© 2013 Journal compilation
http://biology.num.edu.mn
http://mjbs.100zero.org/
Volume 11(1-2), 2013

Mongolian Journal of Biological Sciences

ISSN 1684-3908 (print edition)
MJBS
ISSN 2225-4994 (online edition)

Original Article

Creating a Ruggedness Layer for Use in Habitat Suitability Modeling for Ikh Nart Nature Reserve, Mongolia

Nanette Bragin[1], Navinder J. Singh[2] and Richard P. Reading[1]

[1]*Department of Conservation Biology, Denver Zoological Foundation, 2300 Steele Street, Denver, CO 80205 USA E-mail: nbragin@denverzoo.org; rreading@denverzoo.org. FAX: 720-337-4801*
[2]*Department of Wildlife, Fish and Environmental Studies, Swedish University of Agricultural Sciences, Umeå, Sweden, 90183. E-mail: navinder.singh@slu.se*

Abstract

Key words: ruggedness, habitat modeling, Ikh Nart, SARI, aspect, slope, GIS

Article information:
Received: 13 Jul. 2013
Accepted: 15 Jan. 2014
Published: 20 Dec. 2013

Correspondence:
nbragin@denverzoo.org

Spatially-explicit wildlife habitat models are increasingly used to study optimal habitat for species of conservation focus. A ruggedness layer, that summarizes aspect and slope, provides a useful tool for analyses conducted in a Geographic Information System (GIS), such as developing a habitat suitability index model to measure species habitat use. Ruggedness layers prove especially useful in areas where topography represents a key habitat component. We created a ruggedness layer for the Ikh Nart Nature Reserve and surrounding areas in northern Dornogobi Aimag (province), Mongolia. Using a 90 m Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) and ArcGIS 10 spatial analyst, we created 9 categories for ruggedness. When combined with other thematic layers such as vegetation, the ruggedness layer becomes a powerful tool for analyzing habitat use by individual animals. The results of such analyses may inform decision makers in protected area planning and conservation of endangered species.

Cite this paper as: Bragin, N., Singh, N. J. & Reading, R. P., 2013. Creating a Ruggedness Layer for Use in Habitat Suitability Modeling for Ikh Nart Nature Reserve, Mongolia. *Mong. J. Biol. Sci.*, 11(1-2): 19-23.

Introduction

Spatially-explicit wildlife habitat models are important tools for conservation planning. Models can determine habitat conservation priorities, determine suitability of habitat for reintroduction of endangered species, understand the impact of land management decisions, and identify potential risks to species (Yamada *et al*., 2003). Using a Geographic Information System (GIS), a model can spatially examine the interactions between a species and its environment. Widely used in habitat modeling, a Habitat Suitability Index Model (HSIM) uses an index scale to rate appropriate and inappropriate habitat for a species (Yamada *et al*., 2003).

Topography can represent an important variable in analyzing habitat use. Slope, aspect, deposition of snow and patterns generated, rainfall and watersheds, vegetation growth, and cover from predators depend on the topography of an area (Nellemann & Fry, 1995). Many species that inhabit rugged and mountainous terrain depend on the topography of the landscape to find food and cover from predators. In such areas, ruggedness becomes an important topographic variable. The presence of rocky outcrops, steep cliffs, and rolling hills may characterize the ruggedness of an area. However, such characteristics are difficult to map and measure.

GIS users can generate a ruggedness index using measures of slope and aspect for an area of interest to create a set of classes ranging from the least to most rugged. Such a layer often proves useful in developing a HSIM. We created a ruggedness index to help us assess habitat use and create HSIMs for the wildlife of Ikh Nart Nature Reserve.

Study Area

The Mongolian government established Ikh Nart Nature Reserve (hereafter Ikh Nart) in 1996 to protect about 66,760 ha of northwestern Dornogobi Aimag (N45.723°, E108.645°, Fig. 1). Ikh Nart includes steppe and desert-steppe habitats, with a strongly continental and arid climate (Reading *et al*., 2011). Temperatures range from -40°C to 43°C. Strong winds in the spring may reach 25 mps. Low humidity and precipitation typify the region, with most rain falling in the summer (<100 mm/year) (Bragin, 2010). Water draining the reserve provides a few, permanent, cold water springs. Ephemeral drainages and creek beds, alkaline pools, and ponds also occur in the reserve (Wingard, 2005; Reading *et al*., 2007; Jackson *et al.,* 2006). Our study site encompassed the northern portion of Ikh Nart Reserve and immediately surrounding area (Fig. 2). The study site, bounded by latitude of N45.83°-N45.54°; E108.48°-E108.73°, comprises 72,937 ha. We based the extent on a previous study for vegetative habitat classification

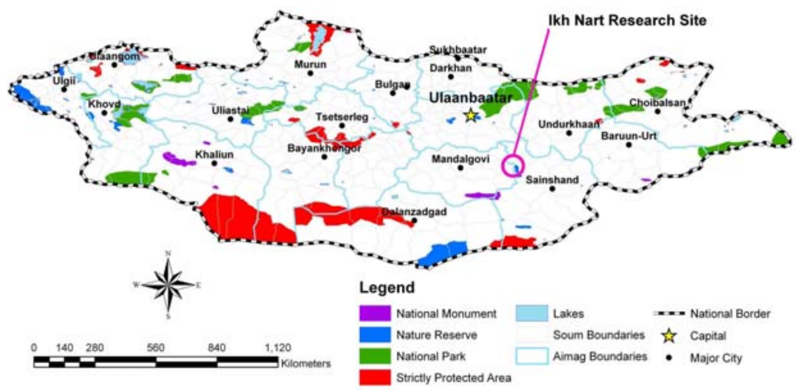

Figure 1. Map of Mongolia's Reserves and indicator for the Ikh Nart Reserve.

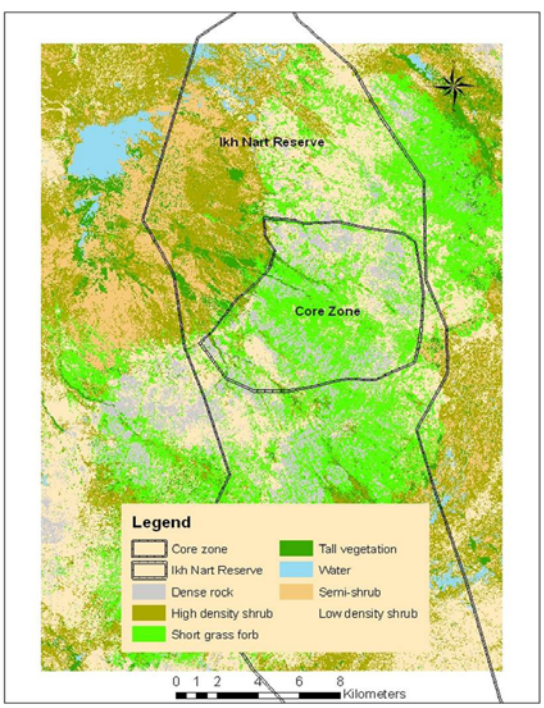

Figure 2. Study site, Ikh Nart Reserve, and core zone.

in Ikh Nart and the surrounding areas (Jackson *et al*., 2006).

Methods

We used ArcGIS 10 to import a 90 m Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) (Fig. 3; https://lta.cr.usgs.gov/SRTM2). We defined all data as WGS84, projected within WGS 1984 UTM Zone 48N, with a cell size of 81 x 81 m. We used Spatial Analyst Surface Tools to create slope and aspect layers. We divided the slope layer into nine classes from 0 to 20.91 degrees (Fig. 4). We divided the aspect layer into 10 classes, but later re-defined the layer into 8 classes with the following breaks: 0-45; 45-90; 90-135; 135-180; 180-225; 225-270; 270-315; and 315-360 degrees (Fig. 5). We prepared the slope and aspect layers using Spatial Analyst Neighborhood focal statistics. We defined the neighborhood as 'circle'; radius = 3; units = map; and statistical type = standard deviation (STD) for slope and 'variety' for aspect (Figures 4 and 5). We used a moving window of circle radius

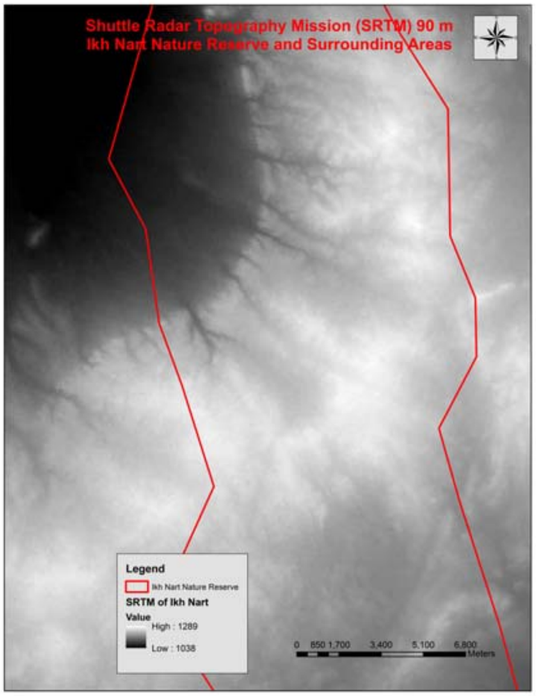

Figure 3. Shuttle Radar Topography Mission (SRTM) 90 m digital elevation model of study area

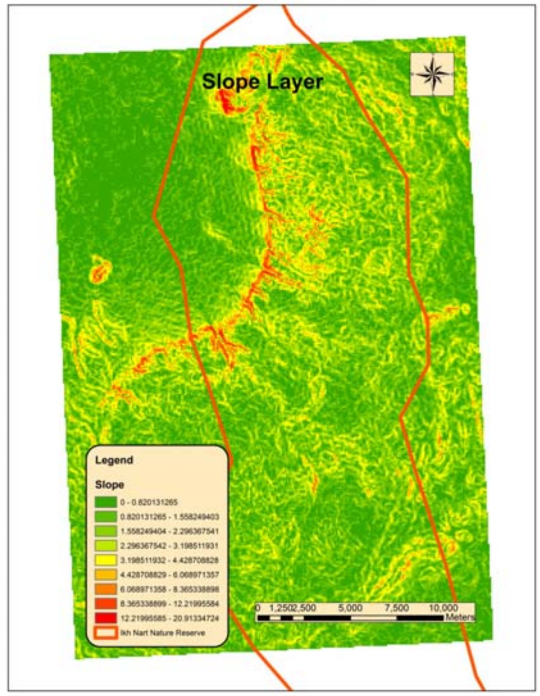

Figure 4. Derived slope layer from SRTM

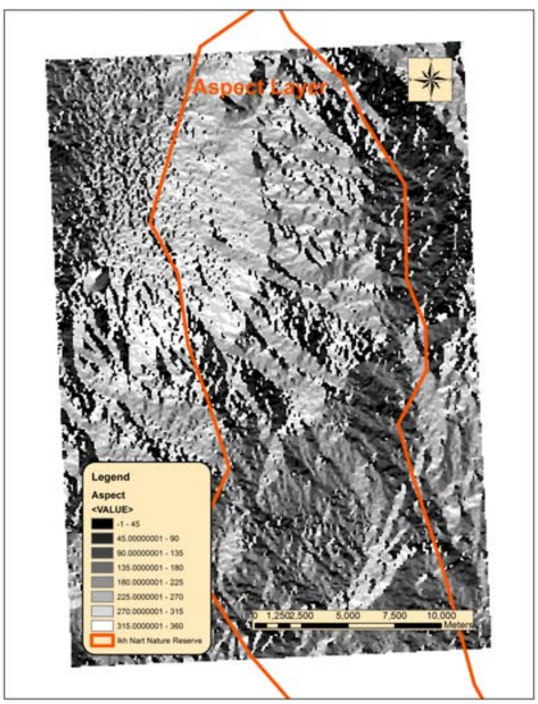

Figure 5. Derived aspect layer from SRTM

with a value of 3 map values (1 map value = 1 cell = 81 m) to match the habitat choice made by mountain ungulates occurring in the study area at the feeding patch scale within the landscape (Sappington *et al*., 2007). A moving window averages elevation values to create a continuum of ruggedness (Danks & Klein, 2002).

We created the slope aspect ruggedness index (SARI) using Spatial Analyst, Math Algebra, Raster calculator, and based the calculation for terrain ruggedness on a modified version of Nellemann and Fry 1995 (Nielsen *et al*., 2001; Singh *et al*., 2009):

SARI=(STDEV Slope) x Variety of Aspect/ (STDEV Slope) + Variety of Aspect.

The resulting layer produced ruggedness values ranging from 1 = least rugged to 9 = most rugged (Fig. 6).

Results

Moderate terrain ruggedness (SARI=5) is most prevalent in the study area comprising twenty percent. SARI classes fit a relatively normal distribution with least rugged classes (1-4) and most rugged classes (6-9) dropping in percent area occupancy. Even though there is a uniform drop in area occupied, the more rugged classes occupy relatively less area than least rugged, 4.29 % for SARI classes 8 and 9; 11.49% for SARI classes 1 and 2 (Table 1). Further, the most rugged classes 6-9 occupy 33.69% while the least rugged SARI

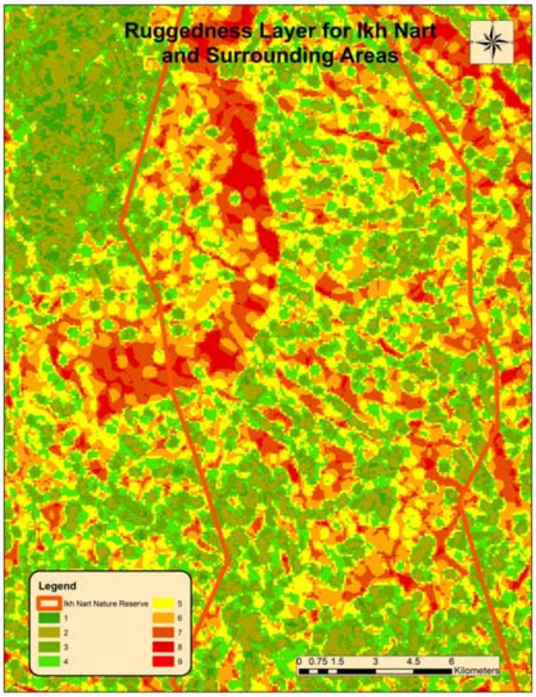

Figure 6. Ruggedness layer of Ikh Nart and Surrounding areas. Aspect and slope were combined to create an index from 1=least rugged to 9=most rugged

classes 1-4 occupy 45.53% of the landscape. As we expected, the most rugged areas occurred at the edge of the uplifted region of the reserve, where it falls to far more level areas surrounding the uplift, but especially to the relatively flat basin in the northwest. As we travel south, the reserve becomes flat entering the core of the Gobi desert with fewer rocky outcrops. This coincides with the higher percentage of less rugged areas in our map.

Discussion

Ruggedness measures the slope and aspect of an area and influences species habitat preference (Nellemann & Fry, 1995). The Slope and Aspect Ruggedness Index (SARI) measures the steepness (fluctuation in elevation) of terrain combined with the total number of fluctuations in aspect, undulations, or “uphills” and “downhills” (Nellemann & Reynolds, 1997). The most rugged terrain reflects many changes in relief, steeper slopes, and considerable fluctuations in aspect. Ruggedness influences temperature, water drainage, soil composition, and vegetation. Ruggedness may provide hollows for denning and protection from climate and predators. For example, an area with high variability in slope and aspect may produce microclimates with a higher biomass for foraging. In addition, windblown bluffs, hill tops and ridges allow greater access to snow covered forage than densely snow covered plains.

Some our main species focus in Ikh Nart include Argali sheep (*Ovis ammon*), and Siberian ibex (*Capra sibirica*). Our efforts in understanding their ecology use many tools. For example, we have thousands of location data and have analyzed home range area. But, our next step encompasses overlaying vegetation, ruggedness, and home range layers to fully understand how argali and ibex utilize the landscapes they inhabit. We can use ruggedness with other variables to conduct more complete studies of species’ habitat use. Vegetation, home range area, prey and predator base, and behavior profiles combined with ruggedness provide a more complete indication

Table 1. Table of Slope Aspect Ruggedness Index (SARI) values. SARI = index of ruggedness values from 1-9 with 1 = least rugged and 9 = most rugged. Cell Count = number of cells with a SARI value. Area = sum of area of the cells of a SARI value. % = percent of areas covered by a SARI value.

SARI	Cell Count	Area (ha)	%
1	285	1142.32	1.50
2	1357	7590.20	9.99
3	3415	11912.10	15.67
4	4714	13962.31	18.37
5	4660	15762.53	20.74
6	3544	13626.23	17.93
7	1765	8717.18	11.47
8	585	2532.05	3.33
9	63	727.03	0.96

of species' habitat preference. Once completed, a profile overlaid in other areas of Mongolia may inform decision makers of the best habitat in similar ecosystems for preservation. We further recommend replicating this work for populations inhabiting other ecosystems of Mongolia, such as the high Altai Mountains. We can also use these methods for other species in Ikh Nart.

Scale and resolution produce different results when analyzing spatial data. Nelleman and Fry (1995) found that fine-scale analyses using maps with 10-20 m contours showed a relationship between potential feeding locations and ruggedness, whereas contours of 30-110 m maps did not. When digital terrain maps (DTMs) become available at 20 m resolution or higher, a combination of terrain ruggedness, vegetation, and DTM layers can automatically analyze habitat use and the influence of ruggedness through advanced software. Analyzing rugged terrain at a fine scale and resolution can detect micro-climates and ecosystems that previously remained unapparent. Also, this method detects subtle differences in relatively smooth terrains such as plains. But, depending on the objective, large scale and coarse resolution layers have been used to determine landscape eco-tones that assist in focusing on priority ecosystems (Eide *et al*., 2001). Fine scale classifications of ruggedness may confound analysis. When a species exhibits a preference for a large range of ruggedness values, it may be useful to lump several classes together.

Understanding optimal habitat for wild flora and fauna can inform planners and managers on park health in a protected area system. One tool useful in determining optimal habitat is a Habitat Suitability Index Model. Combining useful layers, such as vegetation and ruggedness, in a spatial model can create a HSIM to help discover if designated protected areas are designed appropriately, offering wildlife species optimal habitat.

References

Bragin, N. 2010. Creating a Habitat Suitability Index model for Argali sheep (*Ovis ammon),* and Siberian ibex (*Capra sibirica*) in Ikh Nartin Reserve, Mongolia. *Master Thesis*, Denver University, pp. 1-57.

Danks, F. S. & Klein, D. R. 2002. Using GIS to predict potential wildlife habitat: a case study of muskoxen in Northern Alaska. *J. Remote Sensing,* 23(21): 4611-4632.

Eide Nina, E., Nellemann, C. & Prestrud, P. 2001. Terrain structure and selection of denning areas by arctic foxes on Svalbard. *Polar Biology,* 23: 132-138.

Jackson, D. S., Murdoch, J. & Mandakh, B. 2006. Habitat classification using Landsat 7ETM+ imagery of the Ikh Nart nature reserve and surrounding areas in Dornogobi and Dundgobi Aimags, Mongolia. *Mongolian Journal of Biological* Sciences, 4: 33-40.

Nellemann, C. & Fry, G. 1995. Quantitative analysis of terrain ruggedness in reindeer winter grounds. *Arctic,* 48: 172-176.

Nellemann, C. & Reynolds, P. E. 1997. Predicting late winter distribution of muskoxen using an index of terrain ruggedness. *Arctic and Alpine Research*, 29:334-338.

Nielsen, S. E., Herrero, S., Boyce, M. S., Mace, R. D., Benn, B., Gibeau, M. L. & Jevons, S. 2004. Modelling the spatial distribution of human-caused grizzly bear mortalities in the Central Rockies ecosystem of Canada. *Biological Conservation,* 120: 101-113.

Reading, R. P., Amgalanbaatar, S., Kenny, D., DeNicola, A. & Tuguldur, E. 2007. Siberian Ibex (*Capra [ibex] sibirica*) home ranges in Ikh Nart nature reserve, Mongolia: Preliminary findings. *Mongolian Journal of Biological Sciences,* 5(1-2):29-37.

Reading, R. P., Kenny, D. & Steinhauer-Burkhart, B. 2011. Ikh Nature Reserve Nature Guide No. 4 Mongolia. *ECO Nature Edition*, Steinhauer-Burkart OHG., pp. 1-64.

Sappington, M. J., Longshore, D. K. & Thompson, D. B. 2007. Quantifying landscape ruggedness for animal habitat analysis: a case study using bighorn sheep in the Mojave Desert. *The Journal of Wildlife Management,* 71: 1419-1426.

Singh, N. J., Yoccoz, N. G., Bhatnagar, Y. V. & Fox, J. L. 2009. Using habitat suitability models to sample rare species in high-altitude ecosystems: a case study with Tibetan argali. *Biodivers. Conserv.,* 18: 2893-2908.

Wingard, G. J. 2005. Dietary overlap between Argali sheep and domestic livestock in Mongolia. *Master Thesis*, University of Montana, 1-64.

Yamada, K., Elith, J., McCarthy, M. & Zerger, A. 2003. Eliciting and integrating expert knowledge for wildlife habitat modeling. *Ecological Modelling,* 165: 251-264.