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Understanding transportation-caused rangeland damage in Mongolia

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ABSTRACT

Mongolia, a vast and sparsely populated semi-arid country, has very little formal road infrastructure. Since the 1990s, private ownership and usage of vehicles has been increasing, which has created a web of dirt track corridors due to the communal land tenure and unobstructed terrain, with some of these corridors reaching over 4 km in width. This practice aids wind- and water-aided erosion and desertification, causing enormous negative environmental effects. Little is being done to counter the phenomenon, mainly because the logic of the driving behaviour that causes this dirt road widening is not fully understood.

The research in this article postulates that this driving behaviour has rational foundations and is linked to various geographical factors (natural and man-made geographical features). We analysed 11,000 km of arterial routes in the country using spatial statistics and determined that geographically weighted regression (GWR) analysis offers a good explanation for whether, and by how much, the selected geographical factors affect the creation of corridor widths and how their effect varies across the landscape.

We determined that corridor widths are correlated to factors such as proximity to river crossings, traffic intensity, and vegetation abundance. Knowing these factors can help local planners and engineers design counter-measures that could help to control and reduce the widths of these corridors, until paved roads can replace the dirt track corridors.

1. Introduction

It is a commonly accepted paradigm that asphalted roads result in damage to the environment (Clevenger et al., 2003; Forman, 2003; Poteete, 2012; Roedenbeck et al., 2007). However, in rangelands such as those of Mongolia, the scarcity of proper road infrastructure also damages the environment because of unregulated driving. The passage of wheels compresses the grassland, not only killing the vegetation but also compacting the ground and damaging its ability to absorb and retain moisture and nutrients (Belnap, 2002; Dregne, 1983) and thus causing land degradation because of soil compaction, crusting and sealing (Arts et al., 2012; Gubbi et al., 2012). In doing so, the flow characteristics of surface water run-off is concentrated and magnified, thus leading to soil erosion and increased sediment loads in water courses and stream networks (Malczewski and Jelokhani-Niaraki, 2012), which is damaging to aquatic habitats and water quality (Misak et al., 2002). Using carbon, nitrogen, porosity and hardness of the top layers of the Mongolian soil, Li et al. (2006) noted that re-vegetation of such damaged vehicle tracks requires approximately 10–15 years after the track has ceased to be used. They also noted that the pioneering plants of such re-vegetated tracks are invasive weed species and not the endemic species that are socio-economically important to the indigenous pastoralists, whose only income is through livestock herding.

Dirt tracks, formed by the first vehicles diverting from a used track onto the undisturbed grass, are softened by water from rain or snow-melt and worsened rapidly by the passage of succeeding vehicles. Washboards, ruts, potholes and corrugations formed in the softened dirt roads soon render them unsuitable for stable driving. This roughness combined with the accessibility of the surrounding terrain and the general lack of obstructive vegetation in rangelands makes it more attractive for subsequent vehicles to create their own new tracks adjacent to existing ones. The resulting dirt track network, which criss-crosses the country, does not

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consist of a single track but mostly of numerous bunched quasi-parallel tracks and has led to the deterioration and denudation of vast swathes of landscape across the entire, otherwise pristine, Mongolian steppes (see Fig. 1). The absence of fences or land tenure customs and laws, as well as snow covering on the ground, which hides the tracks for more than half the year, only serve to exacerbate the situation.

The resulting swath widths are usually in the range of 30–125 m but quite commonly reach magnitudes of approximately 900 m width, the equivalent of a 250-lane highway with contiguous lanes of 3.6 m width. The maximum width is even 6200 m (Keshkamat et al., 2011). Such widths persist for tens of kilometres across the countryside as corridors of degraded land. Batjargal et al. (2006) estimated that over 0.7 million hectares of Mongolian land is lost due to the redundant wasteful use of land for transportation.

Although Keshkamat et al. (2011) and Batjargal et al. (2006) have highlighted the environmental degradation caused by such land use, a systemic understanding of the rationality behind the creation of such wide dirt corridors has been lacking to date and is necessary for assessing the damage and countering it. In what is the first attempt to do so, this article fills the gap by investigating the corridor characteristics to identify the key geographical factors (both local and 'global') that affect the corridor widths and the extent to which they do. We consider both natural geographical factors, related to landforms and ecosystems, and artificial geographical factors, related to human settlements and engineered constructs such as roads. We postulate that the widening of the dirt roads in rangelands is clearly due to the drivers' response to the local geographical conditions, with some conditions that support widening and others that constrain it. Most of these factors act in combination, rather than singularly, and generally, this behaviour is locally varying. We apply spatial statistical techniques to investigate and compare whether the observed corridor widths are correlated with the selected geographical factors, and if so, what are the characteristics of their effect. In transport studies, such locally varying relationships have been studied by Du and Mulley (2006), Mulley and Tanner (2009), Propastin et al. (2008) and others using geographically weighted regression (GWR) (Fotheringham et al., 2002), showing promising results, which we perform in this paper as well.

As such, the major innovation in this paper is that we explain the width of dirt track corridors in Mongolia using variables from natural and social sciences. By integrating over this spectrum, we are able to formulate recommendations to mitigate the adverse effects of transportation on rangelands. Although this article restricts itself to dirt track propagation in Mongolia, this problem is by no means restricted only to this country. Rather, it appears to be a widespread phenomenon in several arid and semi-arid regions. Similar phenomena can be observed in Kazakhstan, Uzbekistan, Kuwait, Bolivia and Namibia, for example, see Allen et al. (2011), Battisti et al. (2012), Cosens (2011), Wan and Dozier (1996), Xiao et al. (2006) and Zellmer (2009).

In the following sections, the study area and methods of data collection and preparation are described, followed by a description of the geostatistical analysis, its results and implications.

2. Study area

Mongolia is a landlocked country in Northeast Asia bounded to the north by Russia and to the south by China (Fig. 2). The climate is an extreme continental climate with long, cold winters and short summers, during which most precipitation (average 20–35 cm per year) occurs. Frequent blizzards with snow-covered ground occur in the winter months, whereas thunderstorms and winds that can bring soil erosion from floods and dust storms occur in the spring and summer. From north to south, Mongolia can be broadly divided into four natural zones: Taiga forests, steppes, semi-desert and desert, although a few wetlands, alpine meadows and tundra zones are interspersed. This country hosts some of the world's most endangered flora and fauna species.

It is the world's fourth least densely populated country with a total population density of 1.7 person/km^2 (National Statistical Office of Mongolia, 2008). However, the capital city Ulaanbaatar itself contains 1.2 million of its 2.9 million people and a further 0.8 million live in the other three major cities (National Statistical Office of Mongolia, 2008). This distribution leaves the countryside extremely sparsely populated, which has contributed to the lack of nationwide formal transport infrastructure in the country – a total of only approximately 2600 km of asphalt roads for 1,564,115 km^2 of land area and rail transport is almost only along a single line from Russia to China through Ulaanbaatar, while air transport is too expensive for general use. Public transport mostly takes the form of 10-seater vans called *Furgons*. The sparse population, in

Fig. 1. The phenomenon of dirt tracks as seen at location.