinereous Vulture (*Aegypius monachus*) habitat model

1. **species range** based on Gombobataar et al. (2011) and observation records (n=110).
    - semi-desert and steppe [1]

2. **habitat model** (Gombobaatar et al. 2011, Tseweenmyadag unpub. report 2012)
    - steep terrain in mountains [1, 2]
    - in Eastern Gobi [4], elms in dry river beds [1]

3. **classify by condition / disturbance** [3]
    - unsuitable: most disturbed 5% of study area
    - moderate: remaining 45%
    - best: least disturbed 50%



gray: not evaluated (outside study area).

[1] ecosystem classification map (section 2.2.1, Figures 7 and 27)
[2] landform classification map (section 2.2.1, Figure 8)
[3] disturbance index (section 2.4)

## APPENDIX 4a: Cumulative impacts to ecosystem types

This table lists, for each ecosystem type, the area in each disturbance class and the portion in active or exploration mining leases.

| | total area | percent area in each disturbance class [1] | | | percent area in each mining lease type [2] | | | |
|---|---|---|---|---|---|---|---|---|
| **ecosystem type** | **(km²)** | **high** | **mod** | **low** | **active** | **applic.** | **explore** | **tender** |
| barren | 2,909 | 0.1 | 3 | 97 | | | 5 | 11 |
| extreme arid | 19,931 | 1 | 10 | 89 | 0.3 | | 14 | 12 |
| true desert | 50,425 | 1 | 22 | 76 | 1 | 0.3 | 20 | 20 |
| semi desert | 176,585 | 4 | 41 | 55 | 2 | 1 | 26 | 30 |
| desert steppe | 128,627 | 7 | 58 | 35 | 1 | 2 | 21 | 37 |
| dry steppe | 57,129 | 9 | 60 | 31 | 1 | 1 | 13 | 43 |
| wet depressions (small basin) | 23,520 | 4 | 36 | 60 | 1 | 1 | 22 | 30 |
| wet depressions (large basin) | 9,143 | 2 | 31 | 67 | 1 | 1 | 16 | 31 |
| mountain steppe | 13,050 | 5 | 75 | 19 | 0.0 | 2 | 21 | 31 |
| steep mountains | 10,800 | 5 | 74 | 22 | 0.0 | 0.3 | 27 | 31 |
| ephemeral waterbodies | 322 | 4 | 38 | 57 | 2 | 4 | 17 | 31 |
| dense veg.(oasis) – seeps | 1,024 | 19 | 51 | 29 | 5 | 0.4 | 33 | 28 |
| dense veg.(oasis) – dry river beds | 6,910 | 10 | 55 | 35 | 1 | 1 | 16 | 38 |
| mountain valleys | 1,103 | 5 | 78 | 17 | | 1 | 22 | 37 |
| sand massives | 11,952 | 0.3 | 34 | 66 | | 1 | 18 | 28 |

[1] from disturbance index (Section 2.4) [2] source: MMRE (2012)

## APPENDIX 4b: Cumulative impacts focal species distributions

This table lists, for the modeled distribution of each focal species, the area in each disturbance class and the portion in active or exploration mining leases.

| species name | total area (km²) | percent area in each disturbance class [1] | | | percent area in each mining lease type [2] | | | |
|---|---|---|---|---|---|---|---|---|
| | | high | mod | low | active | applic. | explore | tender |
| **Large mammals** | | | | | | | | |
| Asiatic wild ass (Equus hemionus) - current | 233,202 | 4 | 33 | 64 | 1 | 2 | 24 | 26 |
| Asiatic wild ass (Equus hemionus) - potential | 460,956 | 5 | 46 | 48 | 1 | 1 | 21 | 33 |
| Argali (Ovis ammon) | 47,196 | 6 | 56 | 38 | 1 | 1 | 23 | 32 |
| Siberian ibex (Capra sibirica) | 47,005 | 6 | 54 | 40 | 1 | 1 | 23 | 30 |
| Snow leopard (Panthera uncia) | 9,018 | 5 | 63 | 32 | 0.3 | 0.4 | 25 | 29 |
| Bactrian camel (Camelus bactrianus ferus) | | | | | | | | |
| Gobi bear (Ursus arctos gobiensis) | | | | | | | | |
| **Small mammals** | | | | | | | | |
| Alashan ground squirrel (Spermophilus alashanicus) | 11,906 | 12 | 83 | 5 | | | 10 | 15 |
| Forest dormouse (Dryomys nitedula) | 342 | 35 | 61 | 3 | | | 2 | 35 |
| Gobi jerboa (Allactaga bullata) | 409,043 | 4 | 41 | 55 | 1 | 1 | 23 | 30 |
| Small five-toed jerboa (Allactaga elater) | 21,044 | 2 | 38 | 60 | | 0.1 | 10 | 28 |
| Five-toed pygmy jerboa (Cardiocranius paradoxus) | 415,382 | 4 | 41 | 55 | 1 | 1 | 23 | 30 |
| Long-eared jerboa (Euchoreutes naso) | 141,018 | 3 | 23 | 74 | 2 | 1 | 23 | 20 |
| Thick-tailed pygmy jerboa (Salpingotus crassicauda) | 211,969 | 4 | 43 | 53 | 2 | 1 | 25 | 29 |
| Kozlov's pygmy jerboa (Salpingotus kozlovi) | 193,060 | 4 | 29 | 67 | 2 | 1 | 23 | 21 |
| Mongolian three-toed jerboa (Stylodipus sungorus) | 26,272 | 2 | 37 | 61 | | 1 | 12 | 25 |
| Grey hamster (Cricetulus migratorius) | 208,166 | 5 | 39 | 56 | 2 | 2 | 25 | 31 |
| Tamarisk gerbil (Meriones tamariscinus) | 3,687 | 6 | 38 | 56 | | 0.2 | 5 | 33 |

[1] from disturbance index (Section 2.4) [2] source: MMRE (2012)

## APPENDIX 4B: (CONTINUED)

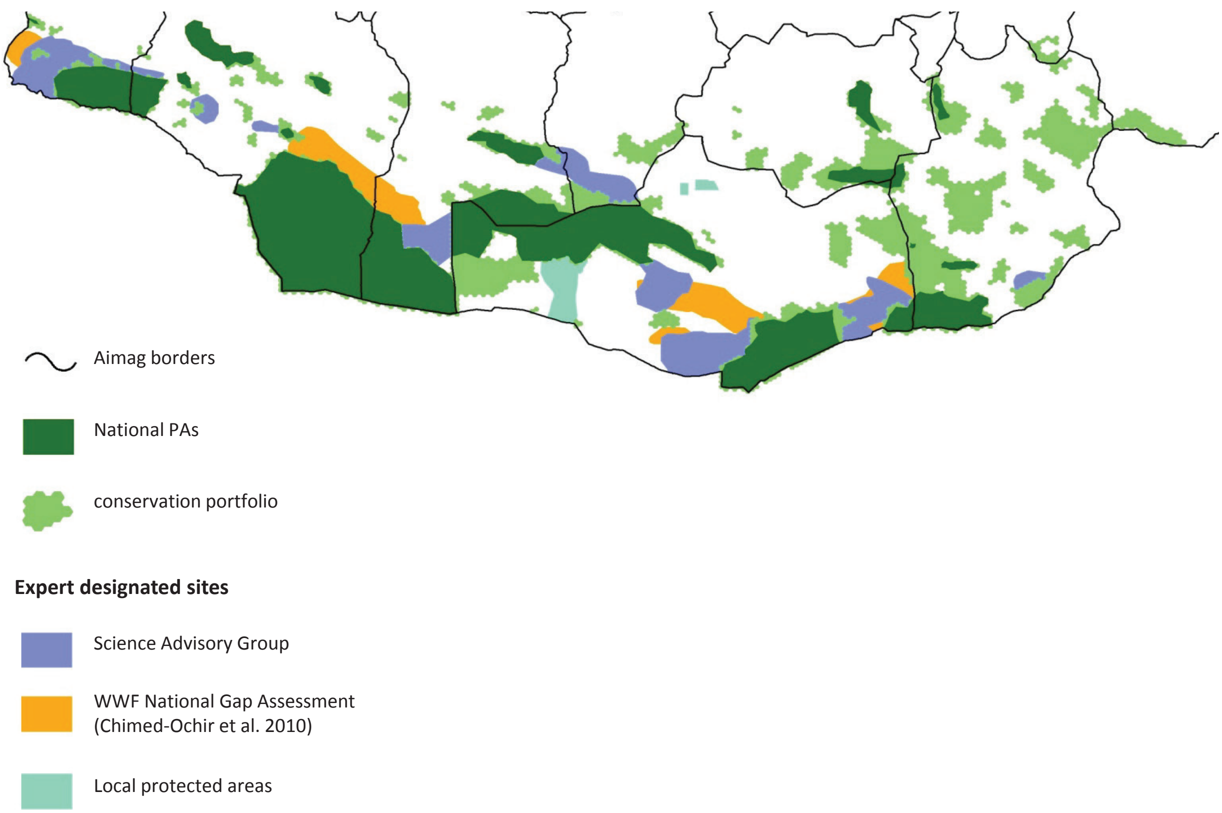
| species name | total area (km²) | percent area in each disturbance class [1] | | | percent area in each mining lease type [2] | | | |
|---|---|---|---|---|---|---|---|---|
| | | high | mod | low | active | applic. | explore | tender |
| **Amphibians & Reptiles** | | | | | | | | |
| Pewzow's toad (Bufo pewzowi) | 1,195 | 18 | 45 | 37 | | | 1 | 61 |
| Gobi naked-toed gecko (Cyrtopodion elongatus) | 38,655 | 1 | 18 | 82 | 0.5 | 0.4 | 13 | 17 |
| Przewalski's wonder gecko (Teratoscincus przewalskii) | 185,930 | 4 | 30 | 66 | 2 | 1 | 24 | 24 |
| Mongolian agama (Laudakia stoliczkana) | 66,530 | 2 | 32 | 66 | 1 | 0.2 | 20 | 23 |
| Tatar sand boa (Eryx tataricus) | 138,201 | 5 | 31 | 64 | 3 | 1 | 28 | 25 |
| Slender racer (Coluber spinalis) | 296,327 | 5 | 46 | 49 | 2 | 1 | 24 | 33 |
| **Birds** | | | | | | | | |
| Houbara Bustard (Chlamydotis undulata) | 429,428 | 5 | 42 | 53 | 1 | 1 | 21 | 32 |
| Short-toed Snake-eagle (Ciracaetus gallicus) | 194,617 | 5 | 43 | 52 | 2 | 2 | 29 | 39 |
| Saker Falcon (Falco cherrug) | 438,731 | 6 | 50 | 45 | 1 | 1 | 22 | 34 |
| Lammergeier, Bearded Vulture (Gypaetus barbatus) | 438,731 | 6 | 50 | 45 | 1 | 1 | 22 | 34 |
| Saxaul Sparrow (Passer ammodendri) | 432,717 | 4 | 41 | 55 | 1 | 1 | 22 | 30 |
| Mongolian Ground-jay (Podoces hendersoni) | 523,725 | 5 | 45 | 51 | 1 | 1 | 21 | 31 |
| Altai Snowcock (Tetraogallus altaicus) | 24,179 | 5 | 74 | 21 | | 1 | 23 | 31 |
| Cinereous Vulture (Aegypius monachus) | 523,709 | 5 | 45 | 51 | 1 | 1 | 21 | 31 |

[1] from disturbance index (Section 2.4) [2] source: MMRE (2012

## APPENDIX 5: Descriptions of sites designated by the Science Advisory Group and the WWF National Gap Assessment (Chimed-Ochir et al. 2010)

| ID | Site name | Aimag | Addition / Expansion | Justification | Source |
|---|---|---|---|---|---|
| 1 | Dzungarian Gobi and Baitag Bogd | Khovd and Govi-Altai | Expand Great Gobi SPA, re-named Dzungarian Gobi SPA | • Endangered flora and fauna.<br>• Habitat area for Khulan, especially in winter.<br>• small mammals, inlcuding Jerboa and Gerbil.<br>• Endemic insect taxa, including Orthoptera species and darkling Beatle.<br>• Central Asian (Khazakhstan and Turanian) endemic plant species. | Rachkovskaya 1993; Batsaikhan 1989; Kaczensky & Ganbaatar 2011 |
| 2 | Alag Lake Valley | Gobi-Altai | New: Alag Lake Valley SPA | • Rare plants.<br>• High diversity of small mammals including Jerboa species.<br>• Transition between Trans-Altay and Dzungarian Gobi deserts.<br>• Oasis complexes. | Rachkovskaya 1993; Batsaikhan 1989 |
| 3 | Nariin Tooroin Bulag | Gobi-Altai | New: Nariin Tooroin Bulagn SPA | • Oasis with Populus deversifolia.<br>• Historic sites | |
| 4 | Nogoon Tsav | Bayankhongor | Expand Gobi Gurvansaikhan NP | • Central Asian Desert ecosystem<br>• Unique geological formation. Important paleontological site.<br>• High diversity of reptiles.<br>• area connects Great Gobi A SPA with Gobi Gurvansaikhan NP. The most likely area range expansion of wild Bactrian camel (Kaczensky et al. in prep.) and Gobi Bear (Gobi Bear Project /Harry Reynolds pers. comm.) is this area and east of Great Gobi A | |
| 5 | Arts Bogd and Baga Bogd | Bayankhongor | New: Arts Bogd Expand Ikh Bogd SPA to include Baga Bogd. | • Important for connectivity of Snow Leopard between the Ikh bogd and GGS Mountains.<br>• Argali, Ibex, Goitered gazelle, Mongolian gazelle. | |
| 6 | Zuramtai Uul, Bugiin Hooloi | Omnogovi | New: Zuramtai Uul, Bugiin Hooloi | • Argali, Ibex, Goitered gazelle, Khulan.<br>• Endemic plant: *Ammopiptanthus mongolicus*<br>• High diversity of Jerboa spp. and reptiles including two endangered snake spp.<br>• Corridor area for Mongolian gazelle and Goitered gazelle, based on radiocollar data (B.Lhagvasuren pers. comm.).<br>• Patch ecosystem of *Iris oxypitala* (D.Zumberelmaa pers. comm.) | |
| 7 | Sain Tooroin Ulaan Uul and Dersen Us | Omnogovi | Expand Small Gobi SPA A | • Goitered gazelle, Khulan<br>• Endemic plant species<br>• Threatened Jerboa species: *Gymnocarpus przewalskii*, *Potanina mongolica*.<br>• Historic site (Chingis Khaan Wall) | |

| ID | Site name | Aimag | Addition / Expansion | Justification | Source |
|---|---|---|---|---|---|
| 8 | Daichin Zag and Haya Hudag | Omnogovi | Expand Small Gobi SPA A | • important for movement of Goitered gazelle, Khulan<br>• IBA | |
| 10 | IBA | Omnogovi | Expand Small Gobi SPA B | • IBA | |
| 11 | Khutag Uul | Omnogovi | | • Argali, Wild Ass, Mongolian gazelle and Goitered gazelle | |
| | | | | | |
| 101 | | Hovd | | designated by WWF National Gap Assessment (Chimed-Ochir et al. 2010) | |
| 102 | | Govi-Altai, Bayanhongor | | designated by WWF National Gap Assessment (Chimed-Ochir et al. 2010) | |
| 103 | | Omnogovi | | designated by WWF National Gap Assessment (Chimed-Ochir et al. 2010) | |
| 104 | | Omnogovi | | designated by WWF National Gap Assessment (Chimed-Ochir et al. 2010) | |
| 105 | Galba Gobi | Omnogovi, Dornogovi | | designated by WWF National Gap Assessment (Chimed-Ochir et al. 2010) | |
| | | | | | |
| 201 | Baysah | Omnogovi | | local protected area | |
| 202 | Mandal Ovoo | Omnogovi | | local protected area (May 1, 2013) | |
| 203 | Mandal Ovoo | Omnogovi | | local protected area (May 1, 2013) | |

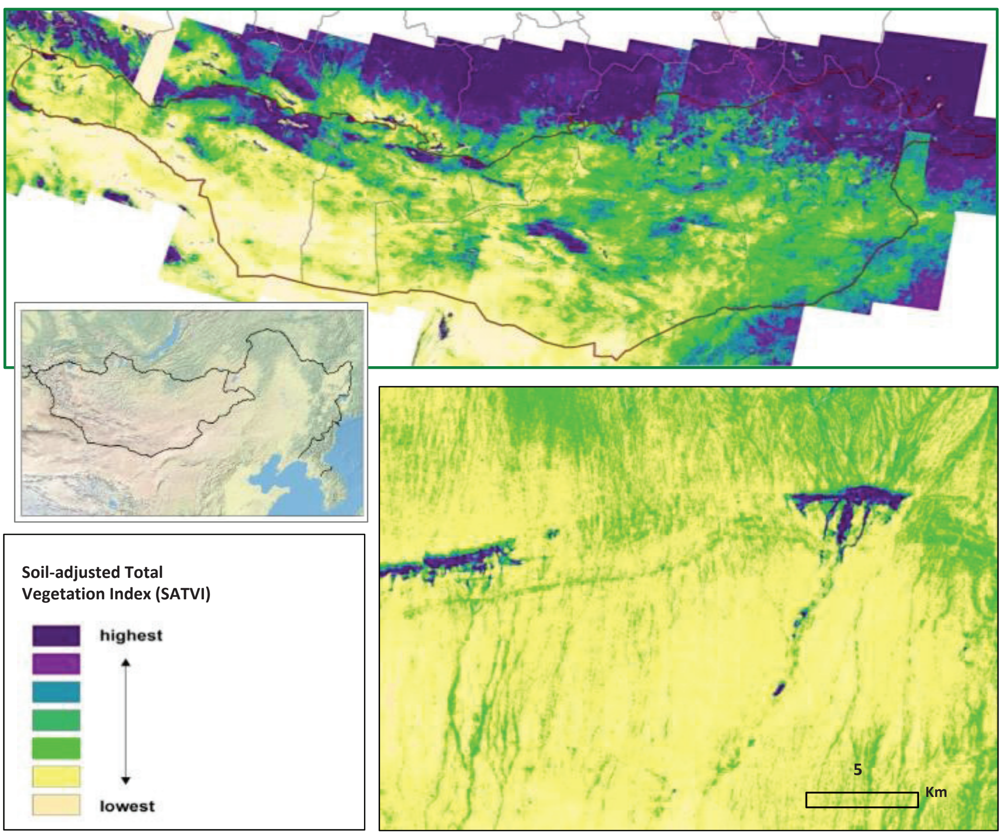


## APPENDIX 6: Monitoring groundwater impacts by remote sensing

In the Gobi Desert of Mongolia, water withdrawals to support mining operations could affect groundwater supplies, with impacts on wells, springs and vegetation productivity that could reduce water sources and forage availability for livestock and wildlife. Because current understanding of the hydrology of this system is limited, it is difficult to estimate the amount, spatial extent or duration of mining- related ground water impacts. Ongoing efforts are attempting to fill data and knowledge gaps. For example, the Mining Infrastructure Investment Support Project (MINIS), funded by the World Bank and AusAID, includes US $3.23 million to strengthen understanding of groundwater management. For more information see: http://www.ausaid.gov.au/countries/eastasia/mongolia/Pages/economic-development-init-1.aspx.

This analysis is not likely to be available for several years and will likely provide only basic information for managing groundwater at the Aimag (province) level, and will not produce the data necessary for estimating impacts of specific mine operations.

**Figure. 1:** Landsat imagery available for Southern Mongolia, and an example of the Soil Adjusted Total Vegetation Index (SATVI) that identifies dense vegetation around a spring.



Given the challenges associated with understanding groundwater hydrology in the Gobi, we suggest developing a framework that can detect changes in surface vegetation related to mining ground water withdrawals. Using satellite imagery (Landsat 5 TM), for the Gobi ecoregional assessment, we have measured and mapped vegetation biomass using a Soil-Adjusted Total Vegetation Index (SATVI; Marsett el al. 2006) that was developed for grasslands and aridlands (see Fig. 1). Specifically, we have mapped areas of dense desert vegetation dependent on ground water. These areas are generally either mature Saxaul stands, groups of Elm trees in Sayrs, or Populus diversifolia and Tamarisk around spring-fed oases.

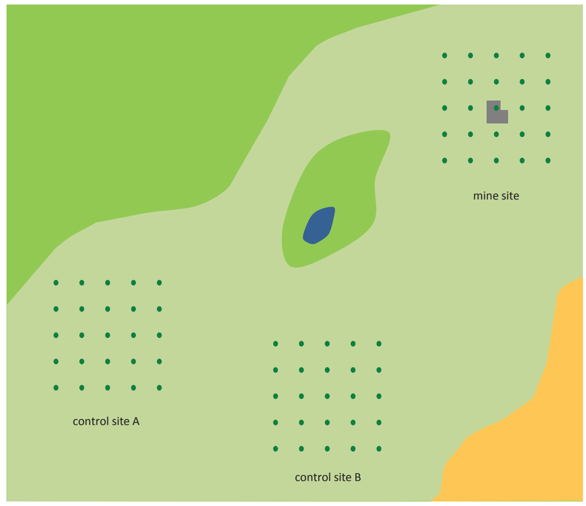
With this vegetation index, we can also measure changes in vegetation over time and compare sites. By comparing changes near a mine site with similar control sites, it's possible to detect the impacts of groundwater withdrawals on vegetation (see Fig.2). The Landsat 5 image archive covers the last 27 years, and the Landsat 7 satellite continues to collect images at approximately monthly intervals.

The availability of this data will allow us to develop a rigorous impact assessment framework (i.e. Before-After-Impact-Control Design, Smith 2002) capable of evaluating whether mining has changed vegetation patterns, to determine which components are adversely affected, and to estimate the magnitude of the effects. The remotely sensed information described here could be used in conjunction with ground monitoring to further strengthen inference. All the information from this assessment will be made publically available as part of the spatial database created from this project.

In the Gobi ecoregional assessment, groundwater-dependent ecosystem types include:

- Oases: large patches of closely-spaced tall shrubs and trees, typically near oases, including tamarisk, Populus, Elm and Saxaul.
- Wet depressions: dry river beds or salty depressions with shallow water table following broad drainage patterns. These areas typically support distinct vegetation types (including Saxaul forests and Elm in the Eastern Gobi) and contain physically diverse soil types due to near-surface groundwater and hydrology.
- Ephemeral waterbodies.
- Sand massives, or large areas of sand dunes, with unique hydrology of sand dunes often creates small wetlands that support distinct plant communities and habitat with high species diversity..

**Figure.2** diagram of sampling sites for monitoring vegetation change in the vicinity of a mine site and at control sites using a before-after control-impact (BACI) design (Smith 2002).

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Smith EP (2002) BACI design. Volume 1, pp 141–148 in Encyclopedia of Environmetrics (ISBN 0471 899976) Edited by Abdel H. El-Shaarawi and Walter W. Piegorsch. John Wiley & Sons, Ltd, Chichester, 2002.

## APPENDIX 7: Advisory working groups and Provincial Stakeholders: members designated by Minister's Order and schedule of activities

Working group leader:

| | |
|---|---|
| D. Enkhbat, | Director, Department of Environment and Natural Resources, Ministry of Environment and Tourism (MNET) |

Secretary:

| | |
|---|---|
| G. Erdenebayasgalan, | Senior officer, Department of Environment and Natural Resources, MNET |

### Science advisory working group designated by Minister's Order

| | |
|---|---|
| R. Gankhuyag, | Head, Administration of Land Affairs and Urban Development, Department of Land Affairs, Construction, Geodesy and Cartography, MRTCUD |
| D. Dash, | Scientific-secretary of Geo-ecological Institute, MAS |
| L. Amgalan, | Scientist, Mammal laboratory, Biological Institute, MAS |
| N. Tseveenmyadag, | Head, Ornithological Laboratory, Biological Institute, MAS |
| A. Khaulenbek, | Scientist, Geo-ecological Institute, MAS |
| D. Zumberelmaa, | Scientist, Botanical Institute, MAS |
| B. Oyungerel, | Scientist, Geographical Institute, MAS |
| S. Amgalanbaatar, S | cientist, Mammal laboratory, Biological Institute, MAS |
| O. Batkhishig, | Head, Soil Laboratory, Geographic Institute, MAS |
| S. Tsedendash, | Head, Pastoral and fodder studies department, Animal Husbandry Research Institute |
| G. Davaa, | Head, Water studies division, Meteorological Institute |
| R. Samiya, | Professor, Biology and Biotechnological School, National University of Mongolia |
| Kh. Terbish, | Head, Natural tourism faculty, Biology and Biotechnological School, National University of Mongolia |
| D. Suran, | Professor, Botany studies faculty, Biology and Biotechnological School, National University of Mongolia |
| N. Batsaikhan, | Professor, Zoological faculty, Biology and Biotechnological School, National University of Mongolia |
| M. Munkhbaatar, | Head, Zoology and Ecology faculty, School of Natural Science, Mongolian State University of Education |
| Ya. Gombosuren, | Professor, School of Mining Engineering, Science and Technology University of Mongolia |
| M. Altanbagana, | Head, Environmental Policy Division, National Development Institute |
| R. Battumur, | Ground water researcher |
| B. Lkhagvasuren, | Director, WWF/Mongolia |
| D. Sanjmyatav, | GIS specialist, WWF/Mongolia |
| L. Bolor-Erdene, | Specialist, Mercy Corps/Mongolia |
| L. Ochirkhuyag, | GIS specialist, WCS |
| Sabine Schmidt, | Director, New Zealand Natural Institute/Mongolia |
| J. Oyunsuvd, | Environmental manager, Oyu Tolgoi project |
| Yu. Bayarjargal, | Project Manager, Development by Design for Southern Gobi Eco-regions project, TNC/Mongolia |
| G. Munkhzul, | Stakeholder Relations Coordinator, Development by Design for Southern Gobi Eco-regions project, TNC/Mongolia |

Secretary:

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|---|---|
| G. Erdenebayasgalan, | Senior officer, Department of Environment and Natural Resources, MNET |

### Science advisory working group meetings

1. October 7, 2011: Kick off meeting and first working group session. Establish Terms of Reference.
2. February 17, 2012: Establish study area and focal biodiversity elements.
3. March 20, 2012: Review data development workplan
4. June, 07, 2012: Midterm review meeting: progress report, review data processing and analysis.
5. October 5, 2012: Review draft results of ecoregional assessment.
6. January 9, 2013: Review conservation portfolio and designated additional sites based on expert knowledge.
7. March 13-21, 2013 (three meetings): Form editorial committee, review and edit draft ERA report.

### Policy advisory working group established by Minister's Order

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| B. Dolgor, | Senior Advisor to the Prime Minister of Mongolia |
| D. Myagmarsuren, | Advisor, Standing Committee on Environment, Food and Agriculture, Parliament of Mongolia |
| P. Zorigtbaatar, | Senior Officer, Cabinet Secretariat, Government of Mongolia |
| Ts. Banzragch, | Director, Sustainable Development and Strategic Planning Department, MNET |
| D. Munkhbaatar, | Deputy Director, Urban Development and Land Relations Policy Department, Ministry of Road, Transportation, Construction and Urban Development |
| Ch. Tsogtbaatar, | Deputy Director, Mining and Heavy Industry Policy Department, Ministry of Mineral Resources and Energy (MMRE) |
| N. Boldkhuu, | Deputy Director, Oil Policy Department, MMRE |
| Kh.Gantumur, | Deputy Director, Road and Transportation Policy Department, MRTCUD |
| J. Davaabaatar, | Head, Division of Land Planning, Department of Land Affairs, Construction, Geology and Cartography, MRTCUD |
| P. Tsogtsaikhan, | Senior officer, Department of Environment and Natural Resources, MNET |
| G. Erdenetsetseg, | Senior officer, Department of Environment and Natural Resources, MNET |
| A. Dolgormaa, | Senior officer, Department of Protected Areas Management, MNET |
| G. Tamir, | Senior officer, Mining and Heavy Industry Policy Department, MMRE |
| T. Zuunnast, | Senior officer, Mining and Heavy Industry Policy Department, MMRE |
| B. Elbegzaya, | Senior officer, Mining Studies Department, Mineral Resources Authority |
| L. Undes, | Officer, Sectoral Development and Investment Policy Department, National Committee of Development and Innovation |
| S. Namjilmaa, | Officer, Sectoral Development and Investment Policy Department, National Committee of Development and Innovation |
| L. Tsedendamba, | Scientific-secretary, National Development Institute |
| B. Chimed-Ochir, | Director, WWF/Mongolia |
| G. Sugar, | Senior manager, Oyu Tolgoi Project |
| D. Munkhzorig, | Manager of Health, Safety and Environment, Energy Resources LLC |
| L. Baigal, | Executive Director, Responsible Mining Initiative for Sustainable Development |
| Ts. Tuyatsetseg, | Deputy Director, Association of Environmental Lawyers |
| D. Galbadrakh, | Conservation Director, TNC/Mongolia |

### Policy advisory working group meetings

1. October 7, 2011: Kick off meeting and first working group session. Establish Terms of Reference.
2. November 7, 2011: review policy and legal framework necessary for implementing mitigation hierarchy.
3. June 07, 2012: Midterm review meeting: progress report, discuss implementation mechanism including offsets.
4. March, 12, 2013: Progress report: draft results, final review process.

### Provincial (Aimag) stakeholder outreach

Government representatives from Department of Nature, Environment and Tourism, Department of Land Affair, Constructions and Urban Development,s and Department of Policy Implementation of the seven Aimags in the study area were invited to all the major meetings in Ulaanbaatar. The seven Aimags are:

- Khovd
- Gobi-Altay
- Bayankhongor
- Omnogovi
- Ovorkhangai
- Dundgovi
- Dornogovi

The project team travelled to four Aimags for stakeholder engagement meetings to introduce the project goals and discuss cooperation to integrate the ecoregional assessment into Aimag land use planning.

- Dornogobi Aimag, March 26-29, 2012 (Development Investment Conference)
- Dundgobi Aimag, April 24, 2012 Department of Nature, Environment and Tourism, and the Land Affairs, Construction and Urban Development Office. 43 participants including the governors, vice-governors and officials from the province soums.
- Umnugobi Aimag, April 27, 2012 39 participants including the specialists and the nature inspectors of the Department of Nature, Environment and Tourism, and the Land Affairs, Construction and Urban Development.
- Gobi-Altay Aimag, November, 2012 54 attendances for the meeting, including the staff of ANET, rangers, environmental inspectors, and the staff of Land Administration of the province.

The project team organized two GIS trainings for Aimag land use planning staff, which were attended by staff from all seven Aimags.

- Beijing, China, 18-22 December, 2011, at ESRI GIS training center.
- Ulaanbaatar, 19-21 September, 2012, at NUM Geology and Geography School.

**IDENTIFYING CONSERVATION PRIORITIES IN THE FACE OF FUTURE DEVELOPMENT:**

Applying Development by Design in the Mongolian Gobi

2013

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