Identifying Conservation Priorities in the Face of Future Development:

APPLYING DEVELOPMENT BY DESIGN IN THE GRASSLANDS OF MONGOLIA

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Ministry of Mining Resources and Energy (MMRE)
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The products of this assessment, including this report, GIS datasets and a web-based GIS application, are available online at http://50.18.62.210/DevByDesign/.

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FOREWORD

I am pleased to present the final report of the Ecoregional Assessment of the Grasslands of Eastern Mongolia. The working group that completed this study was established by Order # 312 of the Minister of Nature, Environment and Tourism on October 28, 2009 to ensure coordination of stakeholders, exchange information and data, as well as oversee implementation of Development by Design.

For thousands of years, Mongolian grasslands have provided habitat for many species of grassland animals and plants, and forage for livestock of Mongolian herders. In recent years, mineral and oil development, and the construction of associated infrastructure, have increased in the region. Pastoral livestock husbandry is recovering from the collapse during transition, and livestock numbers have increased dramatically. While it is pleasant to note these positive growths in the economy, it is important to balance the rapid economic development with conservation of wildlife habitat and pastoral rangelands. Human-induced impacts, in combination with climate change, are causing declines and extinctions of flora and fauna, and may cause irreversible disruption of ecological functions and ecosystem services such as forage production, freshwater supplies and soil fertility. This report contributes to meeting the abovementioned challenges by building capacity in conservation planning to expand the network of protected areas, mitigate impacts of mining development, and adapt to climate change.

The Mongolian National Security Concept urges increased protection of grasslands, and Mongolia made a commitment to increase protection of grasslands at COP-10. Important policy papers, including Mongolia's Master Plan for Protected Areas and Mongolia Biodiversity Conservation Action Plan, aim to designate 30% of country's land as protected areas. Mongolia is progressing toward this goal with roughly 14% of the land area designated as protected areas. Recent studies indicate that protection of the Mongolian Daurian Forest Steppe and Grassland Ecoregions is lower than the national average. In order to achieve the goal, it is important to identify priority conservation sites with ecological and biological significance based on sound science across the grassland ecoregions. I believe that this report will contribute to the expansion of the protected areas network and mitigate impacts of mineral development in the grasslands of Mongolia.

L.Gansukh
Minister of Nature, Environment and Tourism

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PHOTO CREDITS
Cover: Joseph Kiesecker; Page 22: J Joseph Kiesecker, Joseph Kiesecker, Michael Heiner; page 25: Michael Heiner, Joseph Kiesecker; page 34: Michael Heiner, David Kenny, Joseph Kiesecker; page 35: Chris Pague; page 40: Joseph Kiesecker; page 44: Joseph Kiesecker; page 53: Chris Pague, Joseph Kiesecker; page 54: Joseph Kiesecker; page 55: Joseph Kiesecker.

SUMMARY

1. The Central and Eastern Grasslands of Mongolia span an area of 458,000 km^2 that is bounded by the Gobi Desert to the south, the Khyangan Mountains to the west, the Chinese border to the East and the Russian border to the North. Globally, the Temperate Grasslands biome is the most converted and least protected (Hoekstra 2005). The temperate grasslands in Mongolian are largely unconverted, support a full assemblage of native wildlife and the pastoral livelihood of half of Mongolia's population. However, the wildlife and indigenous livelihoods of this area are threatened by overgrazing and rapid growth in mining and oil development.

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 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 targets are defined by a mapped ecosystem classification that consists of three levels: biogeographic zones, ecosystems based on vegetation, and landforms. 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 a GIS index of disturbance and cumulative anthropogenic impacts. To ensure long-term viability of biodiversity, additional consideration should be given to the maintenance of connectivity between sites

3. The portfolio includes a) areas already designated within the National Protected Area system, b) a set of wetland complexes that have been designated as Important Bird Area and c) sites selected with the conservation planning software MARXAN to meet representation goals for ecosystems and optimize ecological condition. The portfolio covers 147,000 km^2, or 32 % of the study area, and consists of 45 sites that range in size from 100 km^2 to 18,000 km^2. National Protected Areas are 29% of the portfolio area. To evaluate the significance to conservation 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 or petroleum development. Within these conflict areas, the areas with relative conservation value in the highest 30th percentile 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.

5. We also illustrate how the conservation portfolio can be used to offset impacts associated with mining, oil and gas as well as 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.

1.0 INTRODUCTION

Purpose of this study

The purpose of this study is to support sustainable development for the Eastern Steppe grasslands by providing a sound basis for land-use planning that balances the needs of mineral and energy development, pastoral livelihoods, and wildlife habitat conservation. We believe the study can inform decision-making in several ways:

- Support protected areas design and management
- Provide "early warning" of potential conflicts between development and conservation goals
- Provide basis for applying the "mitigation hierarchy" (i.e., impact avoidance versus offsets), supporting decision-making about appropriate impact mitigation practices
- Inform offset design to maximize their conservation values

The Mongolian Steppe is one of the last remaining intact temperate grasslands in the world. Globally, the Temperate Grasslands biome is the most converted and least protected (Hoekstra 2005). The temperate grasslands in Mongolia support a large assemblage of native wildlife including Grey wolf, Red fox, Corsac fox, Pallas cat, Great bustard, Saker Falcon, Lesser Kestrel, Siberian marmot and over one million Mongolian gazelle (Olson 2008). Lakes, ponds, and wetlands provide stopovers and nesting sites for globally-endangered waterbirds including Swan goose, Relict gull, and several species of cranes (Nyambayar & Tsveenmyadag 2009). The Mongolian Steppe has a relatively low population density with less than 0.5-1 person per square kilometer (Institute of Geography, 2009). For recorded history, the steppe has been grazed to support livelihoods of nomadic herders (Dashnyam 1974).

However, threats and pressures on grassland have increased dramatically following the transition to a market economy in 1990. The number of livestock has nearly doubled over the last two decades reaching approximately 40 million animals (National Statistical Office of Mongolia, 2008). This has lead to overgrazing, particularly in areas near rural population centers and water sources.

Mineral resources exploration and exploitation has also increased dramatically. To date, surface rights for mineral and petroleum exploration have been leased across approximately 27% of the country, with 47% available for lease (MMRE 2010). Expansion of the railroad is underway to connect the mineral rich southern dessert region to the Trans-Siberian railroad network. Development plans for the central and eastern grasslands parallel the national trend; 25% of the grasslands study area has been leased for exploration and 46% is available for lease (MMRE 2010).

The transition in Mongolia's political and economic landscape over the past two decades is forcing difficult decisions to balance rapid development of natural resources with conservation of rare and remarkable natural landscapes. Mining and oil operations and related transportation infrastructure have the potential to fragment the landscape and endanger wildlife. Large quantities of water used in the mining and oil processes can disrupt the hydrology of this arid landscape, impacting pastoral livelihoods and wildlife habitat. Disturbing vegetation cover leaves soil vulnerable to erosion and desertification. However, most of the planned development has not yet begun. The window of opportunity for Mongolia to harness land use planning for sustainable development is now, to manage its vast natural wealth to achieve lasting benefits for people and nature.

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). Development by Design (DbyD) blends landscape conservation planning with the mitigation hierarchy – avoid, minimize, restore, or offset – to identify situations where development plans and conservation outcomes may be in conflict, and to identify which step of the mitigation hierarchy is consistent with conservation goals. For development impacts that are consistent with conservation goals, DbyD seeks to maximize the return to conservation provided by compensatory mitigation, or biodiversity offsets. The four-step DbyD framework supports sound land use planning, helping decision-makers avoid and mitigate conflicts between development impacts and conservation priorities, and supporting the use of compensating conservation actions (offsets) to achieve better outcomes for people and nature.

DbyD is applied for two distinct spatial scales. First, DbyD focuses at a landscape level (see Study Area below) 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 be a priority consideration (Steps 1 &2). Second, DbyD is applied at a project or site level (mining or energy 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 optimal offset portfolio.
4. Estimate offset contribution to conservation goals

This study focuses on providing a landscape-level analysis, as this is essential for addressing the first critical question concerning the application of 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, in particular the ecoregional assessment (e.g. Groves 2003) carried out for this study, provides the structure to ensure mitigation is consistent with conservation goals, 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: 1) considers the cumulative impacts of both current and projected development; 2) provides regional context to better guide which step of the mitigation hierarchy should be applied (i.e. avoidance versus offsets); and 3) offers increased flexibility for choosing offsets that can maximize conservation return by focusing efforts towards the most threatened ecosystems or species.

Figure 1: Major Habitat Types and Terrestrial Ecoregions of Mongolia

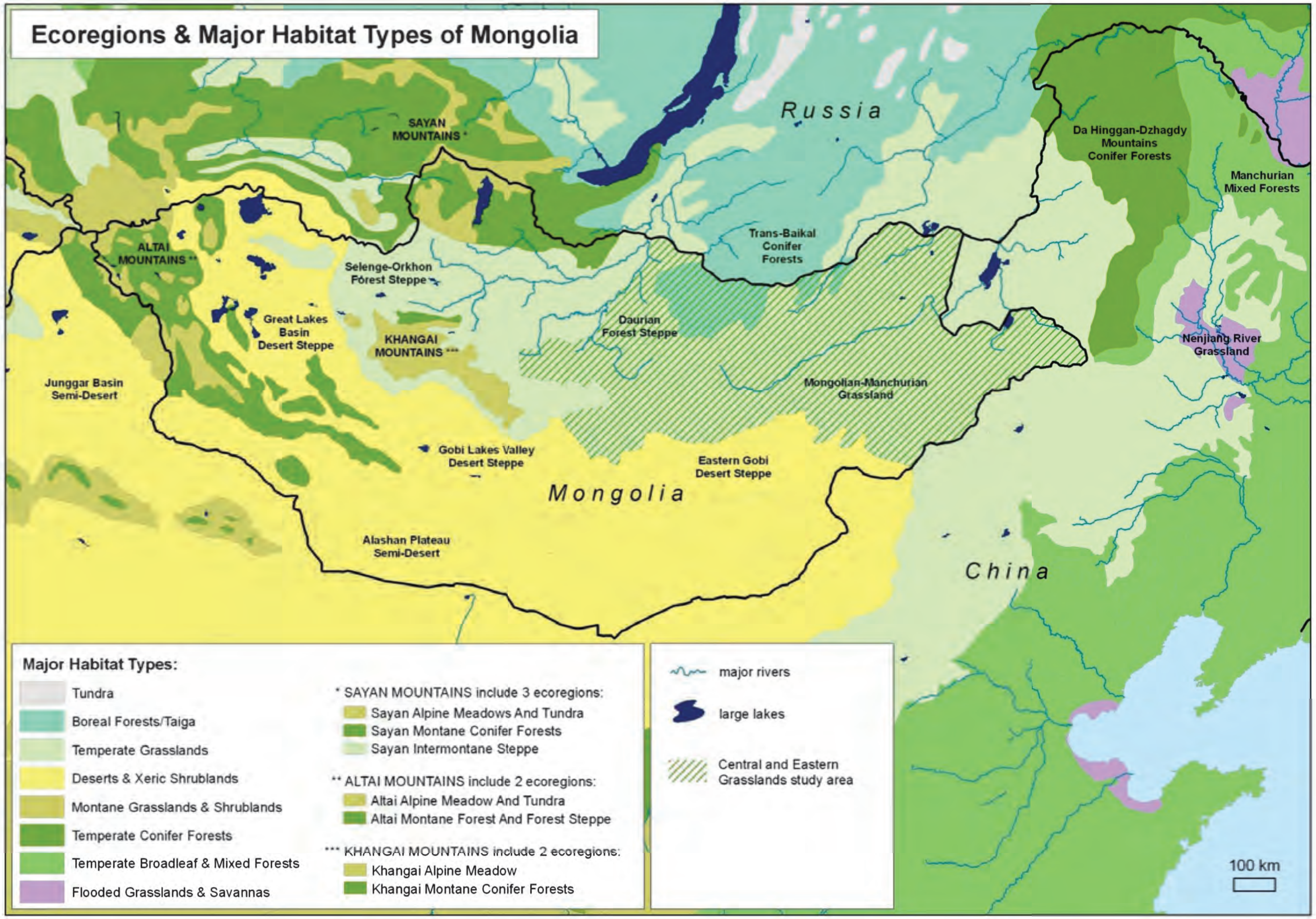
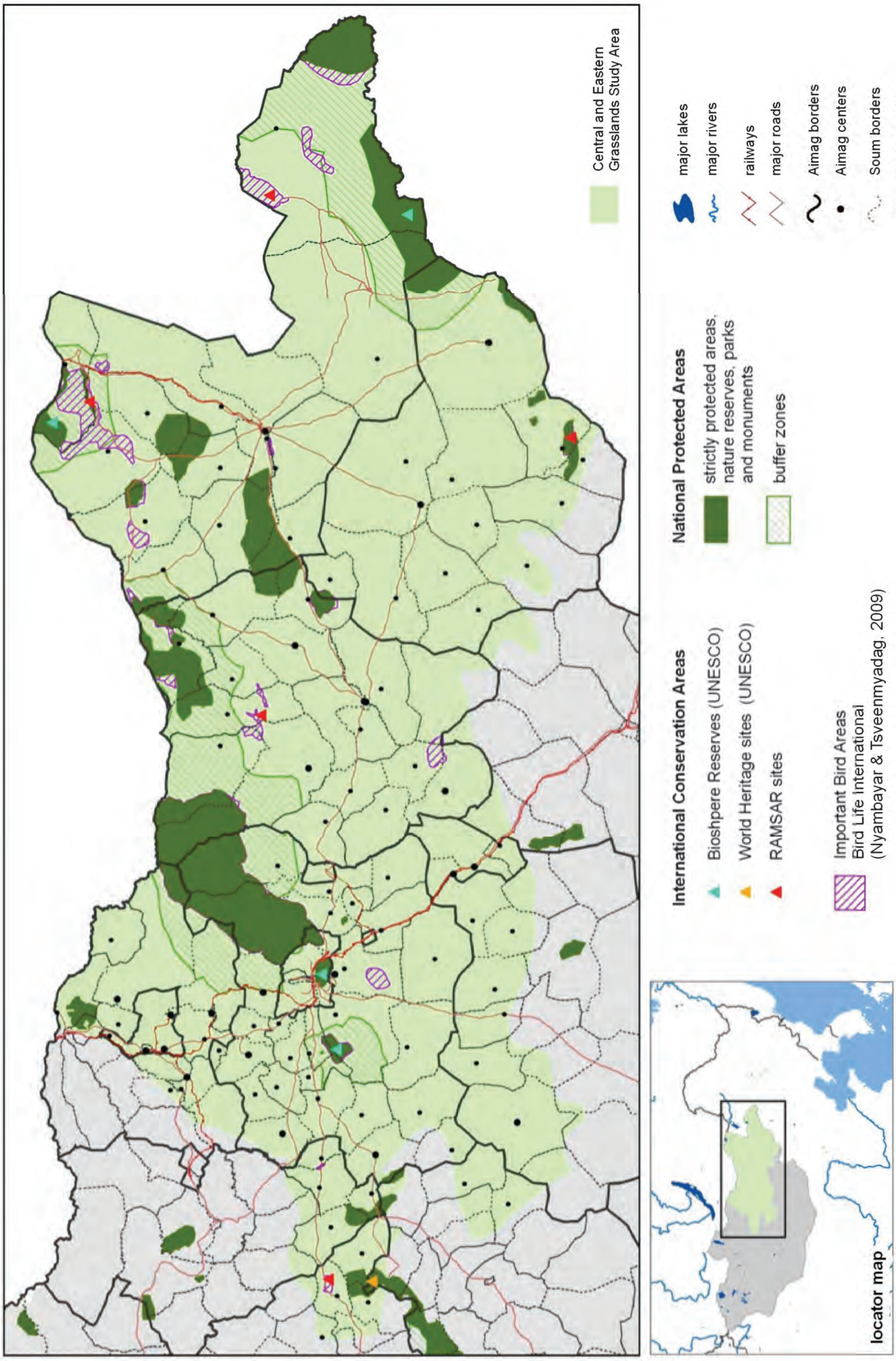


Figure 2: Study Area: Central and Eastern Grasslands of Mongolia



Study Area

The study area is the Mongolian portions of three terrestrial ecoregions: The Mongolian-Manchurian Grasslands, the Daurian Forest Steppe and the Trans-Baikal Boreal Forest (see Figure 1). This covers 458,000 km^2 and spans the Khentii Mountain Range and Trans-Baikal Coniferous Forest to the north, the Khangai Mountain Range to the far west, the Khyangan Mountain Ranges to the east, and Central Asian Desert Steppe to the south, and is bounded by the Chinese border to the East and the Russian border to the North. The region is characterized by extreme continental climate with annual average precipitation of 200-300 mm. Long term average temperature ranges between +18 - +22 C in July and -20 – (-24) C in January, and winter temperature remains below 0 C from November to March (Dashnyam, 1974).

The climate change trend in Mongolia has been more rapid than other parts of the world. Temperature increases from 1951-2002 are among the highest in the world, with little change in precipitation (Girvetz et al. 2009). This has likely contributed the expansion of the Gobi Desert northward (Yu et al. 2004, Zhang G. et al. 2010) and the drying of rivers and waterbodies.

Applications of this study

A primary objective of this study was to identify a set of areas that could maintain the representative terrestrial biodiversity features and ecological processes of the Mongolian Steppe, given adequate protection and management as high quality core habitat within a larger landscape matrix that supports habitat use and movement. We designed a conservation portfolio that met the Mongolian government's goal of preserving 30% of all natural systems, in a configuration that is optimized to meet the following design criteria: avoid areas of low ecological integrity, require the smallest amount of land, and maintain ecological goals despite projected mining/petroleum development. We developed methods for regional terrestrial conservation planning that address the scope and scale of the 458,000km^2 study area with available data. These methods are suitable for application in other landscapes. 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: 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. The Resolution #13 of the Parliament of Mongolia (2008) specified that 15% will be national protected areas and remaining 15% will be local protected areas. Today, Mongolia has designated 61 national protected areas that cover about 21.8 million hectares or 14% of the country's land (Myagmarsuren 2008). At the National- and the Aimag-level, the results of this study will support new designations to meet Mongolian government goal of protecting 30% natural habitat, and the development of priorities and strategies for improving management effectiveness of existing protected areas.
- "Early warning": By identifying potential conflicts between development and conservation goals, pro-active steps can be taken to reduce conflict and ensure development and conservation needs are met.
- Mitigation of mining and energy development impacts: By providing a framework to implement the mitigation hierarchy, decision-making about impact avoidance, appropriate impact mitigation practices and compensatory mitigation (offsets) can be more science-based and better informed.

- Offset design: An understanding of 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.

Conservation Planning

Systematic conservation planning is a methodical and comprehensive process for identifying a set of places or areas that, together, represent the majority of species, natural communities, and ecological systems found within a planning area. Landscape-level planning and action is rapidly emerging as a necessary strategy for achieving conservation results (Olson et al. 2001). A conservation portfolio of priority sites**,** the end product of conservation planning, is a set of areas selected to represent the full distribution and diversity of these systems (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 portfolio is meant to meet the minimum viability needs of each biological target 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 of these approaches are: (1) define and map a suite of biodiversity targets 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 targets 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 targets; (4) use this information to identify the occurrences of biodiversity targets that collectively meet representation goals and are the most likely to persist, i.e. are viable, with highest relative ecological integrity and minimal risk from future threats. A diagram illustrating this process is shown in Figure 3.

Previous regional conservation plans and priority-setting efforts

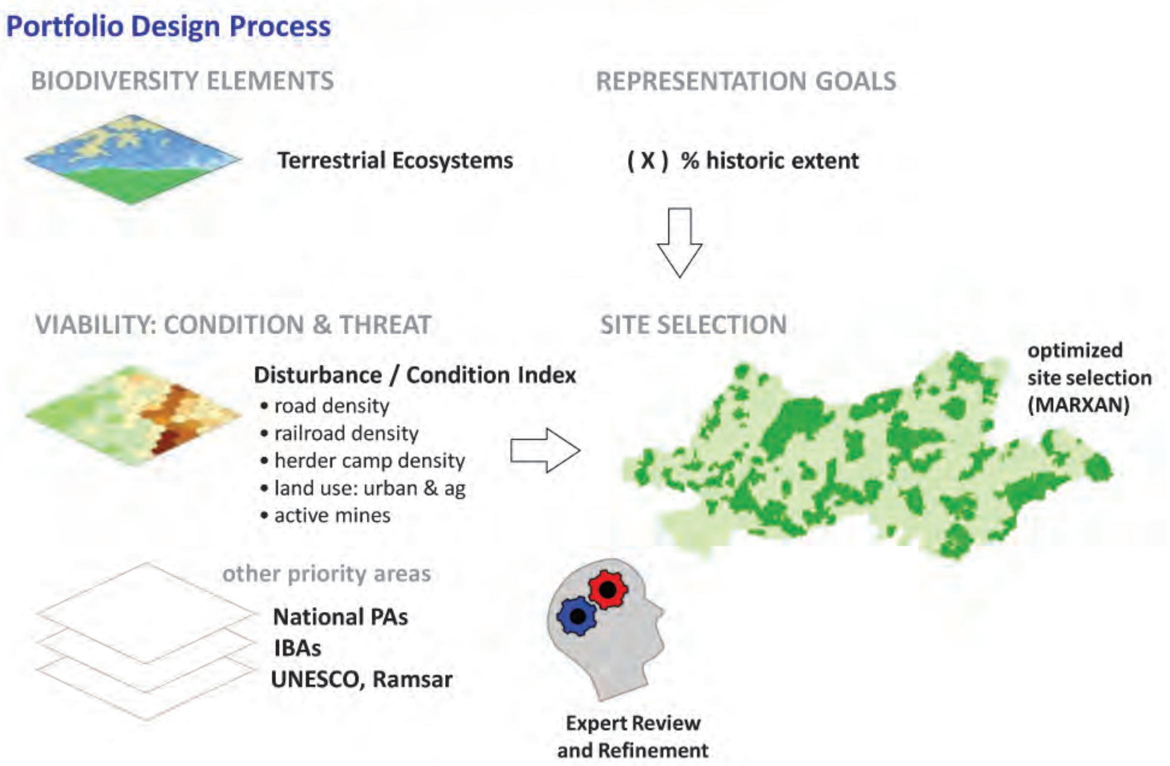
Mongolia established one of the world's earliest known nature reserves, Bogd Khan, in 1778. In 1996, the Mongolian Ministry of Nature and Environment published the Biodiversity Conservation Action Plan for Mongolia. (MNE 1997). This report recommended designation of eight strictly protected areas, 40 national parks and 37 heritage areas. As of 2008, approximately 40% of the recommended areas have been designated as National Protected Areas (WWF 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. The Resolution #13 of the Parliament of Mongolia specified that 15% will be national protected areas and remaining 15% will be local protected areas.

Today, Mongolia has designated 61 national protected areas covering about 21.8 million hectares or 14% of the country's land (Myagmarsuren 2008). 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 in Mongolia (Nyambayar & Tsveenmyadag 2009).

Within the study area, the National Protected Areas cover 42,000 km^2 (9%) of the study area. These 24 PAs include include three Biosphere Reserves (UNESCO 2011a), two World Heritage Sites (UNESCO 2011b), and five Ramsar Sites (see Figure 2). The study area contains 21 Important Bird Areas, eight of which are National Protected Areas. These sites are the foundation, or starting point on which the conservation portfolio was built.

Figure 3: Process for designing a portfolio of conservation areas



2.0 METHODS & RESULTS

2.1 Overview

Our objective was to identify a portfolio of sites that support the native biodiversity and ecological processes representative of the Mongolian Steppe. To define biodiversity targets, we developed a terrestrial ecosystem classification that maps 216 ecosystem types. We designed the portfolio to meet the following criteria:

- **Representation:** meet goals for a specified number or amount of each biodiversity target needed to maintain their ecological and evolutionary potential over time. We defined biodiversity targets 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 targets 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 that meet biodiversity goals.
- **Connectivity:** where there is a choice, 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. This does not consider landscape connectivity beyond adjacent first-order neighbors. Evaluating the functional landscape connectivity of the portfolio, to support movement across the study area, is a critical next step.

We designed the portfolio through several steps or components:

1. **Assemble the working group.** We convened a group of experts and stakeholders to advise and review the planning process. The working group was organized as follows; members and affiliations are listed in Table 1.

    a. Core technical team: technical and science staff responsible for analysis and reporting.

    b. Science Advisory team: biologists and geographers with expert knowledge of the study area and available data; responsible for advising data development and reviewing results.

    c. Policy team: Senior managers with knowledge and expertise regarding implementation strategy.

The Science Advisory team reviewed the data development and analysis at several intervals during the course of the study, which included three team meetings and many informal interviews. We held two government workshops, in April and August of 2010, to review results and discuss implementation strategies. These workshops were attended by the full working group and other representatives from National and Aimag government and NGOs.

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, and excluding buffer zones. These areas served as the foundation, or starting point, for portfolio design.

Table 1: *Planning team members and organization*

Core Technical Team
D. Galbadrakh (Conservation Director, TNC)
M. Heiner (GIS and Conservation Planning, TNC)
E. Tuguldur (Assistant Biologist, TNC)
L. Ochirkhuyag (WCS Mongolia Program)
D. Sanjmyatav (WWF Mongolia, GIS Specialist)
R. Gankhuyag (Director, Cadastral Division, ALAGAC)
G. Sergelen (Scientist, Faculty of Geology and Geography, MNU)
V. Ulziisaikhan (GIS Specialist, TNC)
J. Kiesecker (Lead Scientist, TNC)
B. McKenney (Senior Economic Advisor, TNC)
Science Advisory Team
B. Oyungerel (Scientist, Geography Institute)
D. Dash (Science Secretary, Geoecology Institute, Academy of Sciences)
L. Jargalsaikhan (Scientist, Institute of Botany, Academy of Sciences)
Kh. Munkhbayar (Professor, Biology Dept., Pedagogical University of Mongolia)
N. Batsaikhan (Zoologist, Faculty of Biology, MNU)
N. Tseveenmyadag (Head of the Bird Study Laboratory, Academy of Sciences)
D. Ariungerel (Pasture Land Specialist, Gobi Pasture Project, Mercy Corps)
A. Nyambayar (Scientist, MNU, Wildlife Science and Conservation Center)
D. Zumburelmaa (Scientist, Institute of Botany, Academy of Sciences)
Policy Team
D. Enkhbat (Director of Dept. of Natural Resources and Environment, MNET)
R. Gankhuyag (Director, Cadastral Division, ALAGAC)
N. Boldkhuu (Deputy Director, Dept. of Fuel Policy, MMRE)
G. Tamir (Officer, Mining Policy Dept., MMRE)
B. Magvanjav (Director, Dept. of Mining, Technology and Environment, MMRE)
L. Erdenesaikhan (Mineral Resources and Petroleum Authority, MMRE)
G. Erdenebayasgalan (Officer, Dept. of Sustainable Development and Strategic Planning, MNET)
A. Dolgormaa (Specialist, PA Management Department, MNET)
G. Enkhtaivan (Officer, Dept. of Protected Area Management, MNET)
D. Sansardarimaa (Contract Officer, Mineral Resources and Petroleum Authority, MMRE)
G. Jargalnemekh (Officer, Environmental Restoration and Conservation, MMRE)
O. Enkhtuya (TNC Mongolia Program Director)
O. Chimed (WWF Mongolia Program Director)
A. Fine (WCS Mongolia Program Director)

3. **Wetland Complexes**. We identified seven wetland complexes that are either a) designated by the RAMSAR Convention as wetlands of international importance for fundamental ecological functions and economic, cultural, scientific, and recreational value (Ramsar 2011), and/or b) designated by Bird Life International as Important Bird Areas that support globally threatened species, restricted-range species, biome-restricted assemblages, or large congregations (Nyambayar & Tsveenmyadag 2009), as follows:

- Ogii Nuur (RAMSAR 2MN004; IBA MN04).
- Lakes in the Khurkh-Khuiten river valley (RAMSAR 2MN011; IBA MN058).
- Buul Nuur and its surrounding wetlands (RAMSAR 2MN008; IBA MN068).
- Mongol Daguur (RAMSAR 2MN001; IBA MN066).
- Khukh Lake (IBA MN067; in buffer zone of Mongol Daguur Strictly Protected Area).
- Tashgain Tavan Lakes (IBA MN069; in buffer zone of Dornod Mongol Strictly Protected Area).
- Ulz River and Turgen Tsagaan Lakes (IBA MN064)

4. **Site selection for ecosystem representation**. Through a GIS analysis, we identified a set of areas that, in combination with National-level PAs and IBAs, would meet representation goals for ecosystems. This analysis involved three steps. First, develop 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. 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. 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).

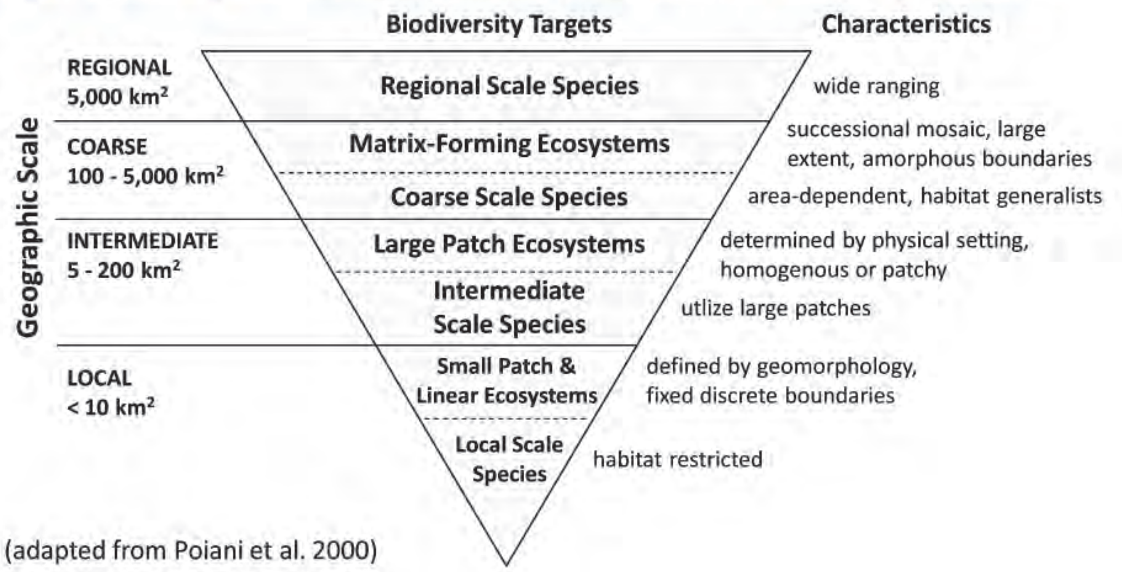
5. **Re-design to minimize conflict with planned mineral and oil development**. We examined how the conservation portfolio overlapped with future potential development. To represent future development pressure we mapped all oil and gas and mining leases within the study area. Overlap between the portfolio and leased areas were re-designed as follows: Overlap between the conservation portfolio and mineral or petroleum leases with biological value in the highest 30th percentile, defined as a combination of optimacity and rarity, 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.

2.2 Biodiversity Targets: Terrestrial Habitat Classification

The essential feature of systematic conservation planning is the clear articulation of a biodiversity vision that incorporates the full range of biological features, how they are currently distributed, and the minimum needs of each feature to maintain long-term persistence. Given the complex organization of biological systems and the limits of existing data and knowledge, it is neither feasible nor desirable to analyze individually the many thousands of biodiversity targets for a given region. Therefore, we must select an effective representative subset of species and environmental features, or biodiversity targets, a) that best represents the broad range of native biodiversity and b) 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 2003, Groves 2003). Biodiversity targets can be organized by spatial scale in a framework created by Poiani et al (2000) that defines local, intermediate, coarse and regional scales (Figure 4).

Figure 4: Selecting focal biodiversity elements: Spatial scales and Biodiversity elements



Regional conservation plans often apply a 'coarse filter / fine filter approach' to define biodiversity targets. 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 targets that represent the range of environmental gradients and settings is a way to address 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 best use of available data to represent the full range of representative biodiversity with a practical number of targets. Our knowledge regarding species ranges and habitat needs will always be incomplete. As coarse filter targets, 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.

Given the short time frame of this assessment and the lack of GIS data to comprehensively map the current range of species that are rare to the study area, we defined biodiversity targets following a coarse filter approach focused on terrestrial habitat, and did not define or develop information for fine filter targets. To define and map coarse-filter biodiversity targets, we developed an ecosystem classification that is organized as a hierarchy of biogeographic zones, terrestrial ecosystems based on vegetation and geomorphology, and landforms. This classification describes 216 ecosystem types, described in Table 3. Source data and mapping method are described below and in Table 2.

Table 2: *Ecosystem types: source data and mapping method*

UPLAND	source data	mapping method
Steppe grasslands Desert Steppe Dry Steppe * Moderately Dry Steppe * Meadow Steppe *	Vostokova & Gunin (2005)	Re-classified by WWF (2010) * stratified by land forms
Sand massives	Vostokova & Gunin (2005)	Re-classified by WWF (2010)
Cinder cones	satellite imagery (Landsat 5 TM)	manual interpretation
Boreal Forest High mountain tundra Alpine meadow and Subalpine woodland High mountain steppe Mountainous boreal coniferous forest High mountain deciduous-coniferous woodland Sub-boreal coniferous-deciduous forest	Vostokova & Gunin (2005)	Re-classified by WWF (2010)
LAKES and WETLANDS		
Riverine and Palustrine Wetlands large river floodplains small river riparian areas ephemerally wet depressions	DEM (SRTM) and drainage network (HydroSHEDs) and satellite imagery (Landsat 5 TM)	1) topographic model 2) edited per manual interpretation of satellite imagery and 3) stratified by major basins.
Lakes and small water bodies Large lakes	Vostokova & Gunin (2005)	
Small lakes and water bodies	satellite imagery (Landsat 5 TM)	manual interpretation, mapped as polygons and point locations;

Table 3: *Ecosystem types: distribution by biogeoraphic zone (page 1 of 2)*

Biogeographic Zones

Terrestrial Ecoregions [2]		Mongolian-Manchurian Grassland					Daurian Forest Steppe			Trans-Baikal Boreal Forest
Ecological zones [1]		**Orkhon**	**Mandal-Gobi**	**Pre-Khingan**	**Menengiin Tal**	**Middle Kherlen**	**Tola-Onon**	**Dharkhan**	**Uldzin**	
UPLAND	Total									
matrix-forming steppe										
Desert Steppe	9,651 km^2		7,360			2,290				
Dry Steppe *	129,505 km^2		30,430	1,998	46,343	48,672			2,063	
Moderately Dry Steppe *	112,378 km^2	8,223	22,860	3,499	30,417	19,836	3,772	13,679	10,090	
Meadow Steppe	89,359 km^2	12,954	10,955	6,639	4,510	2,545	20,077	8,221	19,516	3,942
Sand massives	3,246 km^2	288		1,710	100	985		163		
Cinder cones	135 km^2	--	--	--	--	--	--	--	--	--
Boreal Forest										
High mountain tundra	1,076 km^2	--	--	--	--	--	--	--	--	--
Alpine meadow and Subalpine woodland	2,891 km^2	--	--	--	--	--	--	--	--	--
High mountain steppe	458 km^2	--	--	--	--	--	--	--	--	--
Mountainious boreal coniferous forest	15,759 km^2	--	--	--	--	--	--	--	--	--
High mountain deciduous-coniferous woodland	380 km^2	--	--	--	--	--	--	--	--	--
Sub-boreal coniferous-deciduous forest	25,521 km^2	333		847			8,496	4,441	563	10,842

* stratified by landforms

[1] Vorostokova & Gunin (2005)

[2] Olson et al. (2001)

Table 3: *Ecosystem types: distribution by biogeoraphic zone (continued from previous page)*

LAKES and WETLANDS	Total								
Riverine and Palustrine Wetlands		**Selinge**	**Onon**	**Kherlen**	**Uldz**	**Khalkh**	**Gal Tuul**	**Matad east**	**endorheic**
large river floodplains	10,021 km^2	4,019	1,384	3,014	721	792			
small river riparian areas	10,267 km^2	2,200	919	2,775	1,518	1,878	977		
ephemerally wet depressions	6,566 km^2							2,866	3,701

Lakes and small waterbodies		**Selinge**	**Onon**	**Kherlen**	**Uldz**	**Buul Nuur**	**Gal Tuul**	**Matad east**	**Khalkha**	**Middle Kkalkha**	**Matad north**	**NE Dornod**
Lakes	1,579 km^2	49	10	73	107	691	186	55	56	56	36	260
small water bodies **	1,291	96	41	169	112	70	81	68	268	146	99	141

** units = count

Tier I: Biogeographic Zones

Biogeographic Zones represent broad, regional patterns of climate, physiography and related variation in species and genetics. For widespread ecosystem types such as Dry Steppe, 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.

For upland ecosystem types, we delineated biogeographic zones based on the combination of ecological zones mapped by Vostokova and Gunin (2005) and WWF terrestrial ecoregions (Olson et al. 2001), as shown in Figure 5. For Lakes and wetlands, we defined biogeographic zones according to the boundaries of major river basins, derived from HydroSHEDs (Lehner, Verdin & Jarvis, 2006) as shown in Figures 6 and 7.

Tier II: Terrestrial Ecosystems

Ecosystems are generally defined as a biotic component (vegetation) and abiotic component (physical environmental features and processes). Table 2 lists each ecosystem type, source data and mapping method. Ecological definitions of the ecosystems types are listed in Appendix 1. Table 3 lists the distribution of each ecosystem type by biogeographic zone, and Figure 5 is a map of ecosystem types and biogeographic zones.

For upland ecosystems, our primary data source was a map developed by Vostokova and Gunin (2005). This map was was re-classified by WWF to produce a national mapped ecosystem classification (WWF 2010). This was also the source for mapping large lakes.

To map floodplains and riparian wetlands, we used a GIS topographic model that delineates potential riverine wetlands based on topography of the stream channel, as derived from a digital elevation model (Lehner, Verdin & Jarvis, 2006) at 3-second (77m) resolution. We edited the model results based on manual interpretation of the satellite imagery described previously, and classified the resulting features as large river floodplains and riparian areas associated with smaller tributaries and ephemeral streams. We further classified the floodplains and wet riparian areas according to major river basin. In endorheic basins, we classified the wet lowland features as ephemerally wet valley bottoms, which typically form salty depressions, and divided these into two bio-geographic zones, as shown in Figure 6 and described in Table 3.

To map small lakes and waterbodies, we digitized the boundaries and point locations of water bodies through manual interpretation of satellite imagery. We compiled 34 Landsat TM5 satellite scenes to cover the study area (NASA 2009). The date of acquisition for 31 of the scenes was between June 30 to September 28, 2009. For 3 scenes, the best available image was acquired in September 2007. Pre-processing included an atmospheric correction algorithm and tasseled cap transformation (ERDAS 1999). The tasseled cap transformation produces a 3-band image that improves the contrast between bare ground, water, and vegetation. The resulting image is very useful for classification and manual interpretation of landscape features. Using the transformed images, we digitized waterbodies on-screen at 1:250,000. Through this process, we added 210 polygon lake features for waterbodies larger than 0.3 km^2 and 1,565 point features for small water bodies smaller than 0.3 km^2. Finally, we classified lakes and water bodies by river basin or biogeographic zone, as shown in Figure 7.

Figure 5: Terrestrial Ecosystems

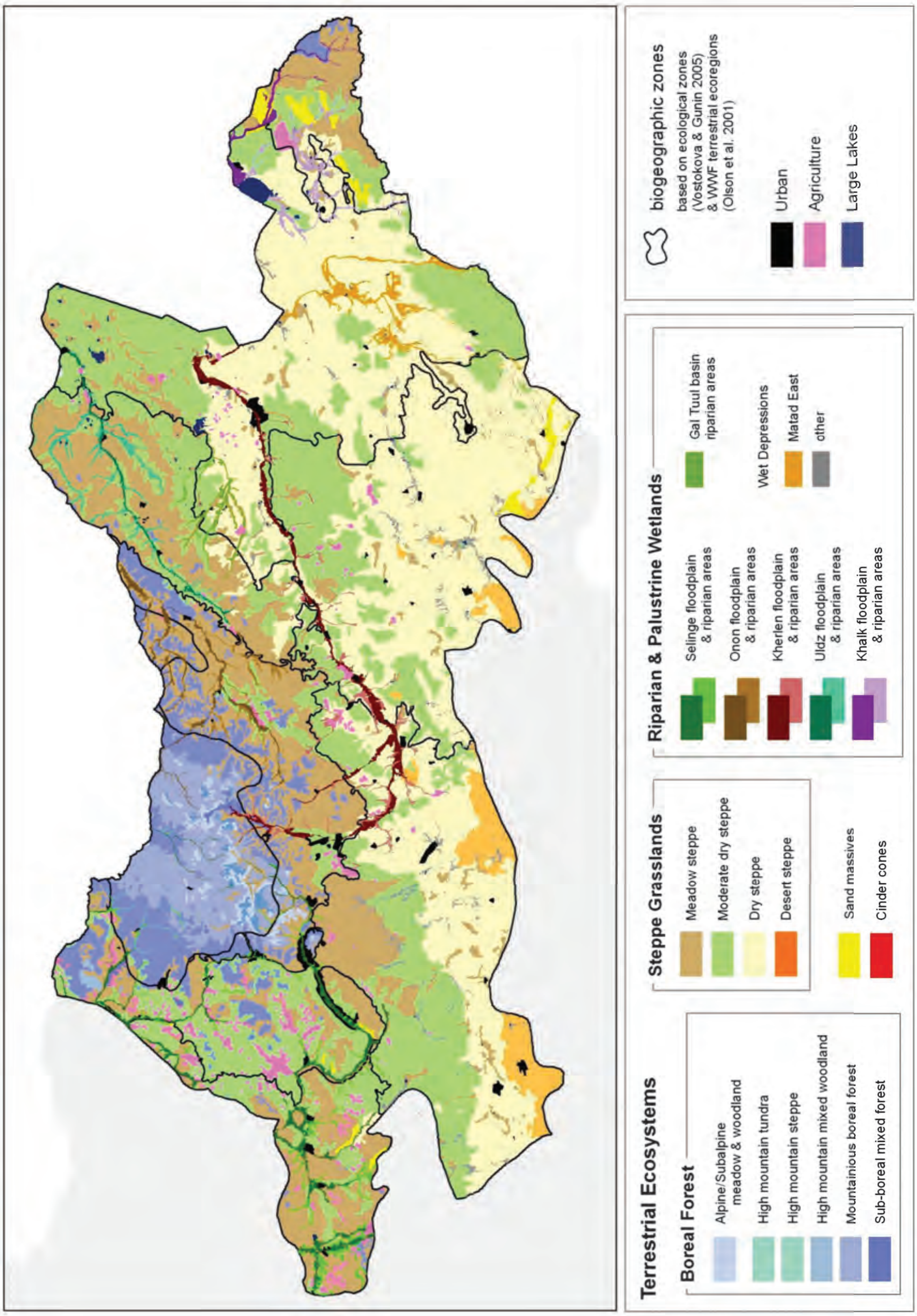


Figure 6: Floodplains, riparian areas and other depressional wetlands

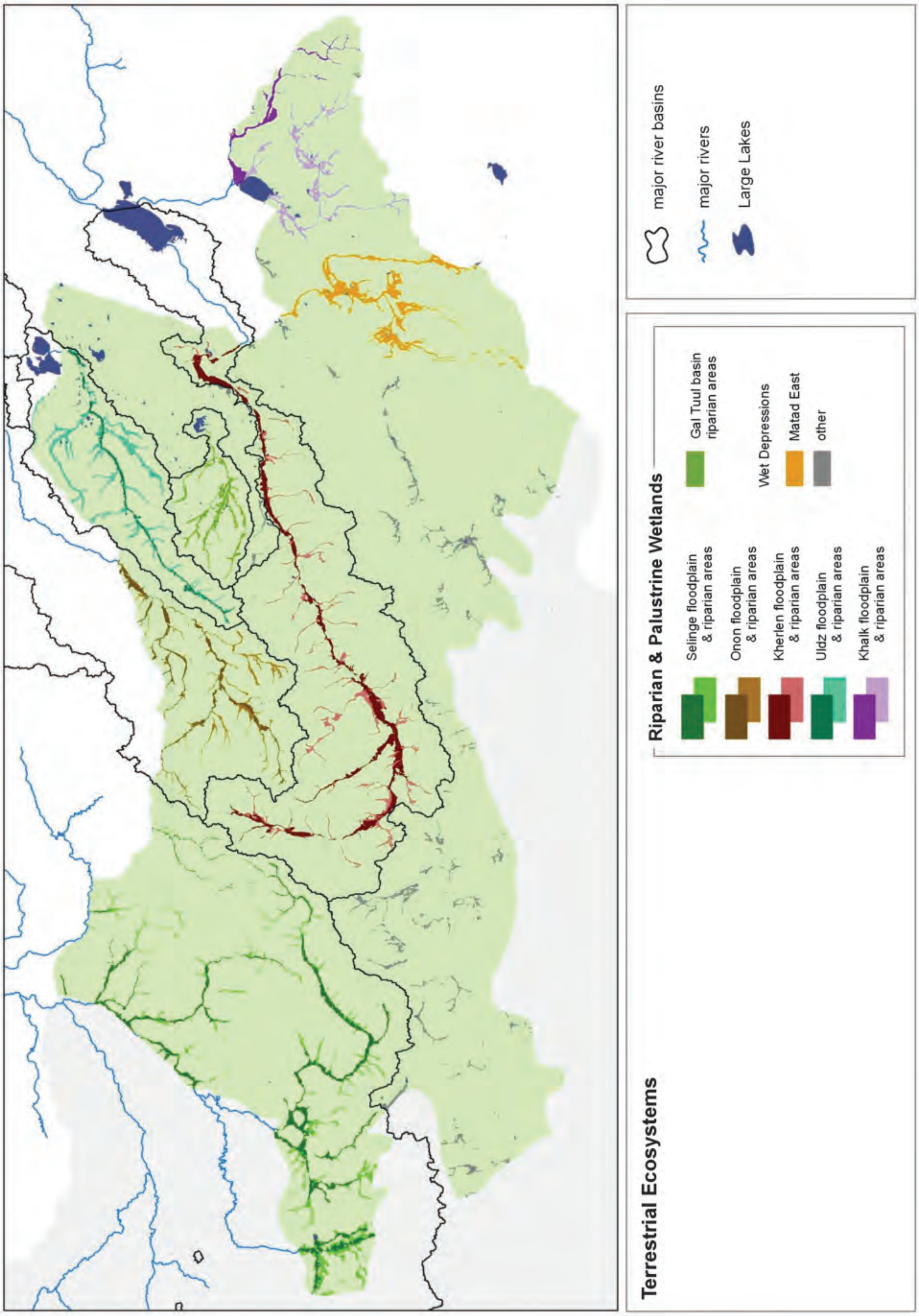


Figure 7: Lakes & small water bodies

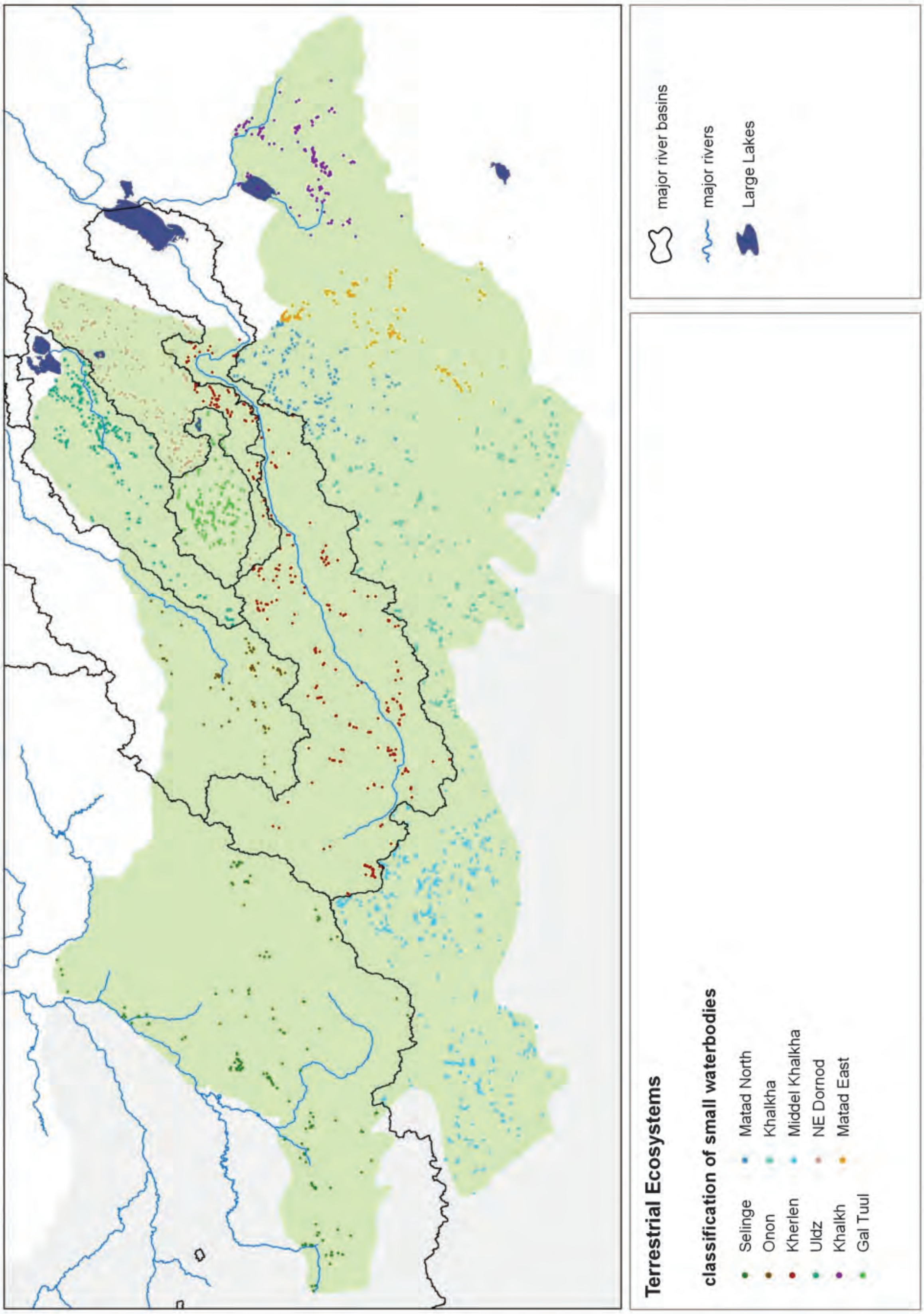
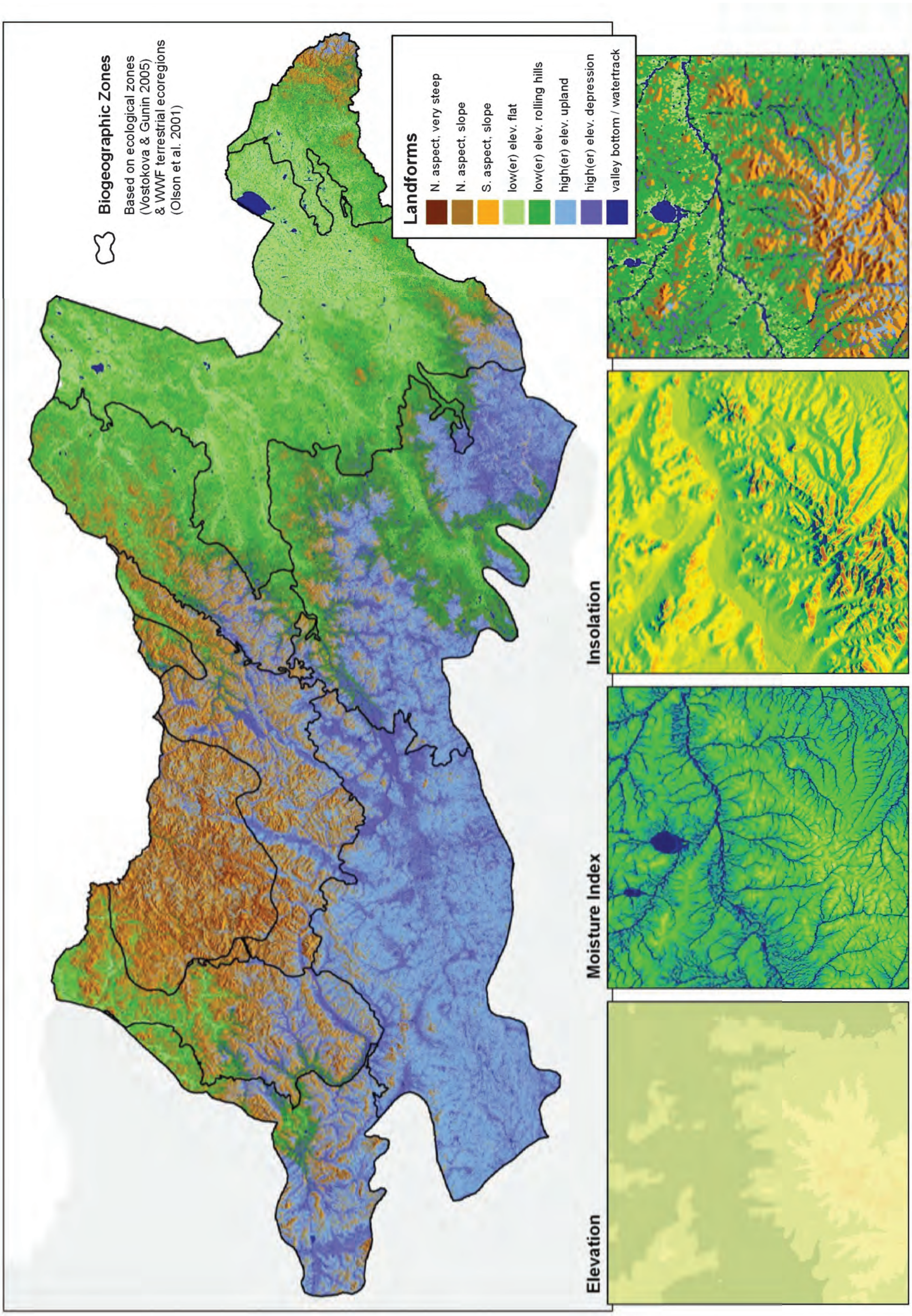


Figure 8: landform classification based on elevation and topography



Tier III: Landforms:

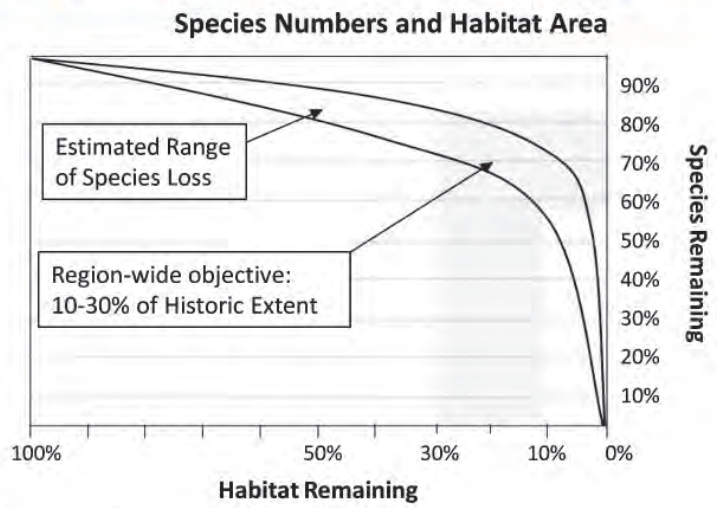
Three steppe ecosystem types - Dry Steppe, Moderately Dry Steppe and Meadow Steppe – occupy almost 80% of the study area, but are a heterogeneous, patchy matrix of plant communities formed by topography, disturbance regimes and successional cycles. Patterns of plant species composition within these matrix-forming 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 elevation, insolation (Rich et al. 1995) and a topographic index (Moore et al. 1991), as shown in Figure 8.

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).

Many regional conservation plans have also set coarse filter goals as 30% of historic areal extent, 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 depicted in 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.

Figure 9: Species / Area Curve: Relationship between species numbers and habitat area



Species / Area Curve, adapted from Dobson (1996)

Setting goals is a challenge because both knowledge and supporting data are limited. 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 are an initial estimate of the amount and distribution required to support the long-term persistence of species and ecological processes, and 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.

2.4 Disturbance/Condition Index

In order 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. Source data included road density, railroad density, population centers and associated area of impact, density of herder camps, urban and agricultural land-use, existing mines and existing petroleum development and infrastructure. The resulting disturbance surface is shown in Figure 10.

We designed this index to maximize selection of un-disturbed ecosystem occurrences, 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, the index functions as a measure of ecological disturbance, and a generalized, coarse-scale measure of relative cost of conservation effort and investment. Source data and calculation of the Cost/Condition Index are described in Table 4.

2.5 Analysis framework

To create a GIS framework for site selection analysis, we divided the study area into approximately 9,200 planning units of uniform shape (hexagons) and size ($50km^2$). This layer of planning units (PUs) is shown in Figure 11. We then populated this PU framework as follows:

- identified PUs occupied by National PAs and wetland IBAs
- calculated cost/condition value of each PU by summarizing disturbance index (see Figure 11)
- calculated amount (area or count) of each ecosystem type, by PU

Table 4: *Calculation of the disturbance index: variables and source data*

Disturbance category / Map features	Calculation of disturbance index	SOURCE DATA: Origin and Date	
transportation corridors			
national roads	road density: moving window, 1 km radius	digitized from topographic maps (1:1 million)	2001
Matad Soum petroluem development	road density: moving window, 1 km radius	digitized from satellite imagery (Landsat 5 TM) at 1:250,000 scale	July 2009
railways	railway density: moving window, 1 km radius	digitized from topographic maps (1:1 million)	2001
population centers and area of impact			
Ulaanbaatar + 20 km buffer	area within moving window, 1 km radius	urban footprint digitzed from satellite imagery (Landsat 5 TM) at 1:250,000 scale	1989 - 1999
Aimags + 10 km buffer	area within moving window, 1 km radius	urban footprint digitzed from satellite imagery (Landsat 5 TM) at 1:250,000 scale	1989 - 1999
Soum centers + 5 km buffer	area within moving window, 1 km radius	MMRE May 2010	May 2010
converted land cover			
urban	urban land area within moving window, 1 km radius	Ecosystems of Mongolia (Vostokova & Gunin 2005)	1989 - 1999
agriculture	agricultural land area within moving window, 1 km radius	Ecosystems of Mongolia (Vostokova & Gunin 2005)	1989 - 1999
active mines and petroleum development			
active mines	active mine area within moving window, 1 km radius	MMRE May 2010	May 2010
petroleum well pads	well pad area within moving window, 1 km radius	digitzed from satellite imagery (Landsat 5 TM) at 1:250,000 scale (2009)	July 2009
livestock grazing			
herder camps (summer & winter)	camp density: moving window, 10 km radius	Policy Research Institute of Mongolia (2009)	date ?

Figure 10: disturbance index derived from available GIS data for infrastructure and land use.

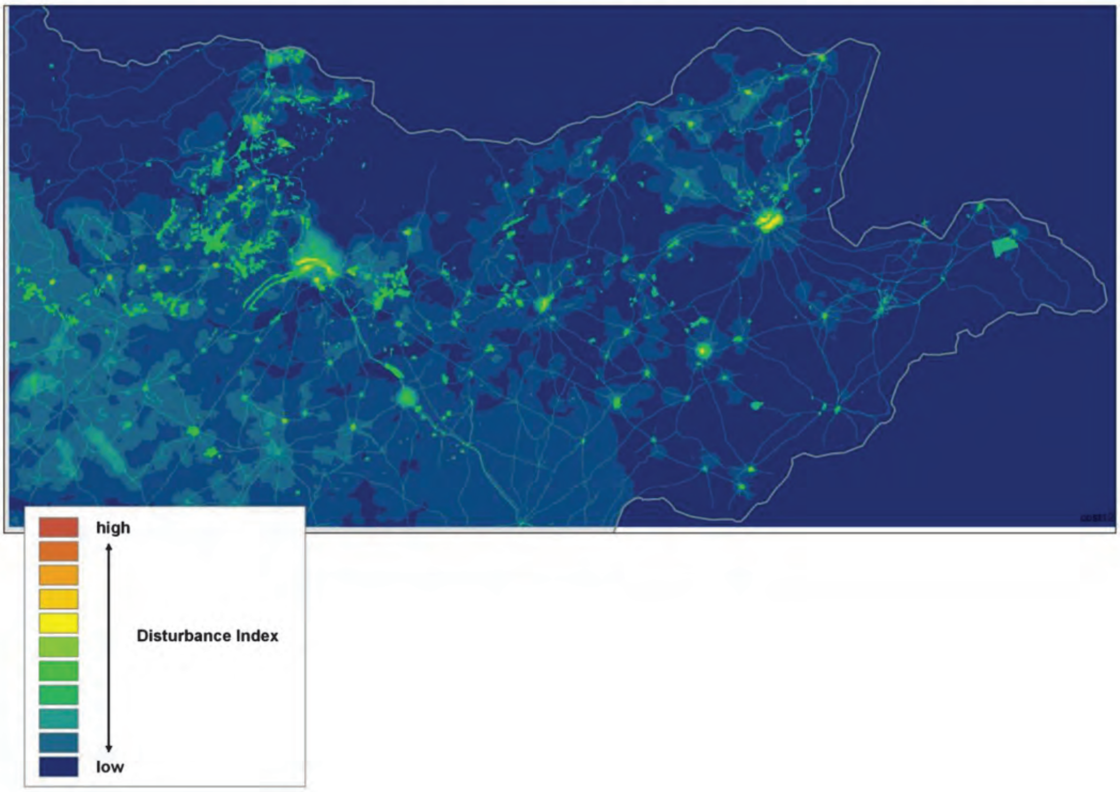
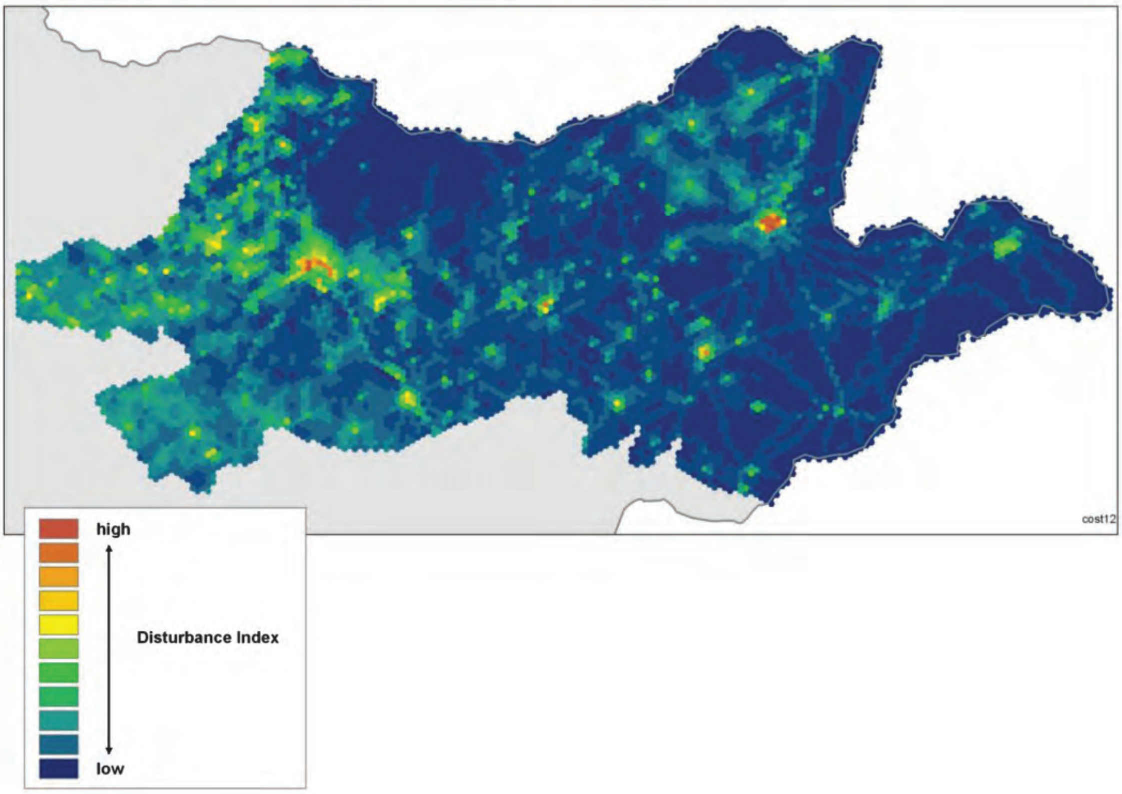


Figure 11: disturbance index summarized by hexagon planning unit



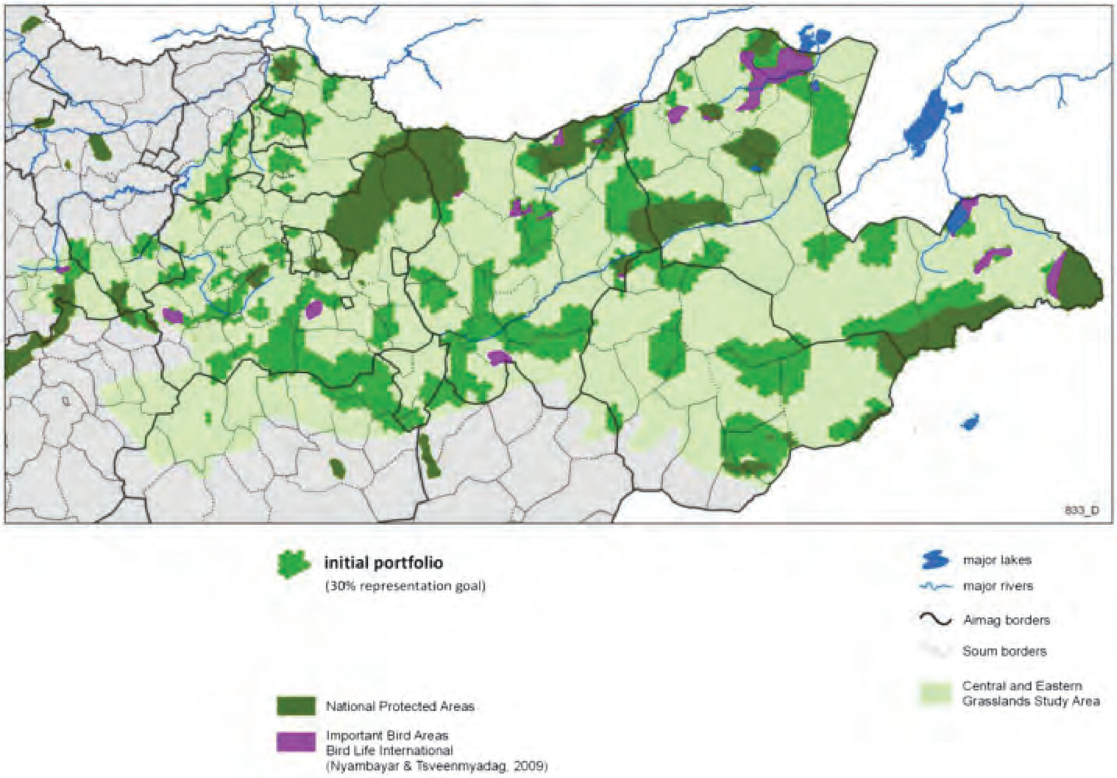
2.6 Site Selection

MARXAN is a software package developed for conservation planning that optimizes site selection to meet user-defined representation goals for biodiversity targets 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 sites. The MARXAN cost function is explained in Ball & Possingham (2000) and Game & Grantham (2008).

In this analysis, the 9,200 hexagons form the planning unit framework. The biodiversity targets are the 216 combinations of biogeographic zones, ecosystem types and landforms defined and mapped by the ecosystem classification. Planning unit cost was derived from the cost/condition index by summarizing disturbance index (see Figure 11). The National protected areas and wetland IBAs were the initial set locked into the site selection optimization, which added planning units to meet ecosystem representation goals. Through MARXAN analysis, we designed a portfolio of sites that includes the National Protected Areas and the IBA wetland complexes and meets the ecosystem representation goals while optimizing for efficiency and condition (based on the cost/condition index) and a configuration that maximizes adjacency or contagion among PUs. This initial portfolio is shown in Figure 12.

For a given set of input parameters (biodiversity targets, 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), target shortfall and boundary length. The 'best' solution is the solution with the lowest combined score relative to the other individual solutions that were 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 data representing biodiversity targets and ecological condition are always limited and incomplete, and 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 priority conservation areas



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 is a measure of relative contribution to an optimal solution, but is 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 is a measure of 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%. The result is shown in Figure 13.

Because the optimacity calculation is largely a function of the cost/condition index and MARXAN parameters, and does not measure rarity directly, we developed a second metric of the conservation value of each PU in terms of the rarity of the biodiversity targets that occur within it. This rarity calculation is based on the relative abundance of a given ecosystem type in a given PU compared to its abundance across the study area. This is a modification of the Relative Biodiversity Index, or RBI (Schill and Raber 2009), that removes the influence of the size of the planning units. 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. The result is shown in Figure 14.

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. The result is shown in Figure 15. This index of combined biological value is a component of portfolio design and the basis for identifying areas to avoid development.

Figure 13: Optimacity: relative contribution to optimal MARXAN site selection

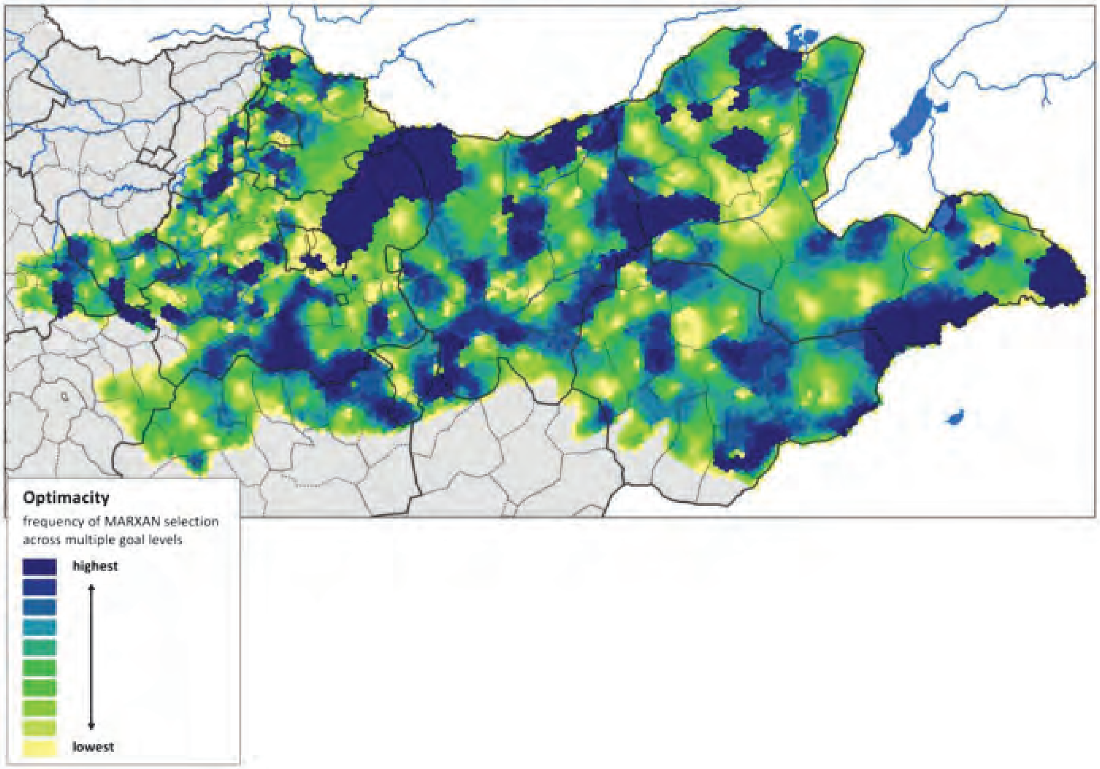


Figure 14: Rarity values for ecosystem occurrences summarized by hexagon planning unit

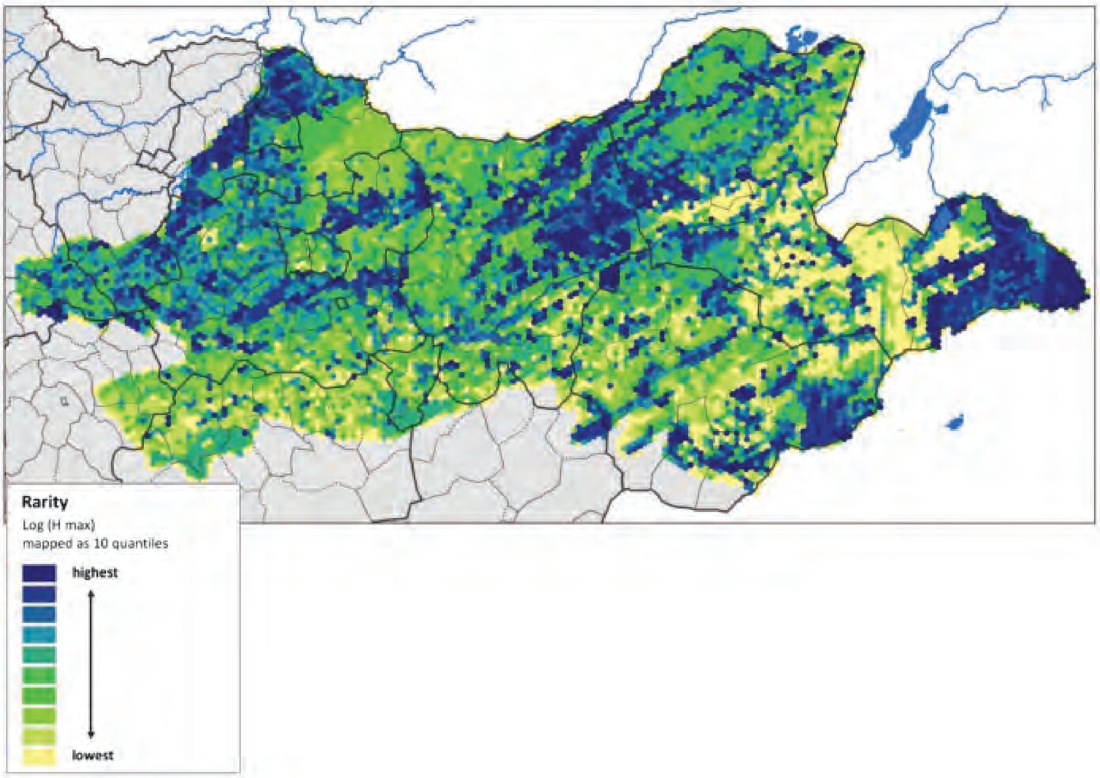
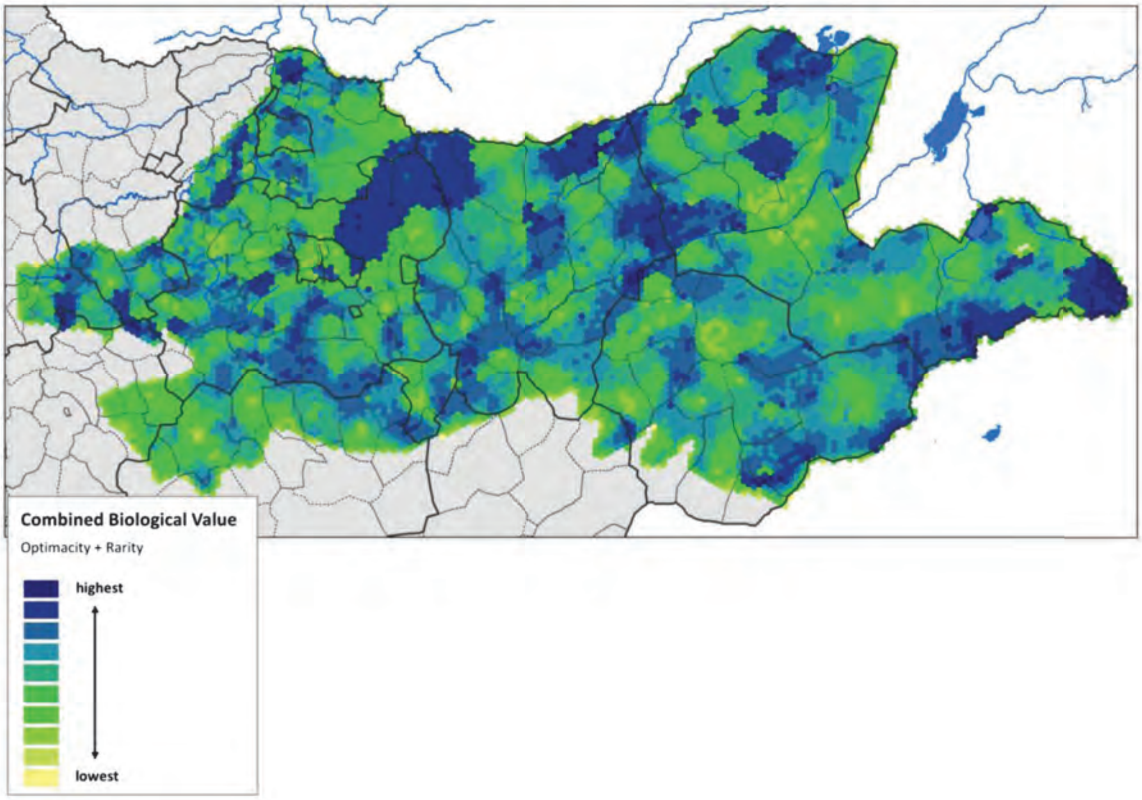


Figure 15: Index of combined conservation value: sum of optimacity + rarity



2.8 Portfolio design

To minimize conflict with planned mineral and oil development, we re-designed the initial portfolio as follows. First, we identified the portions of conservation priority areas that have been leased for exploration or development (see Figure 16). The combined area of these conflict areas was 29,800 km^2, or 21% of the portfolio and 7% of the study area. Within this set of conflict areas, we identified the PUs with conservation value in the upper 30th percentile, (22,000 km^{2}or 74% of the conflict areas) and designated these as areas of high biological value where development should be avoided (see Figure 17). The remaining PUs in conflict areas occupied an area of 7,800 km^2, or 6% of the portfolio and 2% of the study area. We replaced these remaining PUs with sites of similar composition and condition outside existing leases (see Figure 18).

The result is a re-designed portfolio that avoids mining and oil leases except in areas of high biological value (see Figures 19 and 20). The portfolio covers 147,000 km^2, or 32 % of the study area, and consists of 45 sites that range in size from 100 km^2 to 18,000 km^2. Current National Protected Areas are 29% of the portfolio area.

To confirm the accuracy of the portfolio analysis and source data, we conducted a field survey to visit and review portfolio sites in August 2010. The route covered portions of Khentii, Sukbaatar and Dornod Aimags, including Bayan Tsagaan Tal, Matad Uul, Meningiin Tal, Lower Kherlen Floodplain, Yahi Nuur, Mongol Daguur Strictly Protected Area (SPA), Tsav Jargalant Tal, Toson Hulstai Nature Reserve and the Upper Onon River. In Baruun Urt, Choibalsan, Mongol Daguur SPA and Toson Hulstai, we met and reviewed the portfolio design with officials from the Environmental

Protection Agencies and Land Use Agencies of Dornod, Khentii, Sukhbaatar provinces; and the Eastern Mongolian Protected Areas Administration and Eastern Mongolian Community Conservation Association.

Figure 16: initial portfolio and existing leases for exploration and development of mineral and petroleum resources

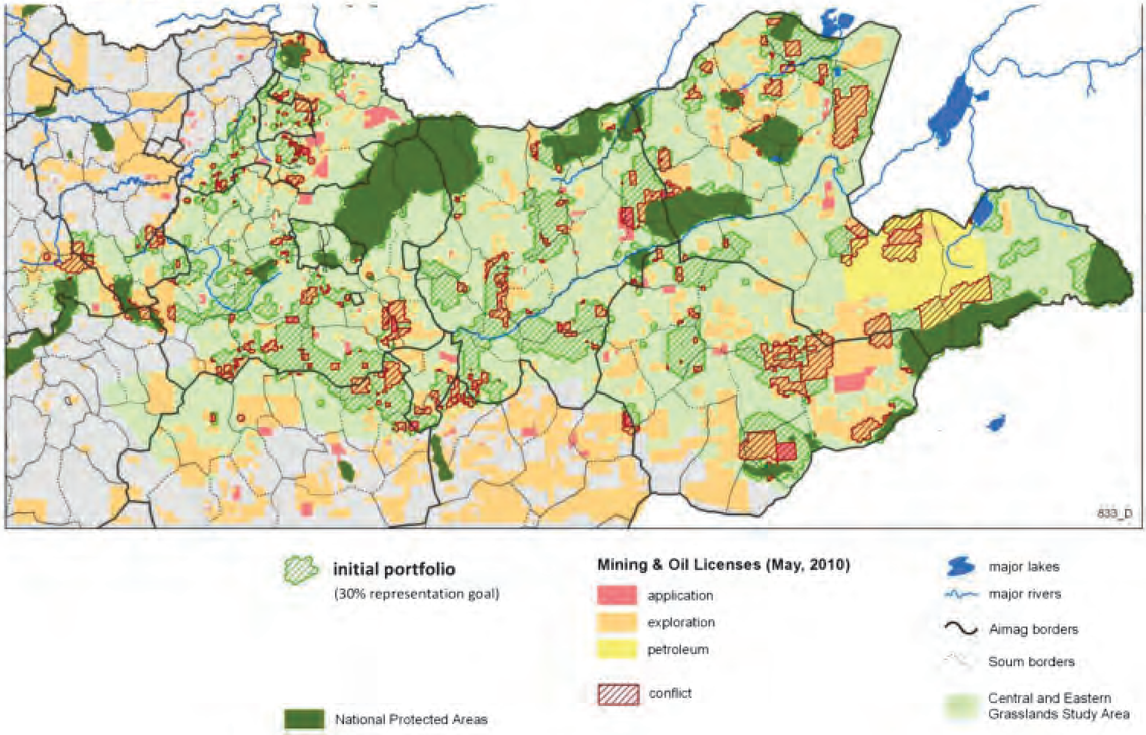


Figure 17: areas of potential conflict with mineral and petroleum development

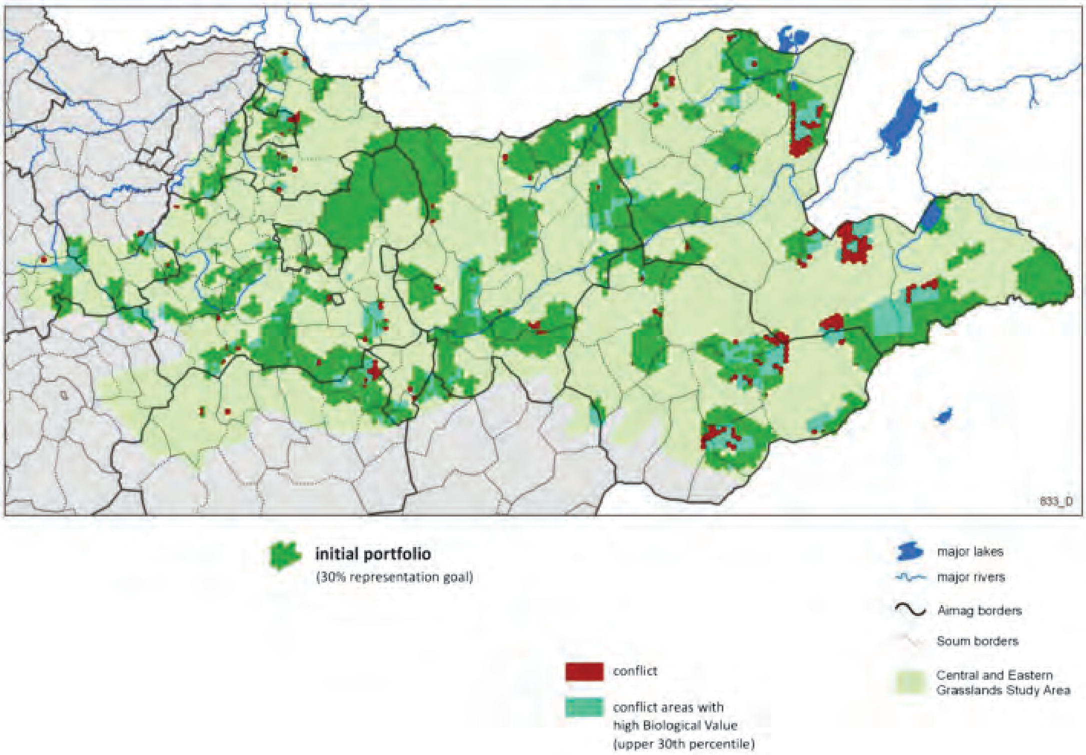


Figure 18: initial portfolio re-designed to minimize conflict with mineral and petroleum development

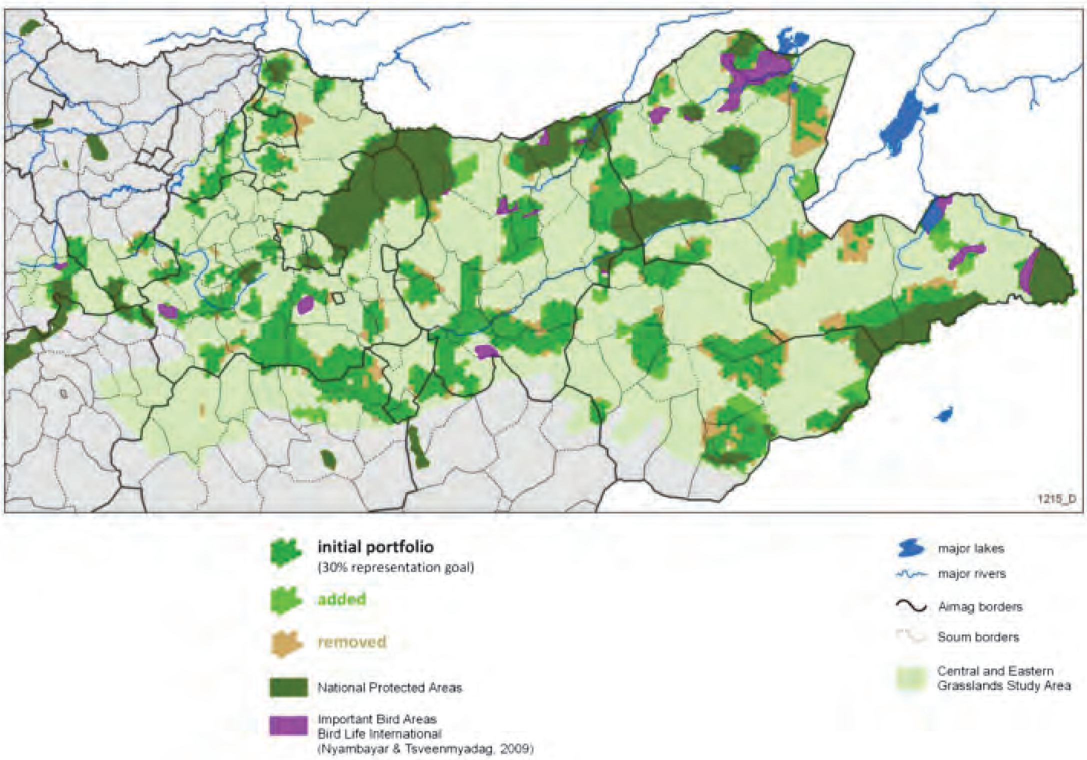


Figure 19: portfolio re-designed to minimize conflict with mineral and petroleum development

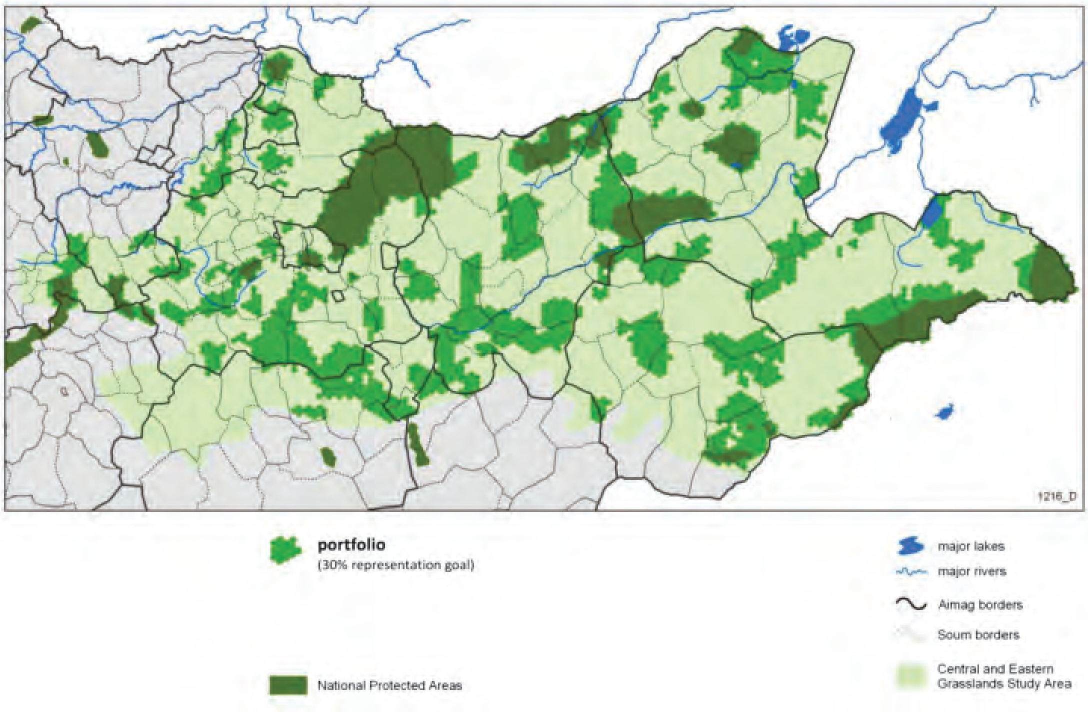
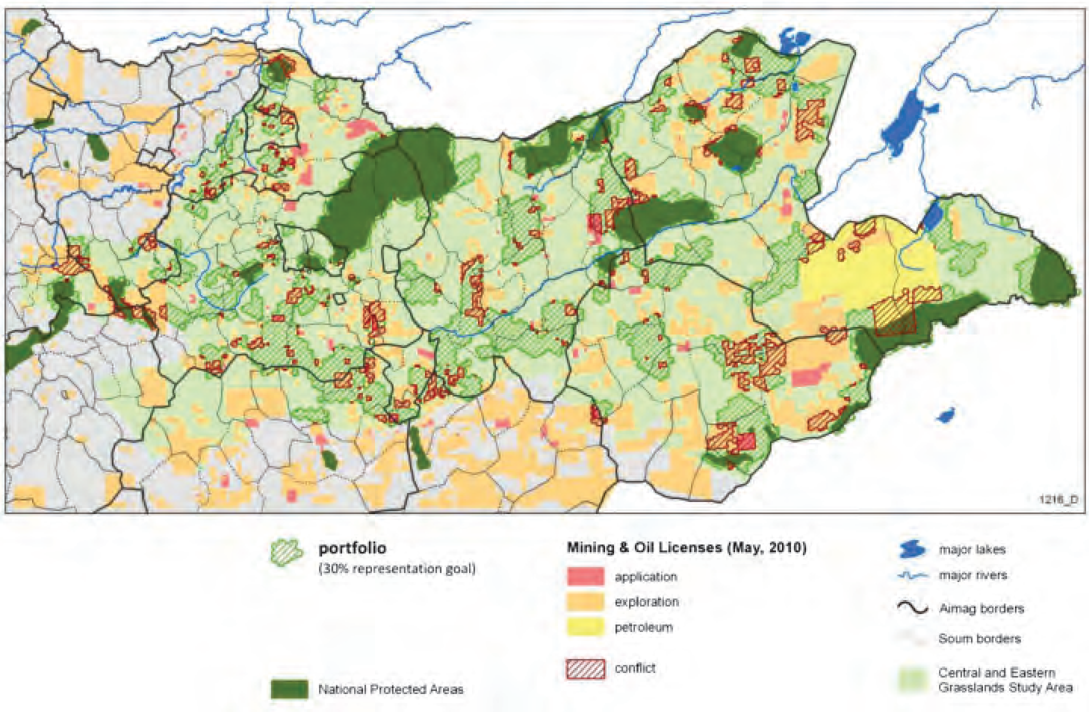


Figure 20: portfolio and remaining areas of conflict with mineral and petroleum development.



3.0 DISCUSSION

3.1 Applications to Conservation and Mitigation

This study can support sustainable development for the Eastern Steppe grasslands 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. The 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 level. Aimag land use agencies are primarily responsible for designing land management plans at intervals of 12-16 years and are responsible for implementation (Law of Mongolia on Land, 2002). At the Aimag level, this study can inform designation and management of local protected areas, including pastoral land use planning.

3.1.2. Mitigation of Mining and Energy Development

This study can support more effective mitigation decision-making for mining and oil and gas leases in the Mongolian grasslands. 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 "re-drawing" of the portfolio to re-capture habitat needed to meet biodiversity goals (Figure 19, Figure 20). However, if conservation goals cannot be met elsewhere within the study area, development should be avoided, or must minimize impacts to the degree that maintains 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.

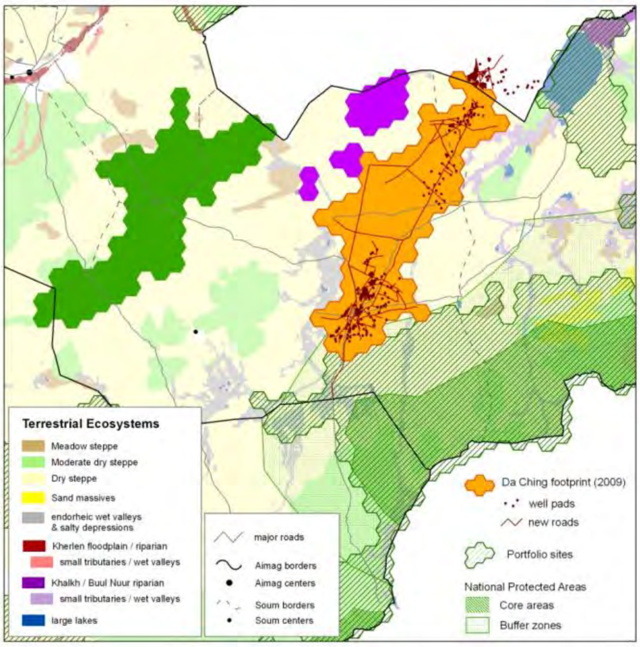
It is clear that not all development will impact all biological targets, and a simple overlap between development and target occurrence does not equate with impact. Thus, translating development into impact will need to be done on a target by target basis. This typically involves a finer scale assessment of target 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. Designing Offsets

For development projects that proceed, the next step in 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 for Mongolia's grasslands, impacts remaining after avoidance, minimization and restoration should be quantified and offset (Figure 21). Applying a goal of no-net-loss to these development areas would also provide a mechanism to achieve conservation goals by translating impacts in areas outside the portfolio to conservation in portfolio sites.

Offsets should deliver values ecologically equivalent to those lost, be located at an acceptable proximity from the impact site, and contribute to landscape conservation goals. Using the existing portfolio sites, development areas can be matched for ecological equivalency and proximity to impacts sites to ensure that offset accrue to similar ecological systems and in close proximity to where impacts will occur. 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).

Figure 21: Illustration of offset planning



Composition of potential offset sites

Ecosystem Type	AREA (km²)	
small water bodies	14	0.4%
Dry steppe | low elev. flat	1,853	50.2%
Dry steppe | low elev. hills	1,105	29.9%
Dry steppe | valley bottom	144	3.9%
wet salty depressions	117	3.2%
Meadow steppe | low elev. flat	39	1.0%
Mod. dry steppe | low elev. flat	210	5.7%
Mod. dry steppe | low elev. hills	190	5.2%
Mod. dry steppe | valley bottom	20	0.5%
	3,692	100.0%

Ecosystem Type	AREA (km²)	
small water bodies	2	0.3%
Dry steppe | low elev. flat	530	72.9%
Dry steppe | low elev. hills	80	11.0%
Dry steppe | valley bottom	25	3.5%
wet salty depressions	86	11.9%
Meadow steppe | low elev. flat	2	0.3%
Meadow steppe | low elev. hills	1	0.2%
	727	100.0%

Development footprint

Ecosystem Type	AREA (km²)	
small water bodies	5	0.1%
Dry steppe | low elev. flat	3,187	74.5%
Dry steppe | low elev. hills	507	11.8%
Dry steppe | valley bottom	164	3.8%
wet salty depressions	413	9.7%
	4,276	100.0%

3.2 Portfolio Improvement: An Adaptive Process

In a landscape that is still largely un-disturbed and un-fragmented, with impending changes in the form of rapid mineral and energy development and climate change, it is important for portfolio design to be flexible, and regularly reviewed and revised, to adapt to new threats and changes in land use, and adapt to new information. The results of this study include both a) a portfolio and b) the underlying geographic information system (GIS), which contains data describing 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 the site boundaries at the local level based on local knowledge and field surveys. For example, work is underway to delineate proposed PA boundaries around 2 portfolio sites, Tsav Jargalant Tal and Bayan Tsagaan Tal, based on local field survey.

Portfolio design is sensitive to the accuracy of the source data, and sensitive to decisions re: targets, goals, and condition index. As new data becomes available, and land use decisions change, we can and should update the portfolio, and the underlying information describing the portfolio sites. Regular review and revision is essential to the iterative, adaptive process of portfolio design. We recommend several important areas for portfolio improvement in Appendix 4. These include improving representation of species, evaluating cultural and historic sites for inclusion in the portfolio, freshwater conservation planning and incorporating functional landscape connectivity in portfolio design.

For wide-ranging species such the Mongolian Gazelle, isolated protected areas alone may not effectively conserve the current population (Mueller et al. 2008, Olson 2008, Olson et al. in review). The functional connectivity of the landscape, i.e. unrestricted movement and access to habitat, must also be maintained. Recent and planned expansion of transportation infrastructure, including fenced railways, to support mining and petroleum development present a serious, immediate threat to gazelle habitat. The portfolio design in this study considers connectivity only in terms of the size and shape of individual sites. Methods exist for evaluating the connectivity of the whole reserve network, by modeling movement and barriers between sites based on graph theory (Minor & Urban 2008; Urban & Keitt 2001; Bunn et al. 2000). However, the critical threat is the location and design of the barriers themselves.

4.0 CONCLUSION

Predictions suggest elevated pressure will be placed on natural resources as human populations grow. 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 27%, of the surface rights for mineral and petroleum exploration have been leased and 47% is available for lease. In order to balance these growing demands with biodiversity conservation, a shift from business-as-usual is clearly in order. By blending a landscape vision with the mitigation hierarchy we move away from the traditional project-by-project land use planning approach. By avoiding or minimizing impacts to irreplaceable occurrences of biological targets, using the best international standards to ensure that impacts are restored on site, and finally offsetting any remaining residual impacts, we can provide a framework 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 targets 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 habitat 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. By adopting the framework outlined here not only do we balance development with conservation but provide the structure to fund conservation commensurate with impacts from development.

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Appendix 1: Ecological descriptions of terrestrial ecosystem types

This section contains ecological descriptions of the terrestrial ecosystem types that are the basis for the ecosystem classification described in section 2.2. These 17 ecosystem types are mapped in Figures 5, 6 and 7, and listed in Table 2, which also lists source data and mapping methods.

UPLAND ECOSYSTEM TYPES

Steppe Grasslands

For upland ecosystems, our primary data source was a map developed by Vostokova and Gunin (2005). This map was was re-classified by WWF to produce a national mapped ecosystem classification (WWF 2010). The ***Dry Steppe***, ***Moderately Dry Steppe*** and ***Meadow Steppe*** compose the great grasslands of Mongolia's Eastern Steppe, together covering 80% of the study area. Characteristic animal species include Mongolian gazelle, Marmot, Great bustard, Steppe eagle, Saker falcon, Mongolian lark.

The grassland steppes have of course been heavily grazed over the centuries, and this has had serious implications for the structure, composition, and ecological function (nutrient cycling, succession, disturbance regimes) of the system. Overgrazed areas are indicated by high densities of *Cleistogenes squarrosa*, *Carex duriuscula*, and some prostrate forbs, replacing less resilient grasses. The most severe degradation could steer some sites toward complete type conversion to annual vegetation without grasses.

Dry Steppe

This grassland system occurs in flat or gently sloping valleys the lower elevations of the study area, 550 – 1200 meters above sea level. The dry steppe ecosystem forms a landscape mosaic of grass communities that are characterized by *Stipa krylovii, Stipa grandis, Agropyron cristatum, Cleistogenes squarossa, Elymus chinensis*, shrubs such as *Caragana and Anabasis* species, and forbs which are well adapted to arid conditions.

In moderately grazed areas, grass species are commonly replaced by *Artemisia*. Heavilyy grazed areas or areas recovering from droughts will be dominated by annual forbs mainly by *Chenopodium* spp, and *Bassia dasyphylla*. In closed basins, the dry steppe mosaic includes patchy salty depressions characterized by Achnatherum spp, Reamuria, Salsola, Nitraria and Allium (mainly A. scenescens A. mongolicum) at the edges. In small rolling hills, there are sparse patches of Populus, Betula, and Salix.

Moderately Dry Steppe: Like the Dry Steppe, this grassland system occurs in flat or gently sloping valleys, but at slightly higher elevations, from 550 – 1600 meters above sea level. The mosaic of plant communities include *Stipa, Festuca, Agropyron, Cleistogenes, Poa, Elymus, Koelaria* species and other grasses in shifting proportions depending on the subregion of occurrence, soil moisture, level of grazing, and other factors. One community dominated by *Filifolium sibiricum* and *Stipa baicalensis* typifies this ecosystem type in the very northeast. Another widely occurring community is typified by the tall grasses *Stipa grandis* and *Elymus chinensis*. *Caragana* shrubs shift in community importance across the steppe region, but favor drier sites and coarser soils; less dry sites share many forbs with the upland meadow steppe, and are often underlain by a darker kastanozem with a thicker, strongly organic upper horizon than drier examples.

Meadow Steppe: This meadow system often occurs at hilly landscapes at elevations just below the forest steppe, from lows of about 650 meters in the northeast of the study area, to more than 1700 meters in the south and west. Meadow Steppe represents a transition zone between forest and forest steppe systems and the vast areas of drier grasslands in the Mongolian-Manchurian Grassland Ecoregion. Broad occurrences of this system type also occur in the Pre-Khyangan foothills of eastern Mongolia and on the high hills of the upper Orkhon and Tarnyn Gol watersheds in the very west of the region. Annual precipitation, approximately 300mm, is high enough to support only small scattered occurrences of trees (Ulmus and Betulus species), but do support vegetation communities rich in forbs, sedges, and mesophytic grasses and shrubs. A relatively moister variant occurs at higher elevations and on northern slopes, and a drier variant at lower elevation and on warmer exposures with shallower soils. Festuca lenensis and F. sibirica, Poa attenuata, and Helichtotrichon schellianum are well-represented. The wide variety of forbs make this a botanically diverse system, including species from the Artemesia, Thalictrum, Aster, Polygonum, Potentilla, Carex, and Gallium genera. Some of these are characteristic of larch forests or elm bush, indicating that much of this system may well have been converted from forests by cutting and overgrazing – and that a return to a more wooded system would be possible if tree cutting and grazing were limited.

Desert Steppe: The Desert Steppe ecosystem type covers 2% of the study area at its southern edge, where it represents a transitional zone between the Mongolian-Manchurian Grassland Ecoregion and the Eastern Gobi Desert Steppe Ecoregion. This ecosystem type is characteristic of Eastern Gobi Desert Steppe Ecoregion, which lies between the Alashan Plateau Semi-Desert and the relatively moist Mongolian-Manchurian Grasslands. The vegetation tends to be homogenous, consisting of drought-adapted shrubs and thinly distributed low grasses.

For more information about Desert Steppe and the Eastern Gobi Desert Steppe Ecoregion, see http://www.worldwildlife.org/wildworld/profiles/terrestrial/pa/pa1314_full.html

Other Upland Ecosystem Types

Sand Massives**:** This dynamic sand dune system is stabilized to varying degrees by patchy embedded vegetation including willows, elm and psammophytic forbs and grasses. Species include *Filifolium sibiricum, Stipa baicalensis, koeleria mukdenesis, Cleistogenes kitagawae, Armeniaca sibirica, Ulmus japonicas, Iris dichotomoa, Hemerocallis minor, Leymus chinensis, Bupleurum sorzonerifolium, Galium verum*. Hollows formed between dunes capture significant amounts of blowing debris and can sustain moisture from trapped snow drifts – thereby providing microhabitats conducive to more mesic vegetation communities than would otherwise be found in typical dune habitats. Dunes formed by trees and shrubs essentially anchoring the sand mounds can provide essential habitat for numerous burrowing animals that rely on the structural stability provided by the root systems within the dunes.

Cinder Cones**:** Cinder cones are historic inactive volcanic vents that are distributed in a concentrated pattern of over 200 cones in the southeastern corner of the Study area in Sukhbaatar Province. Rich volcanic soils greatly increase plant diversity beyond the surrounding grassland steppe ecosystems, and support 28 botanical families, 75 genera and 180 species of both forage and medicinal plants. Cinder cones provide critical habitat for numerous small mammals, reptiles and bird species while also supporting a wide variety of predators, including wolf, foxes and raptors. Ungulates such as Argali sheep and many rodent species can be found on the cones themselves, with Gazelle and Marmots in the valley floors between them. Evidence of the importance of these formations to humans are the more than 60 “man-stones” that are distributed around the area. One cinder cone has already been designated as a Special Protected Area to protect these historic artifacts.

Boreal Forest: The following six Montane and Alpine Boreal Forest ecosystem types are described in the National Gap Assessment published by WWF (2010).

High mountain tundra

Alpine meadow and Subalpine woodland

High mountain steppe

Mountainous boreal coniferous forest

High mountain deciduous-coniferous woodland

Sub-boreal coniferous-deciduous forest

LAKE and WETLAND ECOSYSTEM TYPES

Riverine and palustrine wetlands

To map floodplains and riparian wetlands, we used a GIS topographic model that delineates potential riverine wetlands based on topography of the stream channel, as described in Section 2.2. We classified the resulting features as ***large river floodplains*** or ***small river riparian areas*** associated with smaller tributaries and ephemeral streams. We further classified the floodplains and wet riparian areas according to major river basin. In the closed endorheic basins of the southern part of the study area, we classified the wet lowland features as ***ephemerally wet valley bottoms***, which typically form salty depressions, and divided these into two bio-geographic zones, as shown in Figure 6 and described in Table 3.

Large River Floodplains: The large rivers in northeastern Mongolia, which include the Kherlen, Onon, Uldz, Khalkh and the major tributaries to the Selenge, have creating wide floodplains. Historically, these floodplains support a broadleaf forest of riverine trees and shrubs. In the absence of overgrazing by domestic livestock or physical disturbance by natural flooding or scouring, succession to gallery Salix shrubs is likely. Soils are generally cryic fluvisols and gleysols, with kastanozems that have developed in coarse and fine alluvial sediments on the lower terraces away from river banks. Species of poplar, birch, and larch are most common in the tree layer, and of willow in the shrub layer. Forbs and grasses typically associated with moist or periodically moist sites can be dense below the trees. Floodplains systems are productive, critical habitat for many terrestrial and aquatic species and critical for maintaining water quality, and are easily damaged by over-grazing, mining and infrastructure development. While hydrologic regimes remain mostly intact in the study area, in many areas livestock grazing has altered the original floodplain vegetation.

Small river riparian areas: This system forms a linear pattern of wet meadows along streams that drain into the major rivers (Kherlen, Onon, Uldz, Khalkh and the major tributaries to the Selenge). Soils are cryic gleysols or semi-gleysols, depending on the amount of available groundwater and the length of time the soil stays moist, and are predominantly alluvial, of varying textures, with high organic matter. Vegetation cover is dense and diverse and plant productivity is high with graminoids (Poa pratensis, Agrostis mongholica, Hordeum brevisubulatum, Phragmites, Carex, Eriophorum, Puccinellia, and Juncus species) and forbs (Iris, Geranium, Vicia, Ranunculus, Polygonum, Sanguisorba, and many others). Betula, larch poplar and especially Salix shrubs and small trees can also occur in the system. In the absence of overgrazing by domestic livestock or physical disturbance by natural flooding or scouring, succession to gallery Salix shrubs is likely.

Ephemerally wet depressions: In the dry, closed basins in the southern part of the study area, this system forms in low depressions where the water table is close to the surface. Salty soils support distinct plant communities and habitat. One common indicator plant community is identified by tall Achnatherum bunchgrass.

Lakes and small water bodies

To map small lakes and waterbodies, we digitized the boundaries and point locations of water bodies through manual interpretation of satellite imagery, as described in Section 2.2. We classified lakes and water bodies by river basin or biogeographic zone, as shown in Figure 7.

Large Lakes: These are the large lakes in the study area, as mapped by Vostokova and Gunin (2005). The largest examples include Buul Nuur, Yahi Nuur and Khukh Nuur. These Lakes and associated wetlands support unique aquatic biota and are critical nesting and stopover for waterbirds including the Siberian Crane (CR), White Naped Crane (VU), Hooded Crane (VU), Swan Goose (VU), Great Bustard and Relict Gull (VU) (Nyambayar & Tsveenmyadag 2009).

Small lakes and water bodies: In the dry closed basins in the southern part of the study area, these small waterbodies are often saline or alkaline. Like large lakes, these water bodies and associated wetlands typically support distinct aquatic biota and are critical nesting and stopover habitat for waterbirds.

Appendix 2: Biodiversity targets, representation goals and portfolio composition

ECOSYSTEM CLASSIFICATION				AMOUNT			
code	biogeographic region	ecosystem type	landform	Total	Goal	Portfolio	unit
UPLAND ECOSYSTEM TYPES: Steppe Grasslands							
1904911	DFS - Uldzin	Dry steppe	N. aspect, very steep	16	5	5	area (km^2)
1904912	DFS - Uldzin	Dry steppe	N. aspect, slope	223	67	68	area (km^2)
1904914	DFS - Uldzin	Dry steppe	low(er) elev. flat	90	27	54	area (km^2)
1904915	DFS - Uldzin	Dry steppe	low(er) elev. rolling hills	705	212	239	area (km^2)
1904916	DFS - Uldzin	Dry steppe	S. aspect, slope	182	55	61	area (km^2)
1904917	DFS - Uldzin	Dry steppe	high(er) elev. upland	266	80	83	area (km^2)
1904918	DFS - Uldzin	Dry steppe	high(er) elev. depression	511	153	176	area (km^2)
1904919	DFS - Uldzin	Dry steppe	valley bottom / watertrack	70	21	30	area (km^2)
1913431	MMG - Mandal-Gobi	Dry steppe	N. aspect, very steep	43	13	13	area (km^2)
1913432	MMG - Mandal-Gobi	Dry steppe	N. aspect, slope	480	144	184	area (km^2)
1913436	MMG - Mandal-Gobi	Dry steppe	S. aspect, slope	363	109	145	area (km^2)
1913437	MMG - Mandal-Gobi	Dry steppe	high(er) elev. upland	19,258	5,777	5,779	area (km^2)
1913438	MMG - Mandal-Gobi	Dry steppe	high(er) elev. depression	9,943	2,983	2,986	area (km^2)
1913439	MMG - Mandal-Gobi	Dry steppe	valley bottom / watertrack	342	103	104	area (km^2)
1913712	MMG - Pre- Khingan	Dry steppe	N. aspect, slope	12	4	9	area (km^2)
1913714	MMG - Pre- Khingan	Dry steppe	low(er) elev. flat	1,198	359	374	area (km^2)
1913715	MMG - Pre- Khingan	Dry steppe	low(er) elev. rolling hills	712	214	332	area (km^2)
1913716	MMG - Pre- Khingan	Dry steppe	S. aspect, slope	4	1	3	area (km^2)
1913719	MMG - Pre- Khingan	Dry steppe	valley bottom / watertrack	72	22	27	area (km^2)
1913911	MMG - Menengiin Tal	Dry steppe	N. aspect, very steep	4	1	3	area (km^2)
1913912	MMG - Menengiin Tal	Dry steppe	N. aspect, slope	381	114	115	area (km^2)
1913914	MMG - Menengiin Tal	Dry steppe	low(er) elev. flat	24,201	7,260	7,263	area (km^2)
1913915	MMG - Menengiin Tal	Dry steppe	low(er) elev. rolling hills	18,480	5,544	5,785	area (km^2)
1913916	MMG - Menengiin Tal	Dry steppe	S. aspect, slope	231	69	83	area (km^2)
1913917	MMG - Menengiin Tal	Dry steppe	high(er) elev. upland	178	53	68	area (km^2)
1913918	MMG - Menengiin Tal	Dry steppe	high(er) elev. depression	1,013	304	363	area (km^2)
1913919	MMG - Menengiin Tal	Dry steppe	valley bottom / watertrack	1,854	556	588	area (km^2)
1913921	MMG - Middle Kherlen	Dry steppe	N. aspect, very steep	36	11	12	area (km^2)
1913922	MMG - Middle Kherlen	Dry steppe	N. aspect, slope	1,925	577	606	area (km^2)
1913924	MMG - Middle Kherlen	Dry steppe	low(er) elev. flat	1,462	439	442	area (km^2)
1913925	MMG - Middle Kherlen	Dry steppe	low(er) elev. rolling hills	12,708	3,812	3,818	area (km^2)
1913926	MMG - Middle Kherlen	Dry steppe	S. aspect, slope	1,451	435	438	area (km^2)
1913927	MMG - Middle Kherlen	Dry steppe	high(er) elev. upland	13,885	4,165	4,166	area (km^2)
1913928	MMG - Middle Kherlen	Dry steppe	high(er) elev. depression	15,918	4,776	4,778	area (km^2)
1913929	MMG - Middle Kherlen	Dry steppe	valley bottom / watertrack	1,287	386	386	area (km^2)
1804221	DFS - Tola-Onon	Moderate dry steppe	N. aspect, very steep	152	45	46	area (km^2)
1804222	DFS - Tola-Onon	Moderate dry steppe	N. aspect, slope	443	133	158	area (km^2)
1804225	DFS - Tola-Onon	Moderate dry steppe	low(er) elev. rolling hills	138	42	61	area (km^2)
1804226	DFS - Tola-Onon	Moderate dry steppe	S. aspect, slope	467	140	171	area (km^2)
1804227	DFS - Tola-Onon	Moderate dry steppe	high(er) elev. upland	1,397	419	421	area (km^2)
1804228	DFS - Tola-Onon	Moderate dry steppe	high(er) elev. depression	1,125	337	382	area (km^2)
1804229	DFS - Tola-Onon	Moderate dry steppe	valley bottom / watertrack	50	15	17	area (km^2)
1804421	DFS - Dharkhan	Moderate dry steppe	N. aspect, very steep	778	234	236	area (km^2)
1804422	DFS - Dharkhan	Moderate dry steppe	N. aspect, slope	2,601	780	782	area (km^2)
1804424	DFS - Dharkhan	Moderate dry steppe	low(er) elev. flat	618	186	187	area (km^2)
1804425	DFS - Dharkhan	Moderate dry steppe	low(er) elev. rolling hills	2,506	752	753	area (km^2)

MMG = Mongolia-Manchurian Grasslands; DFS= Daurian Forest Steppe; TBBF = Trans-Baikal Boreal Forest

ECOSYSTEM CLASSIFICATION				AMOUNT			
code	biogeographic region	ecosystem type	landform	Total	Goal	Portfolio	unit
UPLAND ECOSYSTEM TYPES: <u>Steppe Grasslands</u> (continued)							
1804426	DFS - Dharkhan	Moderate dry steppe	S. aspect, slope	2,538	761	781	area (km²)
1804427	DFS - Dharkhan	Moderate dry steppe	high(er) elev. upland	2,699	810	823	area (km²)
1804428	DFS - Dharkhan	Moderate dry steppe	high(er) elev. depression	1,745	523	527	area (km²)
1804429	DFS - Dharkhan	Moderate dry steppe	valley bottom / watertrack	194	58	59	area (km²)
1804911	DFS - Uldzin	Moderate dry steppe	N. aspect, very steep	36	11	12	area (km²)
1804912	DFS - Uldzin	Moderate dry steppe	N. aspect, slope	721	216	218	area (km²)
1804914	DFS - Uldzin	Moderate dry steppe	low(er) elev. flat	2,139	642	775	area (km²)
1804915	DFS - Uldzin	Moderate dry steppe	low(er) elev. rolling hills	5,159	1,548	1,739	area (km²)
1804916	DFS - Uldzin	Moderate dry steppe	S. aspect, slope	635	190	202	area (km²)
1804917	DFS - Uldzin	Moderate dry steppe	high(er) elev. upland	473	142	156	area (km²)
1804918	DFS - Uldzin	Moderate dry steppe	high(er) elev. depression	620	186	192	area (km²)
1804919	DFS - Uldzin	Moderate dry steppe	valley bottom / watertrack	307	92	95	area (km²)
1813421	MMG - Orkhon	Moderate dry steppe	N. aspect, very steep	167	50	53	area (km²)
1813422	MMG - Orkhon	Moderate dry steppe	N. aspect, slope	1,199	360	389	area (km²)
1813424	MMG - Orkhon	Moderate dry steppe	low(er) elev. flat	221	66	72	area (km²)
1813425	MMG - Orkhon	Moderate dry steppe	low(er) elev. rolling hills	1,442	433	435	area (km²)
1813426	MMG - Orkhon	Moderate dry steppe	S. aspect, slope	945	284	298	area (km²)
1813427	MMG - Orkhon	Moderate dry steppe	high(er) elev. upland	2,602	781	814	area (km²)
1813428	MMG - Orkhon	Moderate dry steppe	high(er) elev. depression	1,558	467	480	area (km²)
1813429	MMG - Orkhon	Moderate dry steppe	valley bottom / watertrack	87	26	26	area (km²)
1813431	MMG - Mandal-Gobi	Moderate dry steppe	N. aspect, very steep	211	63	64	area (km²)
1813432	MMG - Mandal-Gobi	Moderate dry steppe	N. aspect, slope	1,087	326	342	area (km²)
1813436	MMG - Mandal-Gobi	Moderate dry steppe	S. aspect, slope	864	259	267	area (km²)
1813437	MMG - Mandal-Gobi	Moderate dry steppe	high(er) elev. upland	14,693	4,408	4,412	area (km²)
1813438	MMG - Mandal-Gobi	Moderate dry steppe	high(er) elev. depression	5,801	1,740	1,778	area (km²)
1813439	MMG - Mandal-Gobi	Moderate dry steppe	valley bottom / watertrack	205	62	62	area (km²)
1813711	MMG - Pre- Khingan	Moderate dry steppe	N. aspect, very steep	1	0	0	area (km²)
1813712	MMG - Pre- Khingan	Moderate dry steppe	N. aspect, slope	76	23	27	area (km²)
1813714	MMG - Pre- Khingan	Moderate dry steppe	low(er) elev. flat	1,542	463	497	area (km²)
1813715	MMG - Pre- Khingan	Moderate dry steppe	low(er) elev. rolling hills	1,680	504	752	area (km²)
1813716	MMG - Pre- Khingan	Moderate dry steppe	S. aspect, slope	40	12	13	area (km²)
1813718	MMG - Pre- Khingan	Moderate dry steppe	high(er) elev. depression	1	0	0	area (km²)
1813719	MMG - Pre- Khingan	Moderate dry steppe	valley bottom / watertrack	160	48	55	area (km²)
1813911	MMG - Menengiin Tal	Moderate dry steppe	N. aspect, very steep	36	11	17	area (km²)
1813912	MMG - Menengiin Tal	Moderate dry steppe	N. aspect, slope	1,405	422	495	area (km²)
1813914	MMG - Menengiin Tal	Moderate dry steppe	low(er) elev. flat	10,207	3,062	3,062	area (km²)
1813915	MMG - Menengiin Tal	Moderate dry steppe	low(er) elev. rolling hills	14,100	4,230	4,236	area (km²)
1813916	MMG - Menengiin Tal	Moderate dry steppe	S. aspect, slope	1,099	330	364	area (km²)
1813917	MMG - Menengiin Tal	Moderate dry steppe	high(er) elev. upland	1,520	456	456	area (km²)
1813918	MMG - Menengiin Tal	Moderate dry steppe	high(er) elev. depression	1,115	335	352	area (km²)
1813919	MMG - Menengiin Tal	Moderate dry steppe	valley bottom / watertrack	935	280	281	area (km²)
1813921	MMG - Middle Kherlen	Moderate dry steppe	N. aspect, very steep	70	21	24	area (km²)
1813922	MMG - Middle Kherlen	Moderate dry steppe	N. aspect, slope	1,973	592	635	area (km²)
1813924	MMG - Middle Kherlen	Moderate dry steppe	low(er) elev. flat	867	260	262	area (km²)
1813925	MMG - Middle Kherlen	Moderate dry steppe	low(er) elev. rolling hills	5,559	1,668	1,668	area (km²)
1813926	MMG - Middle Kherlen	Moderate dry steppe	S. aspect, slope	1,521	456	458	area (km²)
1813927	MMG - Middle Kherlen	Moderate dry steppe	high(er) elev. upland	5,329	1,599	1,606	area (km²)
1813928	MMG - Middle Kherlen	Moderate dry steppe	high(er) elev. depression	4,095	1,229	1,229	area (km²)
1813929	MMG - Middle Kherlen	Moderate dry steppe	valley bottom / watertrack	423	127	140	area (km²)

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ECOSYSTEM CLASSIFICATION				AMOUNT			
code	biogeographic region	ecosystem type	landform	Total	Goal	Portfolio	unit
UPLAND ECOSYSTEM TYPES: Steppe Grasslands (continued)							
1704221	DFS - Tola-Onon	Meadow steppe	N. aspect, very steep	1,739	522	541	area (km^2)
1704222	DFS - Tola-Onon	Meadow steppe	N. aspect, slope	3,663	1,099	1,127	area (km^2)
1704224	DFS - Tola-Onon	Meadow steppe	low(er) elev. flat	100	30	65	area (km^2)
1704225	DFS - Tola-Onon	Meadow steppe	low(er) elev. rolling hills	784	235	243	area (km^2)
1704226	DFS - Tola-Onon	Meadow steppe	S. aspect, slope	4,458	1,337	1,338	area (km^2)
1704227	DFS - Tola-Onon	Meadow steppe	high(er) elev. upland	6,602	1,981	1,997	area (km^2)
1704228	DFS - Tola-Onon	Meadow steppe	high(er) elev. depression	2,575	773	778	area (km^2)
1704229	DFS - Tola-Onon	Meadow steppe	valley bottom / watertrack	156	47	53	area (km^2)
1704421	DFS - Dharkhan	Meadow steppe	N. aspect, very steep	652	196	201	area (km^2)
1704422	DFS - Dharkhan	Meadow steppe	N. aspect, slope	1,700	510	522	area (km^2)
1704424	DFS - Dharkhan	Meadow steppe	low(er) elev. flat	348	104	105	area (km^2)
1704425	DFS - Dharkhan	Meadow steppe	low(er) elev. rolling hills	1,245	373	389	area (km^2)
1704426	DFS - Dharkhan	Meadow steppe	S. aspect, slope	1,778	533	587	area (km^2)
1704427	DFS - Dharkhan	Meadow steppe	high(er) elev. upland	1,784	535	547	area (km^2)
1704428	DFS - Dharkhan	Meadow steppe	high(er) elev. depression	644	193	194	area (km^2)
1704429	DFS - Dharkhan	Meadow steppe	valley bottom / watertrack	71	21	24	area (km^2)
1704911	DFS - Uldzin	Meadow steppe	N. aspect, very steep	312	93	125	area (km^2)
1704912	DFS - Uldzin	Meadow steppe	N. aspect, slope	3,159	948	955	area (km^2)
1704914	DFS - Uldzin	Meadow steppe	low(er) elev. flat	2,081	624	829	area (km^2)
1704915	DFS - Uldzin	Meadow steppe	low(er) elev. rolling hills	7,735	2,320	2,355	area (km^2)
1704916	DFS - Uldzin	Meadow steppe	S. aspect, slope	2,865	859	862	area (km^2)
1704917	DFS - Uldzin	Meadow steppe	high(er) elev. upland	1,574	472	486	area (km^2)
1704918	DFS - Uldzin	Meadow steppe	high(er) elev. depression	1,412	424	432	area (km^2)
1704919	DFS - Uldzin	Meadow steppe	valley bottom / watertrack	379	114	123	area (km^2)
1709001	TBBF	Meadow steppe	N. aspect, very steep	517	155	337	area (km^2)
1709002	TBBF	Meadow steppe	N. aspect, slope	803	241	444	area (km^2)
1709004	TBBF	Meadow steppe	low(er) elev. flat	44	13	17	area (km^2)
1709005	TBBF	Meadow steppe	low(er) elev. rolling hills	444	133	323	area (km^2)
1709006	TBBF	Meadow steppe	S. aspect, slope	984	295	544	area (km^2)
1709007	TBBF	Meadow steppe	high(er) elev. upland	687	206	330	area (km^2)
1709008	TBBF	Meadow steppe	high(er) elev. depression	403	121	234	area (km^2)
1709009	TBBF	Meadow steppe	valley bottom / watertrack	59	18	34	area (km^2)
1713421	MMG - Orkhon	Meadow steppe	N. aspect, very steep	669	201	213	area (km^2)
1713422	MMG - Orkhon	Meadow steppe	N. aspect, slope	1,974	592	595	area (km^2)
1713424	MMG - Orkhon	Meadow steppe	low(er) elev. flat	84	25	28	area (km^2)
1713425	MMG - Orkhon	Meadow steppe	low(er) elev. rolling hills	760	228	228	area (km^2)
1713426	MMG - Orkhon	Meadow steppe	S. aspect, slope	1,724	517	520	area (km^2)
1713427	MMG - Orkhon	Meadow steppe	high(er) elev. upland	5,418	1,625	1,670	area (km^2)
1713428	MMG - Orkhon	Meadow steppe	high(er) elev. depression	2,251	675	683	area (km^2)
1713429	MMG - Orkhon	Meadow steppe	valley bottom / watertrack	75	23	24	area (km^2)
1713431	MMG - Mandal-Gobi	Meadow steppe	N. aspect, very steep	209	63	81	area (km^2)
1713432	MMG - Mandal-Gobi	Meadow steppe	N. aspect, slope	756	227	274	area (km^2)
1713436	MMG - Mandal-Gobi	Meadow steppe	S. aspect, slope	706	212	255	area (km^2)
1713437	MMG - Mandal-Gobi	Meadow steppe	high(er) elev. upland	6,638	1,991	2,025	area (km^2)
1713438	MMG - Mandal-Gobi	Meadow steppe	high(er) elev. depression	2,515	754	773	area (km^2)
1713439	MMG - Mandal-Gobi	Meadow steppe	valley bottom / watertrack	132	39	40	area (km^2)
1713711	MMG - Pre- Khingan	Meadow steppe	N. aspect, very steep	100	30	83	area (km^2)
1713712	MMG - Pre- Khingan	Meadow steppe	N. aspect, slope	1,010	303	720	area (km^2)
1713714	MMG - Pre- Khingan	Meadow steppe	low(er) elev. flat	1,213	364	412	area (km^2)
1713715	MMG - Pre- Khingan	Meadow steppe	low(er) elev. rolling hills	2,720	816	1,290	area (km^2)

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ECOSYSTEM CLASSIFICATION				AMOUNT			
code	biogeographic region	ecosystem type	landform	Total	Goal	Portfolio	unit
UPLAND ECOSYSTEM TYPES: Steppe Grasslands (continued)							
1713716	MMG - Pre- Khingan	Meadow steppe	S. aspect, slope	888	266	642	area (km²)
1713717	MMG - Pre- Khingan	Meadow steppe	high(er) elev. upland	244	73	242	area (km²)
1713718	MMG - Pre- Khingan	Meadow steppe	high(er) elev. depression	265	80	248	area (km²)
1713719	MMG - Pre- Khingan	Meadow steppe	valley bottom / watertrack	199	60	98	area (km²)
1713912	MMG - Menengiin Tal	Meadow steppe	N. aspect, slope	63	19	25	area (km²)
1713914	MMG - Menengiin Tal	Meadow steppe	low(er) elev. flat	2,405	721	737	area (km²)
1713915	MMG - Menengiin Tal	Meadow steppe	low(er) elev. rolling hills	1,799	540	540	area (km²)
1713916	MMG - Menengiin Tal	Meadow steppe	S. aspect, slope	56	17	29	area (km²)
1713919	MMG - Menengiin Tal	Meadow steppe	valley bottom / watertrack	187	56	56	area (km²)
1713921	MMG - Middle Kherlen	Meadow steppe	N. aspect, very steep	26	8	14	area (km²)
1713922	MMG - Middle Kherlen	Meadow steppe	N. aspect, slope	210	63	92	area (km²)
1713924	MMG - Middle Kherlen	Meadow steppe	low(er) elev. flat	232	70	70	area (km²)
1713925	MMG - Middle Kherlen	Meadow steppe	low(er) elev. rolling hills	812	244	252	area (km²)
1713926	MMG - Middle Kherlen	Meadow steppe	S. aspect, slope	198	59	94	area (km²)
1713927	MMG - Middle Kherlen	Meadow steppe	high(er) elev. upland	420	126	130	area (km²)
1713928	MMG - Middle Kherlen	Meadow steppe	high(er) elev. depression	546	164	173	area (km²)
173929	MMG - Middle Kherlen	Meadow steppe	valley bottom / watertrack	101	30	35	area (km²)
313430	MMG - Mandal-Gobi	Desert steppe		1,821	546	549	area (km²)
313920	MMG - Middle Kherlen	Desert steppe		567	170	170	area (km²)
UPLAND ECOSYSTEM TYPES: Other Upland Ecosystem Types							
1104420	DFS - Dharkhan	Sand massives		40	12	15	area (km²)
1113420	MMG - Orkhon	Sand massives		71	21	26	area (km²)
1113710	MMG - Pre- Khingan	Sand massives		423	127	130	area (km²)
1113910	MMG - Menengiin Tal	Sand massives		25	7	9	area (km²)
1113920	MMG - Middle Kherlen	Sand massives		244	73	114	area (km²)
1000000		Cinder cones		33	10	24	area (km²)
UPLAND ECOSYSTEM TYPES: Boreal Forest							
200000		High mountain tundra		266	80	263	area (km²)
1200000		Alpine meadow and Subalpine woodland		716	215	597	area (km²)
1300000		High mountain steppe		113	34	55	area (km²)
1400000		Mountainous boreal coniferous forest		3,900	1,170	2,327	area (km²)
1500000		High mountain deciduous-coniferous woodland		94	28	64	area (km²)
1604220	DFS - Tola-Onon	Sub-boreal coniferous-deciduous forest		2,103	631	635	area (km²)
1604420	DFS - Dharkhan	Sub-boreal coniferous-deciduous forest		1,099	330	332	area (km²)
1604910	DFS - Uldzin	Sub-boreal coniferous-deciduous forest		139	42	42	area (km²)
1609000	TBBF	Sub-boreal coniferous-deciduous forest		2,683	805	806	area (km²)
1613420	MMG - Orkhon	Sub-boreal coniferous-deciduous forest		82	25	28	area (km²)
1613710	MMG - Pre- Khingan	Sub-boreal coniferous-deciduous forest		210	63	208	area (km²)

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	ECOSYSTEM CLASSIFICATION		AMOUNT			
code	biogeographic region	ecosystem type	Total	Goal	Portfolio	unit
LAKE and WETLAND ECOSYSTEM TYPES						
Riverine and palustrine wetlands						
2100000	Selinge River Basin	large river floodplain	4,019	1,206	1,267	area (km^2)
2200000	Selinge River Basin	small stream riparian	2,200	660	742	area (km^2)
3100000	Onon River Basin	large river floodplain	1,384	415	691	area (km^2)
3200000	Onon River Basin	small stream riparian	919	276	401	area (km^2)
4100000	Kherlen River Basin	large river floodplain	3,104	931	994	area (km^2)
4200000	Kherlen River Basin	small stream riparian	2,775	832	845	area (km^2)
5100000	Uldz River Basin	large river floodplain	721	216	310	area (km^2)
5200000	Uldz River Basin	small stream riparian	1,518	455	546	area (km^2)
6100000	Khalkh River Basin	large river floodplain	792	238	324	area (km^2)
6200000	Khalkh River Basin	small stream riparian	1,878	563	564	area (km^2)
7200000	Gal Tuul River Basin	small stream riparian	977	293	303	area (km^2)
8200000	Matad East	wet depressions	2,866	860	883	area (km^2)
9200000	other	wet depressions	3,701	1,110	1,127	area (km^2)
Lakes and small water bodies						
310	NE Dornod	water bodies	141	43	74	point locs.
320	Selinge	water bodies	96	29	41	point locs.
330	Onon	water bodies	41	13	26	point locs.
340	Kherlen	water bodies	169	51	106	point locs.
350	Uldz	water bodies	112	34	131	point locs.
360	Buul Nuur	water bodies	70	22	57	point locs.
370	Gal	water bodies	81	25	25	point locs.
380	Matad east	water bodies	68	21	43	point locs.
391	Khalkha	water bodies	268	81	168	point locs.
392	Middle Kkalkha	water bodies	146	44	62	point locs.
393	Matad North	water bodies	99	30	50	point locs.
3100	NE Dornod	large lakes	260	78	149	area (km^2)
3200	Selinge	large lakes	49	15	29	area (km^2)
3300	Onon	large lakes	10	3	7	area (km^2)
3400	Kherlen	large lakes	73	22	31	area (km^2)
3500	Uldz	large lakes	107	32	91	area (km^2)
3600	Buul Nuur	large lakes	691	207	576	area (km^2)
3700	Gal	large lakes	186	56	133	area (km^2)
3800	Matad east	large lakes	55	16	17	area (km^2)
3910	Khalkha	large lakes	56	17	17	area (km^2)
3920	Middle Kkalkha	large lakes	56	17	22	area (km^2)
3930	Matad North	large lakes	36	11	19	area (km^2)

APPENDIX 3: Next steps in progress

Offset Planning (compensatory mitigation) - see section 3.1.3. This will demonstrate how current information can be used to guide the use of offsets. See Figure 21 for example.

Portfolio site classification: Classification of portfolio sites according to protection status, threat and recommended conservation strategy.

- i. protected area status
  1. National
  2. Local PAs
- ii. other priority-setting efforts
  1. IBAs
  2. 1996 Biodiversity Action Plan
- iii. Threat from mining and petroleum development
  1. existing leases
  2. strategic mineral/petroleum resources
  3. avoid areas
- iv. Threat from grazing
  1. grazing suitability analysis
     a. grazing pressure (current)
     b. grass bank potential

Grazing management: Compare regional patterns of livestock density and grassland productivity (MODIS 2010) to identify:

a. possible overgrazing

b. possible grass banks (emergency forage). A recent study in the Gobi Desert by Hess et al (2011) suggests that in drought years, PAs can provide emergency forage or grass banks for herders, if effectively managed for that purpose.

c. within portfolio sites, areas in need of grazing management (per a.) and potential for grass banks (per b.)

d. impacts of climate change, specifically areas that may experience the combined impact of overgrazing and decreased productivity due to drying trend.

Watershed protection designations: Develop information to support implementation of the headwaters protection law.

a. identify "water towers" i.e headwater watersheds that produce the majority of runoff in the Kherlen, Onon and Selinge River Basins, based on global gridded runoff models (Fekete et al. 2002).

b. map active floodplain and riparian areas of rivers in the study area. Floodplains and riparian areas are productive, critical habitat for many terrestrial and aquatic species and critical for maintaining water quality, and are easily damaged by over-grazing, mining and infrastructure development.

c. estimate potential impacts of climate change to runoff and river discharge based on global climate forecasts and global gridded runoff models.

APPENDIX 4: Limitations of this study and recommendations for improvement

Portfolio Design

Biodiversity Targets

The mapped classification of ecosystems provides a spatially consistent and comprehensive representation of habitat and ecological process patterns across the study area. With this information, we can evaluate a variety of portfolio designs to meet representation goals. The classification is not intended to predict species composition and distribution, as species respond to environmental patterns and processes differently and at different scales. Rather, it is intended to describe and map the variety of environmental patterns and processes that influence the formation and maintenance of habitat and distributions of biota at multiple scales.

Because the ecosystem classification was stratified across major environmental and biogeographic patterns, and at a finer scale by landforms, the resulting portfolio includes areas that we assume support a broad range of common and representative biodiversity, based on a coarse-filter strategy (Hunter *et al.*, 1988; Hunter, 1991; Groves *et al* 2002). Thus, the ecosystem classification plays important role in representing the range of habitat, environmental gradients and ecological processes characteristic of the study area. Given the uncertainty of how species will respond to climate change, setting conservation goals for the range of geophysical settings is a means of representing the underlying physical template for species distributions and biogeography (Anderson and Ferree 2010, Beier and Brost 2010).

The landform classification functioned well as a practical way to capture variation in plant communities within the matrix-forming ecosystem types, and to represent the range of environmental gradients. By using a cluster analysis of several topographic indices, rather than landforms defined a priori, we were able to define a small, practical number of landforms that characterize the dominant physical settings in the study area. Though we assume that the landform classification captures differences in soil properties, we plan to analyze how well the portfolio represents the range of characteristic soil types using existing soil maps.

We did not use species data to develop this first portfolio, because we were not able to acquire distribution data or develop accurate models that provide full coverage of the study area. The only available data for existing range of a red-listed species was Reed Parrotbill, which occurs in the Tashgain Tavan Lakes IBA and is included in portfolio. The Gap analysis report (Moore in prep.) produced maps of potential habitat of 10 species, based on expert input and existing maps of vegetation types. We chose not to use this information for portfolio design because 1) the maps are coarse estimates of historic range, which in several cases is very different from currently occupied habitat, and 2) the maps were derived from source datasets similar those used in the ecosystem classification.

Using survey data with strong sampling bias to represent fine-filter element distributions in site selection can reduce efficiency of site selection (Grand *et al.*, 2007) and may artificially raise the value of surveyed areas relative to un-surveyed areas. Areas difficult to survey may also be undeveloped and ecologically intact for the same reason, and will be undervalued if species data drive site selection. According to the coarse-filter/ fine-filter strategy, rare species are fine-filter targets requiring a focus independent of ecosystems (Hunter *et al.*, 1988; Hunter, 1991; Groves *et al* 2002).

Representation goals

Our choice of representation goals was based the goal set by the Mongolia government to protect 30% of natural habitat (The Master Plan for Mongolia's Protected Areas, 1998). Many regional conservation plans have also set coarse filter goals as 30% of historic areal extent, based loosely on the species-area relationships derived from studies of island biogeography and "habitat islands" (MacArthur & Wilson, 1967; Dobson, 1996; Groves 2003). We do not assume that meeting the area goals, or protecting the set of portfolio sites, will ensure viability of all the native biodiversity of the study area. 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. As discussed earlier in the methods section, representation goals are initial estimates and working hypotheses that provide the basis for adaptive management.

Cost/condition index

The cost/condition index is a major factor in MARXAN site selection. Therefore, the portfolio design is sensitive to (1) the pattern and accuracy of the source data and (2) our method for calculating the index that synthesizes the source data to estimate cumulative anthropogenic impacts. The source datasets that we used to calculate the cost/condition index were the best available at the time of this study that covered the full extent of the study area at a consistent geographic scale. Though we assume that the cost index functioned well at a coarse scale for this regional conservation plan, we suggest the following improvements using new datasets that have become available in the last year:

1. The roads dataset was digitized at a coarse map scale (1:1 million), did not include all roads in the study area and did not distinguish between paved highways and dirt tracks. A more current and comprehensive database of the national roads network has been surveyed with GPS by at least one private GPS vendor.
2. The dataset of herder camp locations was useful for estimating the regional pattern of livestock density, but several similar datasets have been collected more recently that contain a more detailed and complete inventory of the seasonal herder camps across the study area.
3. The delineation of urban and agricultural areas is mapped at a coarse scale and based on field survey conducted over 10 years ago (Vostokova and Gunin, 2005). Several land cover maps exist that delineate urban and agricultural areas at a finer map scale, based on more recent surveys and satellite images.

Improving representation of species

The data developed for this study can be useful in the process of compiling data for species distributions and ranges. Both the ecosystem classification and the portfolio are useful for survey design and could be used to guide the survey of key species that could serve as the basis for developing predictive species models.

In cases where species survey data are insufficient to estimate occurrence patterns across the study area, predictive models can be developed based on species occurrence, observation, and available survey data. Where survey date is adequate inductive modeling approaches can be attempted. Numerous freeware options are available; for example GIS tool developed at the University of Georgia called the Element Distribution Modeling Tools for ArcGIS (Nibbelink 2006) are potential options. Where sufficient survey data is lacking for inductive models a simpler deductive approach can be attempted. Deductive models that create binary models of suitable habitat through a series of GIS overlays based on for example: slope, aspect, topographic roughness, elevation (DEM), stream buffers, and vegetation type, height and percent cover which should be available throughout the study area. These deductive models should be seen as a hypothetical prediction of potential habitat that would need to be validated with survey data but could be used to prioritize survey efforts.

Cultural and Historic Sites

Many sites with historic, cultural and religious significance in Mongolia also contain high quality habitat because human uses are limited. Examples include Matad Moutain west of Matad Soum Center, which is not settled and not used for livestock grazing, Shiliin bogd and Vangiin tsagaan uul. Some cultural sites may have less habitat value because of frequent visitors. For example, Eej Khad, or 'Mother Rock' south of Ulaanbaatar, contains potential rocky breeding habitat for raptors that is frequently disturbed by people (Nyambayar & Tsveenmyadag 2009). We were not able to review the 100s of cultural and historic sites that occur in the study area. However information regarding the location and suitability of these sites would be very useful to future iterations of portfolio design, particularly in the context of land use planning.

Freshwater Assessment

Effective conservation of freshwater biodiversity, and specifically conservation planning for freshwater biodiversity, must consider factors that are often absent from traditional terrestrial conservation planning, and that require a basin-wide perspective(Abell, Allan & Lehner, 2007). These factors include longitudinal connectivity throughout the drainage network, cumulative anthropogenic impacts upstream, fluvial processes and flow regimes. Therefore, protected areas designed for terrestrial biodiversity may not provide the size, configuration, drainage network position and management necessary to maintain key ecological attributes of freshwater systems, such as hydrologic regime or water quality, which can be impacted from areas outside of a designated protected area (Abell, Allan & Lehner, 2007).

We recommend using existing aquatic ecosystem classifications and basin GIS frameworks to design a freshwater conservation area portfolio for the Selinge, Kherlen and Onon River basins that meets representation goals for aquatic habitat and optimize for ecological condition and longitudinal connectivity. Methods exist for regional conservation planning that have been tailored for freshwater planning for basins (e.g., Abell 2002; Higgins, 2003), and applied in North America (e.g., Smith et al. 2002; Weitzell et al. 2003; Sowa et al. 2007; Khoury et al. 2011), South America (e.g., Thieme et al., 2007), Africa (e.g., Nel et al., 2007) and Asia (e.g., Heiner et al. 2011). With the HydroSHEDs datasets it is now possible, for all the river basins in Mongolia, to map the hydrographic analysis framework to support freshwater conservation planning (Lehner, Verdin & Jarvis, 2006).

This freshwater portfolio can support design and management of freshwater protected areas, land use planning that minimizes impact to water quality and hydropower siting and operation that minimizes impacts to flow regimes and longitudinal connectivity of the drainage network. This information will also make it possible to incorporate freshwater biodiversity into offset planning, using the freshwater portfolio and aquatic habitat classification.

Landscape Connectivity and the Mongolian Gazelle

The Mongolian Gazelle is endemic to the Daurian Forest Steppe and the Mongolian-Manchurian Grassland ecoregions, and plays a major ecological role in the grasslands (Olson 2008). The large population, over one million individuals, is a prey base for predators and scavengers. As nomadic ungulates, gazelle redistribute nutrients and may influence diversity patterns of plant communities (Mazancourt *et al*. 1998). Mongolian Gazelle are also an important food source for subsistence hunters (Olson 2008).

For wide-ranging species such the endangered Mongolian Gazelle, isolated protected areas alone may not effectively conserve the current population. The functional connectivity of the landscape, i.e. the unrestricted movement and access to habitat range wide, must also be maintained. In the case of gazelle, because available forage is constantly shifting, annual gazelle movements are nomadic and irregular, covering large distances to follow vegetation growth that follows precipitation (Mueller et al 2008). The dependence of grassland ungulates on movement and access to forage across large distances increases their vulnerability to habitat fragmentation and exposure to hunting, livestock competition and disease (Berger 2004). Recent and planned expansion of transportation infrastructure, including fenced railways, to support mining and petroleum development present a serious, immediate threat to gazelle habitat. Gazelle movements and habitat use are also sensitive to the density of herder camps (Olson in review).

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 reserve systems that optimize for the connectivity of the whole reserve network, by modeling movement and barriers between sites based on graph theory (Minor & Urban 2008; Urban & Keitt 2001; Bunn et al. 2000). However, the critical threat is the location and design of the barriers themselves.

The Mongolian Gazelle Management and Action Plan (WCS 2007), makes recommendations including the following specific to infrastructure: (1) land use planning should consider gazelle migration routes and range status, (2) Gazelle calving areas and winter range should be added as special protected areas and (3) construct gazelle crossings along the railway and country boundary.

NOTE

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