# ASSESSING LANDSCAPE DISTURBANCE AND THE ECOLOGICAL SITUATION OF ENERGY DEVELOPMENT IN THE U.S. AND RUSSIA

**Energy development landscape studies often centre on better understanding how oil and gas extraction creates alterations on the land that contribute to habitat fragmentation, colonisation and loss of natural areas. Today, however, energy sources are drawing on renewables such as solar and wind, because they are viewed as cleaner, don't emit $CO_2$, they receive incentives, and are being increasingly required as part of a balanced energy mix in many US states.**

Meanwhile, these alternative supplies are seen as creating less adverse environmental effects than oil and gas. Yet they too create a disturbance footprint on the landscape that can lead to permanent loss of habitat, thus affecting carbon stores, ecosystem goods and services and biodiversity. This issue is particularly salient in sensitive areas, such as steppes with unique and diminishing grasslands. Additionally, wind turbines often lead to bird and bat mortalities. Our current research on energy production aims to develop diagnostic indicators for mapping and measuring surface disturbance related to energy development, both hydrocarbon and renewable wind power. As part of our NSF-CRDF grant, American and Russian teams are studying energy landscapes in northeastern Colorado and western Russia. Using remote sensing and GIS data and techniques we examine the Pawnee National Grasslands in Weld County, Colorado and the oil and gas fields in and around Buzuluk National Forest in Russia's Orenburg state. Our objective is to better understand the pattern and extent of the energy development footprint in order to develop disturbance indicators to enhance environmental performance standards in the energy industry (both hydrocarbon and renewable). Initial results are reported below.

## Study Area: Colorado

Colorado is 6th largest oil and gas producer in the US, with Weld County having the highest well density in the state. Located in northeastern Colorado, this state is also home of the Pawnee National Grasslands, a unique and diminishing mosaic of natural prairie grasslands that is interspersed with federal, state and private land and where the dominant economic activities are oil and gas extraction, wind production, agriculture and grazing. We selected the eastern Pawnee because it contained both oil and gas and wind production in order to allow a comparison of landscape disturbance associated with each type (see Figure 1).

We began by creating 1km² grids of the study area and systematically examined oil and gas wells provided the Colorado Oil and Gas Commission (COGCC 2015). From each grid we extracted producing wells, which numbered 561, a density of 0.0027 wells per hectare—see figure 2. Then using field data and air photos of eastern Pawnee (NAIP 2015) we visually examined all wells to determine if they indeed were located on a wellpad (a cleared flat area where wells and supporting equipment are established), and digitised the disturbance footprint of each one. This resulted in 444 wellpads of varying sizes, ranging from small remote ones (0.0087 ha) to very large fracking pads (37.60 ha) located along primary roads. In addition, all access roads leading to wellpads were digitised and buffered by road width—see figure 3.

Finally, we calculated the overall disturbance created by the wellpads and the buffered access roads, resulting in 1,267.09 hectares. This translates into an average disturbance of 2.85 ha per wellpad, or 2.26 ha per oil or gas well.

Next, we examined the imagery for the location of the Cedar Creek I and II wind project located in the northern part of the study area (Pacific Power 2015). We digitised the center location of 397 wind turbine pads, then randomly examined the size of 20 pads to calculate an average turbine pad size of 0.6 hectares. Since most turbine pads were of uniform size, we assigned this figure to all pads, creating a buffered polygon which we smoothed with 20° Bélzier curves (using ArcMap 10.3.1). We further shifted and rotated each polygon to overlay on the centre of each turbine to better resemble the disturbance on the landscape.

Additionally, we digitised the lengthy access roads (169.50 km) linking the turbines together, as well as the transmission lines

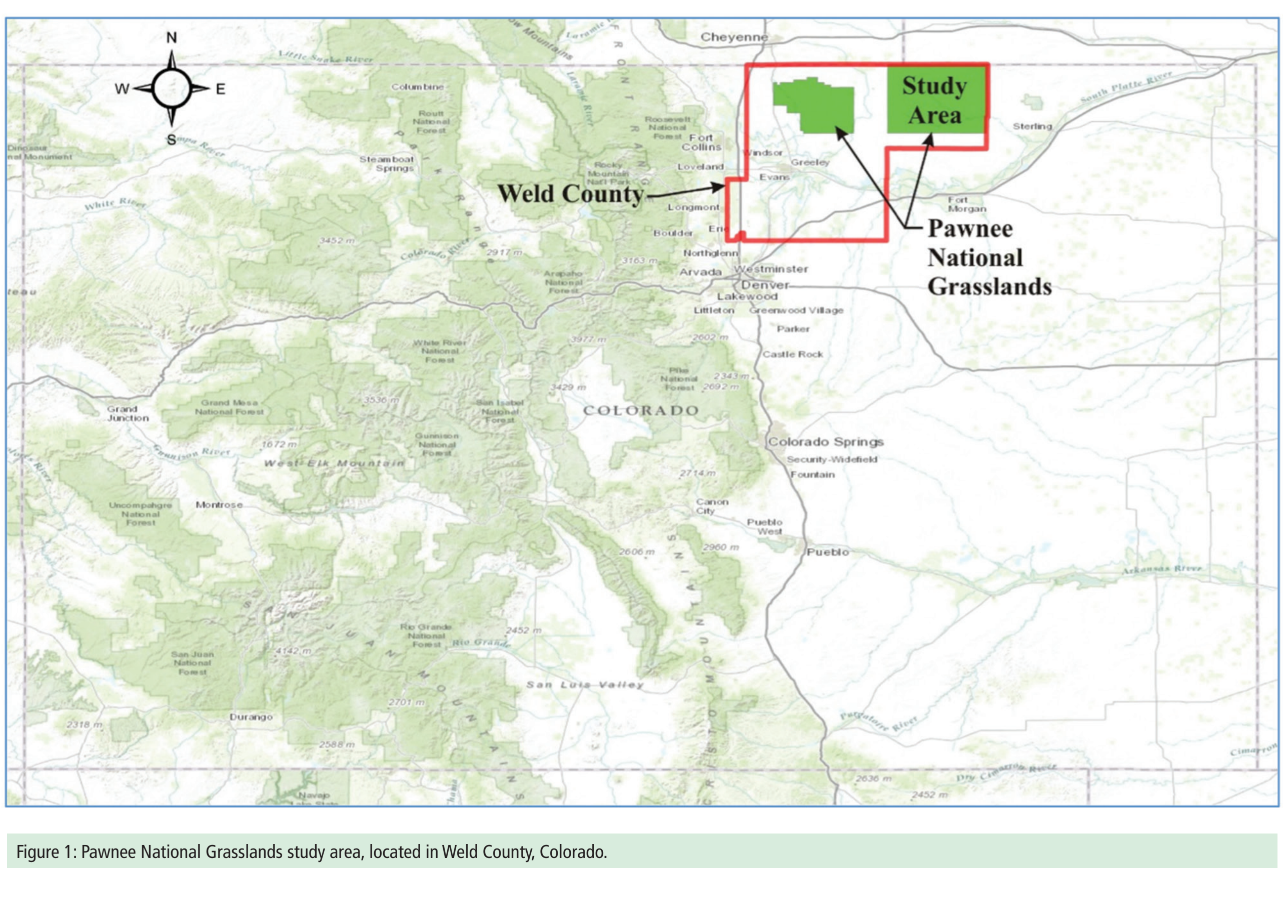


Figure 1: Pawnee National Grasslands study area, located in Weld County, Colorado.

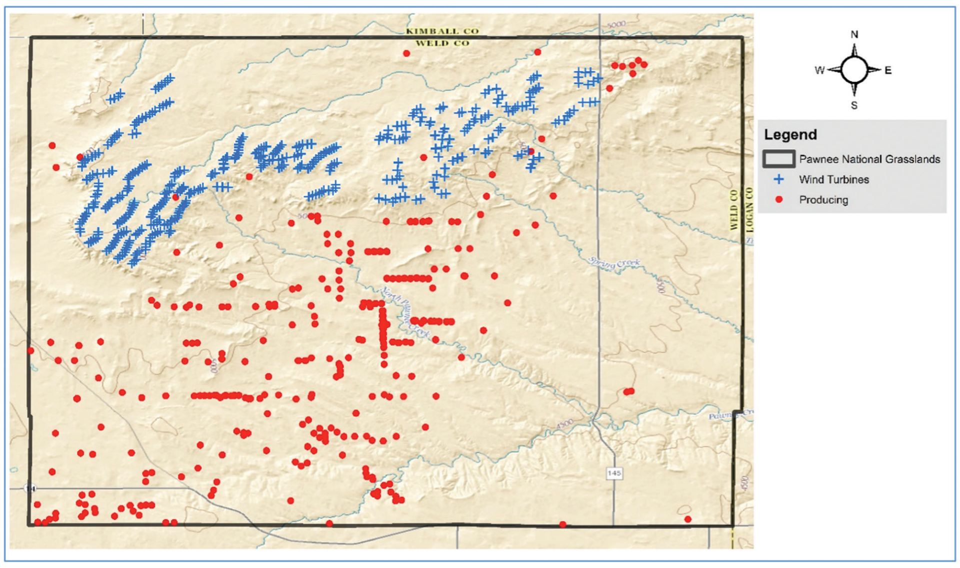


Figure 2: Location of wind turbines and producing oil and gas wells.

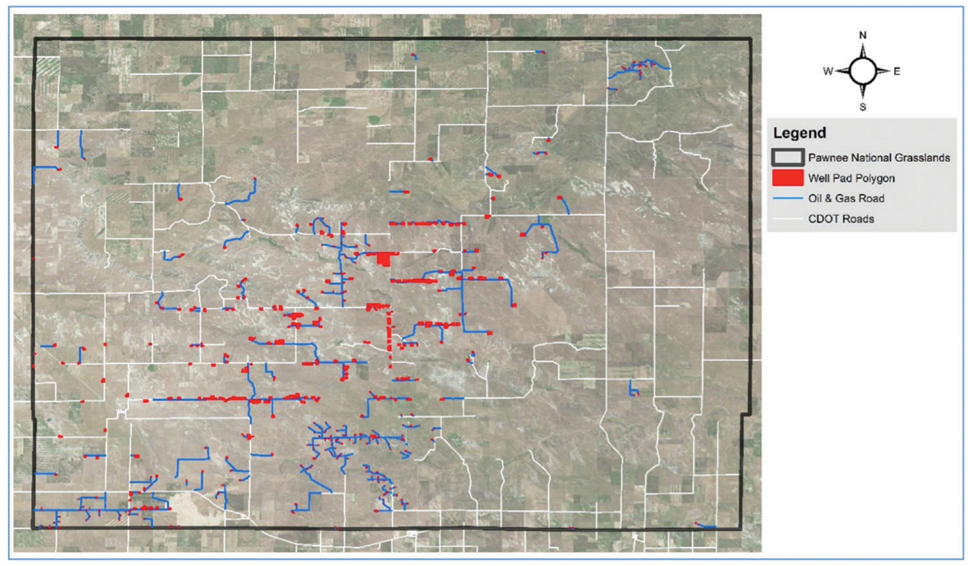


Figure 3: Oil and gas disturbance in the study area. The blue lines indicate oil access roads, while red represents wellpad disturbance.

(86.30 km) and the electricity substations. Based on average width, we buffered the access roads to 11m and the transmission lines to 6.096 m. Combined, the overall disturbance of the wind project was 488 ha, or 1.23 ha per turbine pad.

## Study Area: Orenburg region

Russian Oil and Gas (O&G) key test landscapes are located in Orenburg region and contain three oil fields (figure 5). Development began here in 1994, leading to a considerable bulk of accumulated anthropogenic load which promotes significant transformation of natural complexes. Over 100 areas with oil–producing infrastructure objects are located in this research territory with about 4.75 wells per/100 km². These objects are representative of the various types of O&G steppe landscapes.

Fieldwork in Orenburg region has also been conducted. Many oil and gas production objects (inside wellpads) were visited and we defined key characteristics including: size, shape, amount of land disturbed, variety, as well the spatial distribution of these elements in each wellpad. Initial results show spatial variation according to the type of drilling activity, location and age of operations.

A list of indicators for estimating the geoecological state of oil extraction landscapes was made.

They take into account specific features of natural steppe zone conditions such as: semiarid continental climate, few areas of water; and oil field functioning features such as: the number of infrastructure objects in each wellpad, environmental pollution linked to hydrocarbon production, and the use considerable amounts of fresh water.

At the moment a rating scale is being developed, where each indicator will be assigned a specific point corresponding to its contribution to anthropogenic transformation. Currently we estimate two indicators:

(1) Natural acceptability of landscapes for the location of oil and gas objects (represented as points);

(2) Areas of dense vegetation cover to absorb carbon oxide (carbon sinks).

**The Natural acceptability of landscapes for the location of oil and gas objects involves these parameters:**

- (1) Slope of relief. Slope affects erosion and ravines, which begin to develop intensively after the slope value is more than 3º;

- (2) Aspect of elevation. Aspect is the one of the basic contributors to erosion: ceteris paribus, the band of soil removed by erosion is considerably wider on the southern, south-western and south-eastern sides than on Northern side;

- (3) The distance between the oil fields objects and water objects. The further away from water sources, such as rivers and streams, is important as the migration of chemical and mechanical components into water bodies through agglomeration of oil field objects is possible. Water sample analysis taken from the river within the oil field at the Russian key test plot showed excess maximum permissible concentration (MPC) amounts of hydrocarbons for water basins at 5.5 times (MPC = 0.3 mg/l). Oil and gas objects located within 500 m of a water basin were found to create a higher risk for water contamination.

The natural suitability of landscapes for oil and gas production was calculated based on a SRTM digital elevation model by combining three parameters above. Also we used layers of oil point objects and water objects for our key test plots. Evaluation of each parameter will be realised by a method of expert

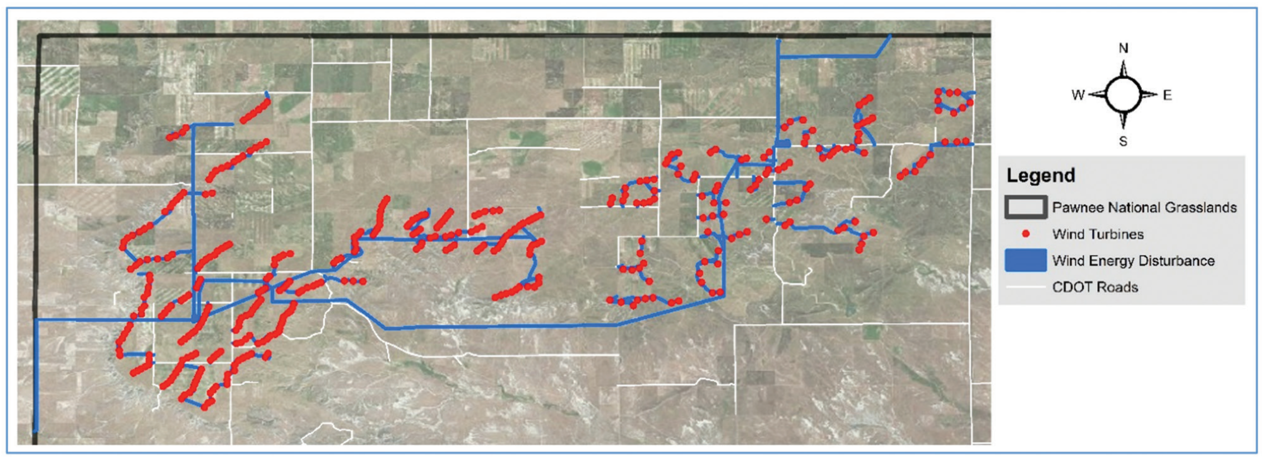


Figure 4: The footprint of wind development in the study area. Red indicates turbine pads, while blue represents access roads and transmission lines.

assessment of parameter's significance as part of total score for general assessment of a landscapes' geoecological state. The conversion of exposure rasters, slope, remoteness and summing of their scaled values (25, 25 and 50%) were made using ArcGIS 10.2 Spatial Analyst tools. The final image was classified into three categories with equal intervals, and landscape acceptability results were shown (see figure 6).

We then counted the oil and gas objects located inside red, yellow and green zones. Next we assigned scores following ecological comparisons of different oil and gas landscapes. We used the method of expert estimations and assigned the scores shown in Table 1:

Table 1: Scoring of parameters of natural acceptability of landscapes

| | Density is < 0.25objects /1 km² | Density is 0.25-0.5 objects /1 km² | Density is > 0.5objects / 1 km² |
|---|---|---|---|
| Red zone | 3 | 4 | 5 |
| Yellow zone | 1 | 2 | 3 |
| Green zone | 0 | 1 | 2 |


Figure 5: The Russian key plot selected for study is located in the Orenburg region (basemap source: ESRI).

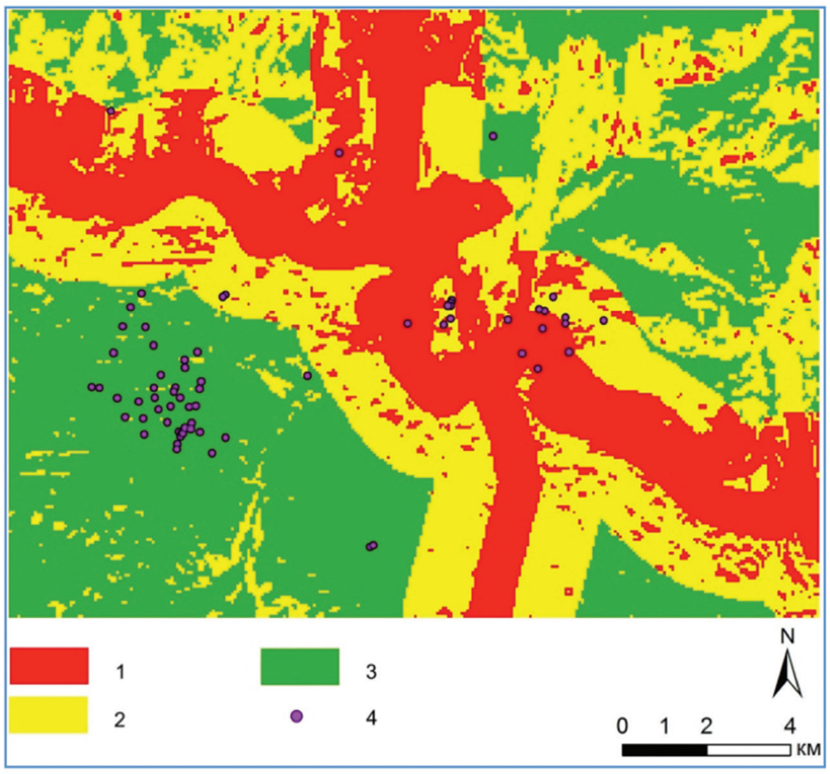


Figure 6: The scheme of the Natural landscapes acceptability for location of oil and gas objects (points). Undesirable areas are marked in red color, average-suitable areas are marked in yellow, and suitable areas - in green colour. The location of oil objects is marked in purple.

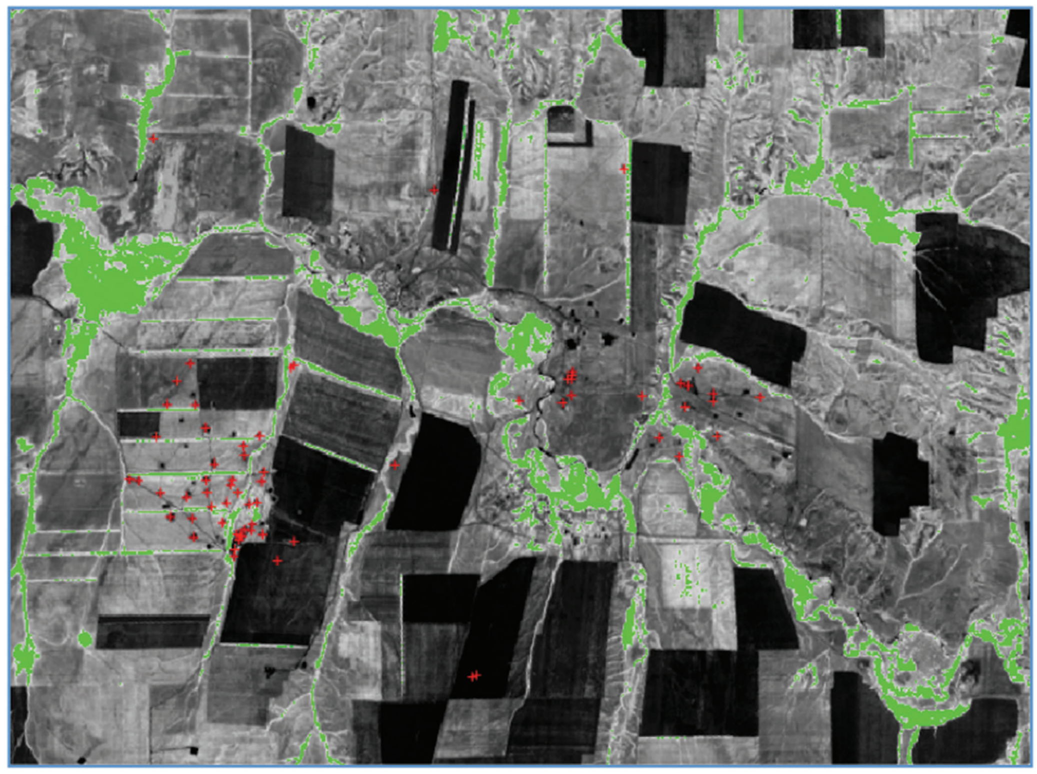

Figure 7: The Russian research plot. Dense vegetation is marked in green.

**Area of dense vegetation cover to absorb carbon oxide.** An area of a dense vegetation cover in the Russian research plot was defined by NDVI index (ENVI Software 5.2) using some early summer Landsat scenes. Areas with a high degree of biomass were singled out with NDVI values ranging from 0.6 to 1 (Myachina and Chibilyev 2015) (figure 7). Average indicators on exhibited 1 to 2 % dense vegetation, showing a low ability of landscapes within the area to absorb carbon dioxide.

We applied the following scale to "Area of dense vegetation cover" to compare the ecological situation of different oil and gas landscapes:

- mean value of woodland area < 1% - 5 scores
- mean value of woodland area 1-5% - 4 scores
- mean value of woodland area 5 - 10 % - 3 scores
- mean value of woodland area 10-20% - 2 scores
- mean value of woodland area 20-30% - 1 scores
- mean value of woodland area > 30% - 0 scores

## Conclusions

Utilising geospatial data and techniques, accompanied by field data collection and observations allowed us to measure the energy development footprint in the eastern Pawnee National Grasslands in Colorado. Though oil and gas and wind energy created numerous disturbances in the study area, they nevertheless created a smaller footprint that anticipated. After all, wind energy occupied 0.0023% of the study area, while oil encompassed 0.006%.

In the Russian example, the proposed solution to the analysis of energy landscapes allows:

- the planning of production activities at the detailed engineering stage to optimise the location of objects in steppe landscapes;
- the regular monitoring of landscapes for timely detection of modification or transformation;
- the comparison of different oil and gas production territories.

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Ksenya Mjachina

Chris W. Baynard

**Author Details**

**Chris W. Baynard, Ph.D. Associate Professor** • Dept of Economics and Geography, Coggin College of Business, University of North Florida, 1 UNF Drive, Jacksonville, FL 32224
Tel: 904-620-1243 • Email: cbaynard@unf.edu

**Ksenya Mjachina Ph.D, Senior scientific researcher** • Institute of Steppe Ural Branch Russian Academy of Sciences; 11, Pionerskaya st. Orenburg, Russia
Tel: +7 961 942 5880 • Email: mavicsen@gmail.com

**Robert D. Richardson** (University of North Florida)

**Alexander A. Chibilyev** (Institute of Steppe, Ural Branch Russian Academy of Sciences)