SUSTAINABILITY ASSESSMENT OF URBAN LAND-USE SYSTEMS: EVALUATING IMPACT INDICATORS OF DARKHAN

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ABSTRACT

In order to implement successful strategies for urban development, decision makers should integrate issues (social, environmental, economic) in the country. Indicator-based methodology that seeks to achieve integration of all issues of sustainability has gradually evolved for this purpose. This paper is concerned with establishing an indicator set and assessing the sustainability of urban land use systems, using Darkhan City of Mongolia as a case study. The aim of the study is to formulate sustainability indicators and criteria by comparing Russian and UK methods and applying them to Darkhan's land use system. The method highlights the impact on water, soil and air quality as the most important environmental effects. Data on household condition and land use with socio-economic effects are taken from official organizations such as the Land office, and Meteorological office of the study area.

There are a total of 21 sustainability indicators which are found to be useful and their criteria are developed to measure sustainability of urban land use in Mongolia and tested in Darkhan city. Evaluation of the criteria determines whether land use in Darkhan is sustainable or unsustainable and what the main determinants are. The methodology is useful for measuring, monitoring and assessing all issues of urban sustainability as well as warning about the risk of lasting social, economic and environmental damage regardless of type, location and scale level. It is hoped that the application of existing methods will greatly accelerate the urban sustainability assessment learning process and improve policy effectiveness.

Keywords: sustainability assessment, indicator-based method, sustainability indicators, urban land use system, Darkhan.

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1. INTRODUCTION

1.1 Mongolia

Urbanization is growing rapidly due to changes in lifestyle in Mongolia. Today 80% of the total population lives in urban areas (World Bank, 2000). There are number of serious problems in Mongolia, particularly in a secondary city such as Darkhan. The desire of people to improve their living standard causes the nomadic herding families to move to the cities, which often places stress on the already fragile environment. The rapid growth and land mismanagement has led to environmental deterioration such as air and water quality and land degradation which negatively affect living condition. Due to the population density and the intensity of economic and social activities, urban land use consumes significant amounts of resources, produces waste and pollution, and degrades the environment. Consequently, there is a demand for tools to find more sustainable solutions for decision makers.

The growth of cities is often accompanied by a number of serious problems, notably environmental deterioration, which negatively affect living conditions at both local and global scales. Damage includes negative effects on the urban atmosphere and the reduction of the urban water supply, and thus lead to higher health risks and safety hazards, e.g. a higher incidence of infectious diseases, deterioration of biodiversity as well as lower worker productivity (United Nations, 2001). At the same time as urban land use is used as a various dedication in a limited space, it has a well condensed and sophisticated procedure of the possession and utilization. From a spatial viewpoint, land use is understood to imply those human activities that can change the bio-geophysical conditions of land as well as being the strongest impact on the environment worldwide (Helming et al., 2008).

Currently these problems are major urban challenges in Mongolia and therefore it is important to take steps towards sustainable development. Sustainable land use and a holistic approach to decision-making that recognizes the interconnection of interconnected social, economic and environmental issues is the most viable approach of spatial planning towards sustainable development. In the world at the European level, the Sustainable Development Strategy stresses the need for integration of economic, environmental and social issues across the policy area.

Unfortunately there is very limited information available for land use planning and management, at the local level in Mongolia. Long term planning is a challenge because of the complications of impacts on the local environment and the opportunity to enhance the quality of life of the citizens. Therefore it is necessary to collect and analyse environmental information to assess the impact of the urban land use pattern in order to evaluate, improve, control and plan for further development.

This paper looks at sustainability assessment of urban land use. There are various approaches available for sustainability assessment of urban land use outside of Mongolia. On the basis of their methodological foundations they can be categorized in three groups: environmental assessment methods, life cycle assessment methods and sustainability indicator assessment methods. In Mongolia, the Agenda 21 action program (Agenda 21, 1998) presents the country's commitment to sustainable use and protection of Mongolia's precious land resources. Fortunately politically there is a readiness to use the principles of sustainable development for the planning and management of national development. Unfortunately, in practice, unsustainable solutions are frequently offered that reflect the personal values of the urban planner or manager and not the best practice in the sector. Some research has been done on natural geographic conditions for assessing urban development, and usually at the municipal level. Decision-makers rarely discuss preconditions for sustainable development and their decisions are usually made on the basis of economic analysis. Very little research has been done on this topic and nobody has developed sustainability assessment approaches in Mongolia. Thus, recently integrated assessment approaches have included environmental, social and economic impacts toward sustainability that are desirable for the local metropolitan level.

1.2 Aim of the project

The aim of the research was to analyse methods to assess the sustainability of urban land in Mongolia and to formulate criteria for the development of Mongolian urban sustainability indicators.

1.2.1 Sub-objectives

- To study different approaches to assess the sustainability of urban land use.
- To compare Russian and UK indicator-based methods and test the baseline condition using their indicators.
- To formulate and develop sustainability indicators and criteria for a particular city.
- To test the case study using existing urban sustainability indicator sets to determine compliance in an urban area.

1.3 Methodology and data

The project was based on both qualitative and quantitative research methodologies: (1) literature review analysis, (2) baseline analysis, (3) comparison of different practices, and (4) urban sustainability assessment. Data was collected by aerial photographs, topographic maps and land use maps using GIS and some available data (on population density, land resources, air and water quality, soil pollution, etc.) from official organizations such as the Meteorology, Land Administration, and statistics for statistical analysis. A simple inventory method to generate the input data for the indicators was used to analyse the data.

The purpose of the comparison of different practices was to identify suitable methods to measure urban sustainability based on indicators. This paper examines two practices selected from developed countries and regions in the world, including Russia and the UK. The northern part of Mongolia, its geographical condition, climate, living habits (houses, foods, etc.) as well as the education system, is similar to Russia. Russia has significantly contributed to the city's development, particularly in Darkhan. The UK government's purpose was to set a more clearly sustainable track based on the WCED international definition of "a better quality of life for everyone, now and for generations to come" (WCED, 1987). The UK system of measuring sustainability is common in Europe. These both were criterion of decision to choose Russia and UK experience.

In order to present in results in an easily understandable form, several thematic maps were created. The digital analysis was carried out using GIS and Image processing software (ArcGIS ver 9.3 and Erdas Imagine ver 9.1). The analyses and the maps provided multi-dimensional assessments of complex urban-environmental systems.

2. SUSTAINABILITY

2.1 Sustainable development

The need for sustainable development was first put forward in Rio de Janeiro in 1992 when 150 countries signed the Action Plan for the 21st century – *Agenda 21* – which defines the actions that are necessary to address global environmental and social development problems (Āboliņa, 2005). Sustainable development refers to resource use that aims to meet human needs while preserving the environment so that these needs can be met not only in the present but also without compromising the ability of future generations to meet their own needs (United Nations, 1987). It ties together concern for the carrying capacity of natural systems along with the social challenges facing humanity. Sustainable development can be divided into three constituent parts: the environment, economy and society (Fig. 1) (United Nations, 1987).

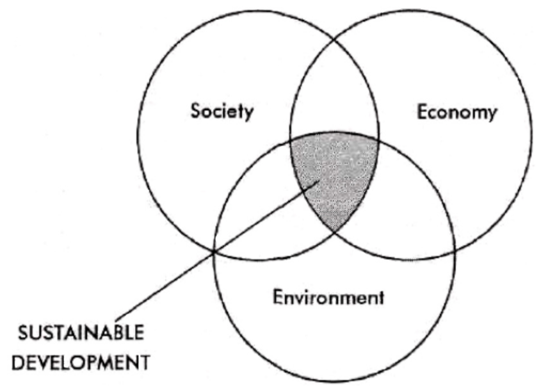


***Fig. 1.** Environmental, economic and social spheres of sustainable development (Source: Āboliņa, 2005).*

According to the Agenda 21 action programme sustainable use and protection of Mongolia's precious land resources should be achieved through:

- creating an integrated approach to land use planning;
- effectively managing Mongolia's land resources through such approaches as strengthening planning and management systems;
- raising awareness of the need for effective land use planning and management;
- promoting public participation;
- improving research on land resources;
- strengthening information systems;
- increasing land protection and restoration activities;
- developing special protected areas;
- emphasizing the proper use and conservation of natural resources;
- substantially improving the quality of life in urban areas, including reducing air and water pollution.

(Agenda 21, 1998)

The concept of sustainability or sustainable development is clearly the basis of sustainability assessment which is being increasingly viewed as an important tool to aid in the shift towards sustainability. However, this is a new and evolving concept and there remain very few examples of effective sustainability assessment processes implemented anywhere in the world (Murray, Ray & Nelson, 2009).

2.2 Sustainability assessment

According to Pope et al. (2003), the aim of sustainability assessment is to ensure that plans and activities create an optimal contribution to sustainable development. It is a tool that can help decision makers and policy makers decide what actions they should or should not take in an attempt to make society more sustainable.

There are currently several methods available for sustainability assessment for the evaluation of environmental impacts on buildings and urban development (Xing, Horner, El-Haram & Bebbington, 2009) but there is no single, robust methodology to assess all three dimensions (economic, social and environmental) of urban development (Huang, Yeh, Budd & Chen, 2009).

In the literature, sustainability assessment is generally viewed as a tool in the 'family' of impact assessment processes with much attention focused on environmental impact assessment.

2.3 Attributes of sustainability indicators

Sustainability assessment tools consists of the use of indicators (Ness, Urbel-Piirsalu, Anderberg & Olsson, 2007) to organize and systemize the issues involved for making policy-making processes consistent, transparent and end oriented. When using indicators, the purpose of the assessment process is important. Sustainability indicators are, firstly, important for assessing progress, secondly for assessing sustainable development practice and experience in different places and, thirdly for assessing the opportunities presented by the new paradigm of sustainable development (Āboliņa, 2005). Sustainability indicators have been identified as follows:

- they are information units that specify the status of major systems;
- they are the means for viewing the larger picture while viewing only a small part thereof;
- they show the direction in which a system is developing – better or worse or remaining the same.

(Āboliņa, 2005)

The beginnings of sustainability indicators can be considered as environmental indicators. Since the development of indicators differs from place to place, a variety of sustainability indicator sets have been developed. These sets have been created on the basis of differing frameworks and, consequently, they differ in terms of content and form (Table 1).

Table 1. *Differences between Environmental Indicators and Sustainability Indicators (Source: Āboliņa, 2005).*

	Environmental Indicators	**Sustainability Indicators**
What do they show?	Usually they describe environmental quality or condition: sometimes with the help of "Driving force-pressure-state-reaction-scheme" they also include other economic and social factors	They cover all spheres – the environment, the economy and society and their mutual relationships.
How do they describe?	The indicators are usually quantitative in nature.	Qualitative evaluation and judgements are often used.
How are they merged?	They emphasize the major aspects and they usually do not represent a " full set" in describing a system in the widest variety of ways	They emphasize the aspect of sustainable development which means that the description of a system requires a full set of indicators
How are they elaborated?	The indicators are elaborated by environmental specialists.	The indicators are elaborated by a variety of specialists, often in co-operation with the public at large.
Why are they elaborated?	They are primarily of an informative nature.	In parallel to informative and educational functions, they promote the involvement of the public in the processes of sustainable development.
For whom are they meant?	Users are mostly specialists.	Users are a wide range of people, including local residents.

Each year a great number of social, economic and environmental indicators are being established in the world, but few of these are recognized as applicable for everyday use.

According to the Agenda 21 Action Programme there are 8 indicators of sustainability.

1. Global environmental impacts – measured by CO_2 emissions per capita.
2. Local environmental impact – assessed using measurement of the most significant local pollutant from the energy sector (SO_x, NO_x, O_3).
3. Rural electrification – measured by the percentage of rural households having access to power supply.
4. Employment intensity – measured by the number of direct energy jobs.
5. Resilience to external impacts – measured by the level of energy sufficiency, i.e. the percentage of net energy exports or imports (including fabricated fuels and, eventually, energy equipment).
6. Burden of energy investments on development-measured by level of public energy investment in GDP.
7. Energy productivity – measured by GDP.
8. Sustainable energy deployment – measured by the share of energy output coming from energy conser vation and renewable sources (excluding mega-hydro and unsustainable biomass exploitation).

(Agenda 21, 1998)

Each country depends on a specific type of economy and large research projects are developing different indicator sets to measure urban sustainable development. Numerous organizations such as the European Union (EU) and the United Nations Commission on Sustainable Development (UNCSD) have developed indicator frameworks on sustainable development which are set up to monitor the implementation of the EU Sustainable Development Strategy at the national level (European Commision, 2004).

The UNCSD constructed a sustainability indicator framework for the evaluation of sustainable development (Singh, Murty, Gupta & Dikshit, 2009). A hierarchical framework groups indicators into 38 sub-themes and 15 main themes, which are divided between the four aspects of sustainable development (Fig. 2).

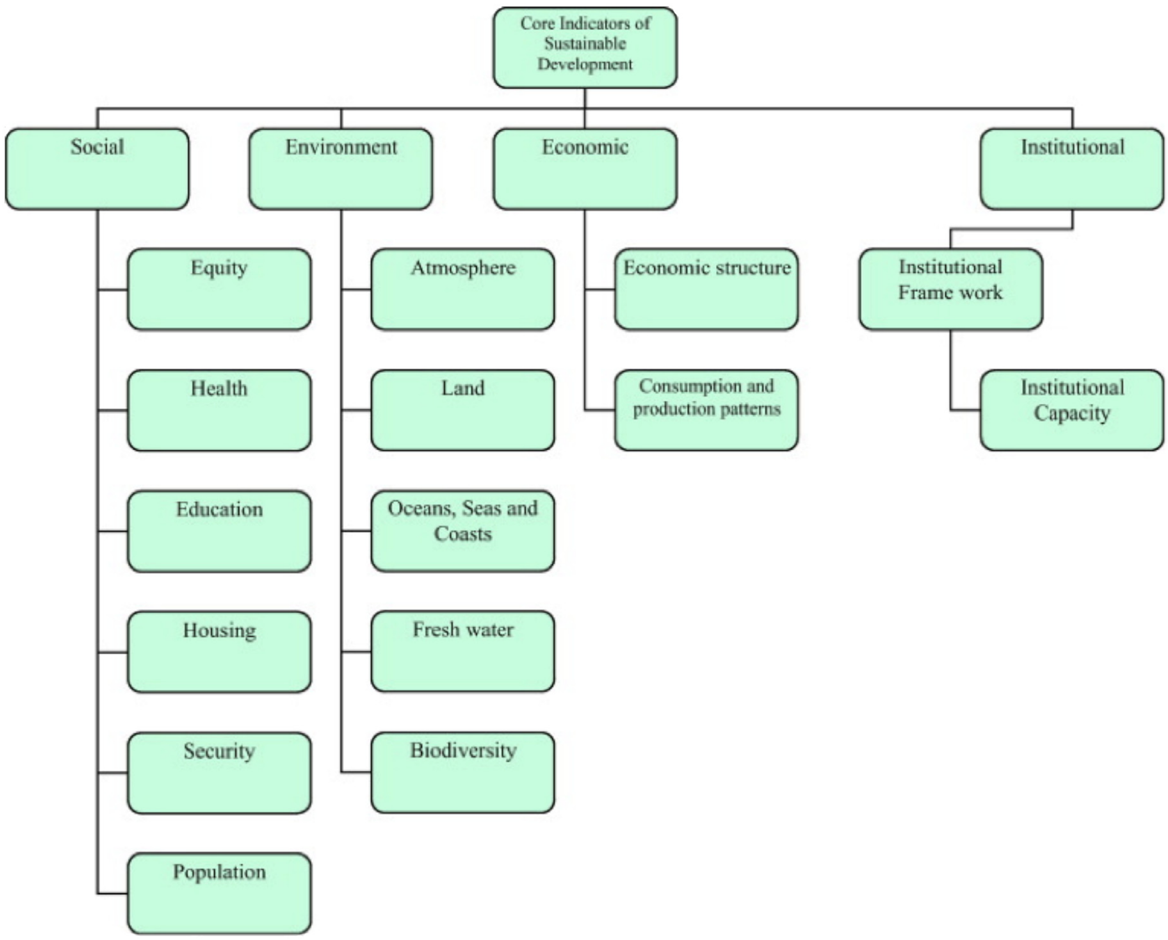


Fig. 2. *The United Nations Commission for Sustainable Development (UNCSD) Theme Indicator Framework (Source: Labuschagne et al., as cited in Singh et al., 2009).*

Nevertheless, the list of urban sustainability indicators is not finite. Moreover, these indicator frameworks within the EU and UN are not transferable to other parts of the world or to different scale levels. They can be used at global and national scales but for a case study it is essential to be aware of the purpose and to select appropriate indicators.

Several authors have developed a framework for sustainability assessment and several models and integrated assessment techniques have been published and are available for use (Gasparatos, El-Haram & Horner, 2008; Wiek & Binder, 2005; Ness et al., 2007; Singh et al., 2009; Walter & Stützel, 2009; Xing, et al., 2009) and extensive lists of sustainability indicators have been proposed by a number authors (Milman & Short, 2008; Wiek & Binder, 2005; Hellstrom, Jeppsson & Karrman, 2000; Shen, Ochoa, Shah & Zhang, 2010; Murray et al., 2009; Putzhuber & Hasenauer, 2010;

Huang et al., 2009; Xing et al., 2009) addressing different main subjects. For example Huang et al. (1998, 2009) developed urban sustainability indicators for measuring Taipei´s urban sustainability which consists of 6 subsystems – land use, population, transportation, water resource, solid waste and waste water treatment, which were organized to deal with several background disciplines (i.e. economics, sociology, environmental engineering ecology, geography, urban planning, and legal experts organized into a research team). Shen et al. (2010) defined 9 different practices and proposed a comparative basis, namely, International Urban Sustainability Indicator List (IUSIL) which is categorized in 4 different dimensions: environmental, economic, social and governance. The aim of this study was to compare different practices of urban sustainability in order to select suitable urban sustainability indicators.

This paper focuses on two different approaches to get a better understanding of sustainability assessment. The first one was developed by Russia and provides a set of indicators (Homich, Kakareka, Kukharchik & Kravchuk, 2004; Kravchenko, 2006; Kulashova, 2004; Sizov, 2002; Trifonova & Krasnoshekov, 2004). The second one is a UK method to measure sustainability based on UK framework indicators developed by the UK government.

2.4 The Russian approach

Kulashova (2004) noted research on the condition of separate components of a city environment (soil, vegetation, snow cover and ground layers of the atmosphere), allowing him to develop qualitative and quantitative system of accounting for adverse factors at carrying out a cadastral estimation of the lands (for example the city of Ivanovo). Homich et al. (2004) suggested new trends in urban land assessment in Sverdlovsk which allowed them to assess the relation between different functional land use systems (residential area, industrial, transportation, recreational area, etc.) and pollution sources and spheres of air, ground water and soil contamination. This project examined an indicator set of natural and human impact which was tested by Kravchenko (2006) in the Kursk district that included 8 cities in Russia.

The aim of the study was to develop an indicator set of natural and human impact in the Kursk district in order to assess the urban land. In line with the study aim, several objectives were planned in this research work: (1) to develop urban sustainability indicators of natural and human impact; (2) to identify urban natural-geographical conditions, population density, sanitation and conditions of life leading to satisfaction; (3) to assess anthropogenic pressure; and (4) to develop an arrangement that maintains an ecological and environmental balance.

The author identified 17 natural-anthropogenic impacts which include geo-morphological condition, land depression, water regime, soil quality, land resource, and industrial activity. Based on these impacts 14 main indicators were formulated: geological processes, gully erosion, soil acidification, marshy land, land polluted by heavy metal, organic matter, pesticides, wastes and grey water and land degradation. These indicator sets allowed the identification of the relationships between form, types, intensity of human activity and the natural environment.

Urban land quality assessment has following steps as Kravchenko (2006) points out:

1. To assess urban land quality using integrated indicators which consist of natural and anthropogenic indicators. Natural indicators include geological, geo-morphological, microclimate, hydrology and soil (see Tables a and b in Appendix 1). Anthropogenic indicators are technogenic depression on the surface, ecological condition, urban planning and life satisfaction and their changes (see Table c in Appendix 1). The evaluation process is that each indicator has criteria and it starts with a score 3 to 1. The sum of the score can be tracked against progress or deterioration.

2. To assess urban land quality by land use type (industry, transportation, residential area, built-up area, etc.) (Table d in Appendix 1). Kochurav (2006)'s comprehensive methods (specifically of land use in Russia) appeared to be the most universal evaluation method for determining the significance of dependence of anthropogenic pressure on the correlation of different land use on concrete territory. For determination of the degree of anthropogenic modification (AM) of land the system uses classification units of land cadastre assessed by an effective scoring system. Each land type gets a corresponding score based on its ecological state, after which land areas are grouped into homogenous groups; the form of the AM, minimal on land of natural units, up to a maximum AM for lands which are occupied by industry and transport (Kolbovskii, 2008).

2.5 The UK approach

The UK government's purpose was to set a more clearly sustainable track, as defined by the WCED (1987): "a better quality of life for everyone, now and for generations to come". In 1999, the UK established many new democratic bodies in Scotland, Wales and Northern Ireland to cope with facing the challenge of achieving sustainability (Scottish Executive, Northen Ireland Office & Government, 2005). The UK government and the administrations in Scotland, Wales and Northern Ireland produced a "UK strategic framework for sustainable development" to function until 2020, and to introduce a new set of high-level indicators – the "UK Framework Indicators" – to monitor the key issues on a UK basis (HMGovernment, 2005).

The UK Framework Indicators aim to provide an overview of progress across the four themes of sustainable consumption and production, climate change and energy, protecting natural resources and enhancing the environment and creating sustainable communities which can indicate information on international trends, not just what is happening in the UK (Scottish Executive et al., 2005). Assess by the Department for Environment, Food and Rural Affairs of the UK (DEFRA) there are 68 indicators that measure everyday concerns including health, housing, jobs, crime, education and the environment (DEFRA, 2010). The UK Government Strategy assess and report on using all the UK framework indicators annually and use this assessment, together with other evidence from monitoring and evaluation, to determine goals or to develop different policies.

The twenty key indicators (see Appendix 2) are selected to provide a framework for a proposal for sustainable development. In order to measure progress sustainability, a set of traffic lights assessment method is used:

 = clear increasing
 = little or no change
 = clear deterioration
 = insufficient or no data

The traffic lights that are green, amber or red across the indicator measures in the latest year together with their positions in an earlier base year indicate the trends (DEFRA, 2010).

The UK indicators are arranged into environmental, social and economic categories and with more focus on human health and well-being provide comprehensive measures, although to make use of them for another area or under different circumstances it is obviously necessary to adapt them to local circumstances and problems. For instance, an urban system would not include information on countryside characteristics, on land and soil with a lesser emphasis on social inclusiveness (Therivel, 2006). Considering that the indicators is established and assessed based on proposal and data availability of Darkhan which are selected from UK framework indicators. These are used to describe the urban sustainability and identify problems which in turn influence the strategic action objectives.

3. STUDY AREA

3.1 General Introduction of the study area

The city of Darkhan (or in Mongolian: Дархан, which means a blacksmith) is located in central Mongolia, approximately 236 km northwest of Ulaanbaatar, in Darkhan-Uul *Aimag* (province), close to the Russian border. As its name implies, the city was originally conceived as a manufacturing site for Mongolia's northern territory. The city was built with extensive economic assistance from the Soviet Union on October 17, 1961. Today, Darkhan is the second largest city in Mongolia but still with a population less than one-tenth that of the capital city, Ulaanbaatar. According to Planning and Development Collaborative International (PADCO) 86% of the aimag's population live in residential blocks in Darkhan and most of the residents are young people. It is one of the most intensively industrialized cities in Mongolia with a high population density (Ganbold, 2000; PADCO, 2005). Even though Darkhan covers only small area there are 102.2 thousand head of livestock as well as people (PADCO, 2005).

3.2 Environmental condition

3.2.1 Geography

The city of Darkhan is a municipal unit of Darkhan province in the northern part of Mongolia (Fig. 3). The total territory of the city is 10315 ha and it is the second largest city in Mongolia. On average it has an altitude of 707 meters above sea level in the region of Orkhon and the Selenge River basin. The highest point is Modot Mountain, at 905.7 meter above sea level, and the lowest point is the valley of the River Kharaa, at 720 meters above sea level. Generally it is located in the valley of the Burkhant with a landscape of mounds and mixed hills. The borders of Darkhan

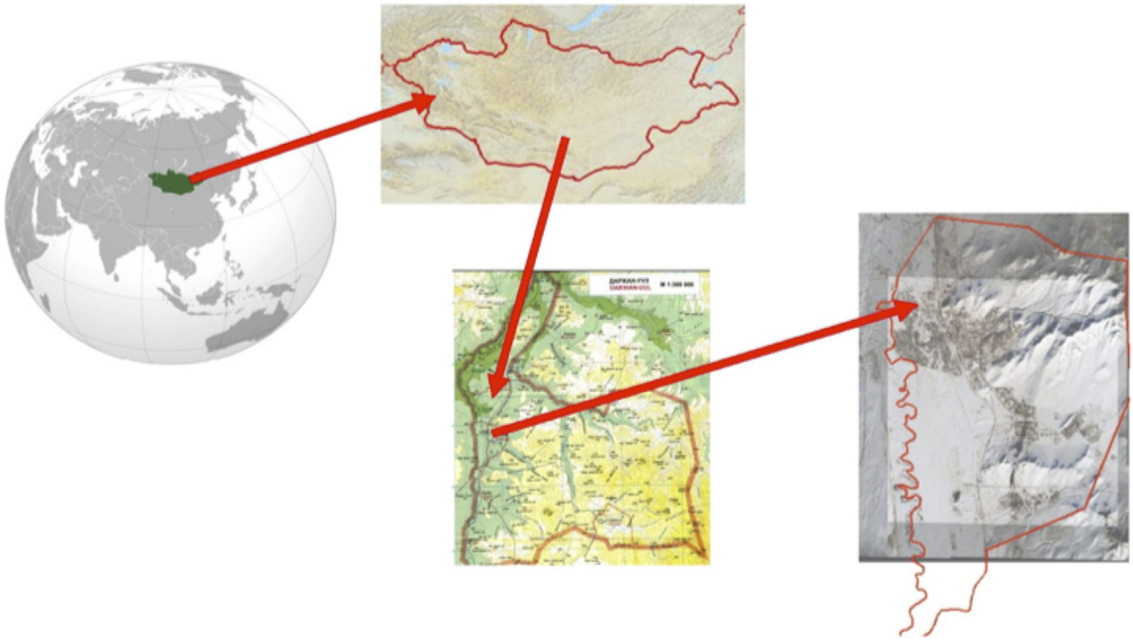


***Fig. 3.** Geographical location of case study (Darkhan city of Darkhan province in Mongolia).*

city are: Khongor *soum* in the south-east, Orkhon *soum* in the north and Saikhan *soum* of Selenge province in the west. It is 220 km from the capital city of Ulaanbaatar (e_Darkhan.com, 2009).

3.2.2 Climate

Darkhan has a harsh continental climate with four distinctive seasons, high annual and diurnal temperature fluctuations, and low rainfall. It has generally a cold winter and hot summer. However, sometimes the cold winter continues for a long time with ground frost and during summer the daytime can be very hot, though cooling at midnight, with the wind speed higher during the day and slackening at night, usually leading to poor precipitation. These are the characteristics of a harsh continental climate which promote the growth of particular plant species and vegetation. The average annual temperature is 0.3°C, with the lowest temperature -23.6°C in January and the highest 18.8°C in July. Since 2000 the average annual hot temperature has increased and the hours of sunlit are long. Darkhan has over 260 sunny days per year (Narmandakh, 2009).

The average annual precipitation is 324.8 mm with the highest precipitation 77–86 mm in July and August and the lowest precipitation 2.8–2.9 mm in February and March. A total of 60.8% of annual wind force is calm but at the beginning of March it is increased to 10–25 m/s and sometimes becomes 28–32 m/s. Wind direction is prevailing from north, north-east and north-west (Narmandakh, 2009).

3.2.3 Soil

The soil type of Darkhan city includes the Khangai-Khentiin region's soil. The dominant soil type of the province is brown soil of the dale steppe in Darkhan and meadow soil spread over the valley of the River Kharaa (Narmandakh, 2009).

3.2.4 Vegetation

Even though the territory is small the vegetation cover differs from desert plants to weeds. More precisely there are 169 species from 37 families, of which 157 species or 92.8% are from 34 families of weed plants (Agency of Land Affair, Geodesy and Cartography, 2006).

Forty years after Darkhan city was established, exotic species emerged, due to anthropogenic impact, causing overgrazing around the city. According to the ecological analysis of these 157 species of weed plants, they belong to 7 groups such as epiphytic, terrestrial, epiphytic-terrestrial, and aquatic plants. Of the 15 biological groups of weed plants found throughout Mongolia 13 groups grow in Darkhan city. From these groups, aerial roots and primary roots are dominant and spread over 69.2% of the total territory (Nyamdorj, 2004)

3.2.5 Bird population

There are 19 bird species in Darkhan city such as *Coccothraustes Coccothraustes, Parus major, Acanthis flammea, Passer domesticus, Passer montanus, Acanthis hornemanni, Calandrella rufescens, Motacilla alba, Pirgilauda davidiana, Bombycilla garrulous, Motacilla citreola, Anthus richardi, Embeiza pallasi, Parus cyanus, Parus ater, Calandrella cinerea, Parus montanus, Turdus sibirica,* and *Motacilla flava*. *Passer domesticus* and *Passer montanus* are widespread in the case study area (Purev, 2009).

3.3 Socio-economic conditions

Beginning in 1962, Mongolia's major industries were particularly construction materials developed by Mongolian and Soviet workers from the various former socialist countries such as the Soviet Union, Hungary, Poland, and Czechoslovakia who came to work in Darkhan. Land use in the industrial district of Darkhan includes a cement factory, a steel plant and a sheepskin processing plant. In recent years, small and medium-sized enterprises have been developed including a meat processing plant, flour mill, and small-scale producers of bakery products, confectioneries, dairy products, soft drinks and alcoholic beverages. Today this is a highly industrialized region of Mongolia (e_Darkhan.com, 2009; Ganbold, 2000).

The city population has been stable from 2002 to 2009 (Table 2), but the growth rate is about 3.2% per year and the number of out-migrants has also steadily increased by 1,414 (PADCO, 2005).

Darkhan has the distinction of being the city with the only metallurgical plant in Mongolia because the surrounding land is rich with iron ore. The metallurgical plant of Darkhan produced MNT 248 billion worth of products, including iron wire, steel reinforcement, steel conductors,

Table 2. *Population of Darkhan city (data from the Statistical Office 2009 Annual Report, Darkhan-Uul province).*

	Darkhan city						
	Population (2002)	Population (2004)	Population (2006)	Population (2008)	Population (2009)	Area (km²)	Density in 2009 (/km²)
Darkhan	70,029	74,275	73,457	75,104	74,454	103	722.85

etc. The infrastructure of Darkhan is well developed with an international railway system connecting the country to Russia and China. A north-south railway runs through Ulaanbaatar and Darkhan City. The roads of the city are paved, though some are gravel roads. The city has reliable energy sources. A modern telecommunication system and communication services such as Internet and satellite cable TV transmissions and cell phone services are also available (Ganbold, 2000).

The second largest educational centre in Mongolia is located in Darkhan. There are 12 higher schools and scientific institutes, including the Medical College and branches of the Mongolian University of Science and Technology, and the Agricultural University.

3.4 Structural and administrative entities

The city of Darkhan is the capital of Darkhan-Uul province which is one of the 21 *aimags* of Mongolia. It is one of 4 districts of the province Darkhan-Uul *aimag* which includes 16 subdistricts, called *bags*. Darkhan city includes three zones: the Old Darkhan in the north, New Darkhan in the south and, further south, the main industrial zone with heavy industry and the thermal power station (Fig. 4). To the north of Old Darkhan there is another, smaller industrial zone, blocks of flats and a ger area[1]. Ger areas can be found within bags 1, 2 and 3 in the west of Old Darkhan, and bags 5, 6, 7 and 8 in the east of Old Darkhan (Fig. 5) (IWAS & UFZ, 2010). Bags 6 and 7 are the oldest and most densely populated ger areas in Darkhan (MoMo, 2009). These two ger areas in Old Darkhan are separated by the railway line. In New Darkhan there are mostly blocks of flats and private houses and only one ger area, within bag 15 (Fig. 5) (IWAS & UFZ, 2010).

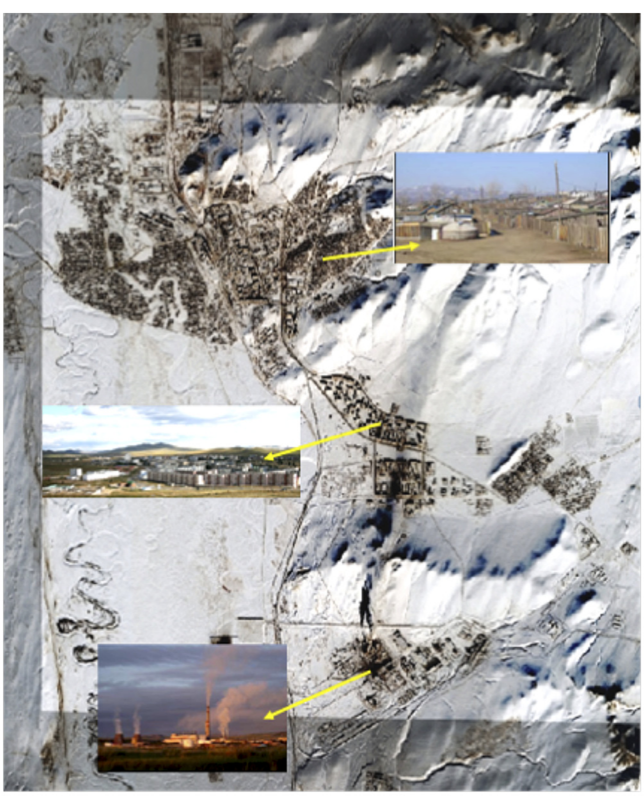


Fig. 4. *Land use map of Darkhan.*

[1] *Ger area: Portable felt traditional dwelling structure or tent, also known as a yurt. More information in Section 4.2*

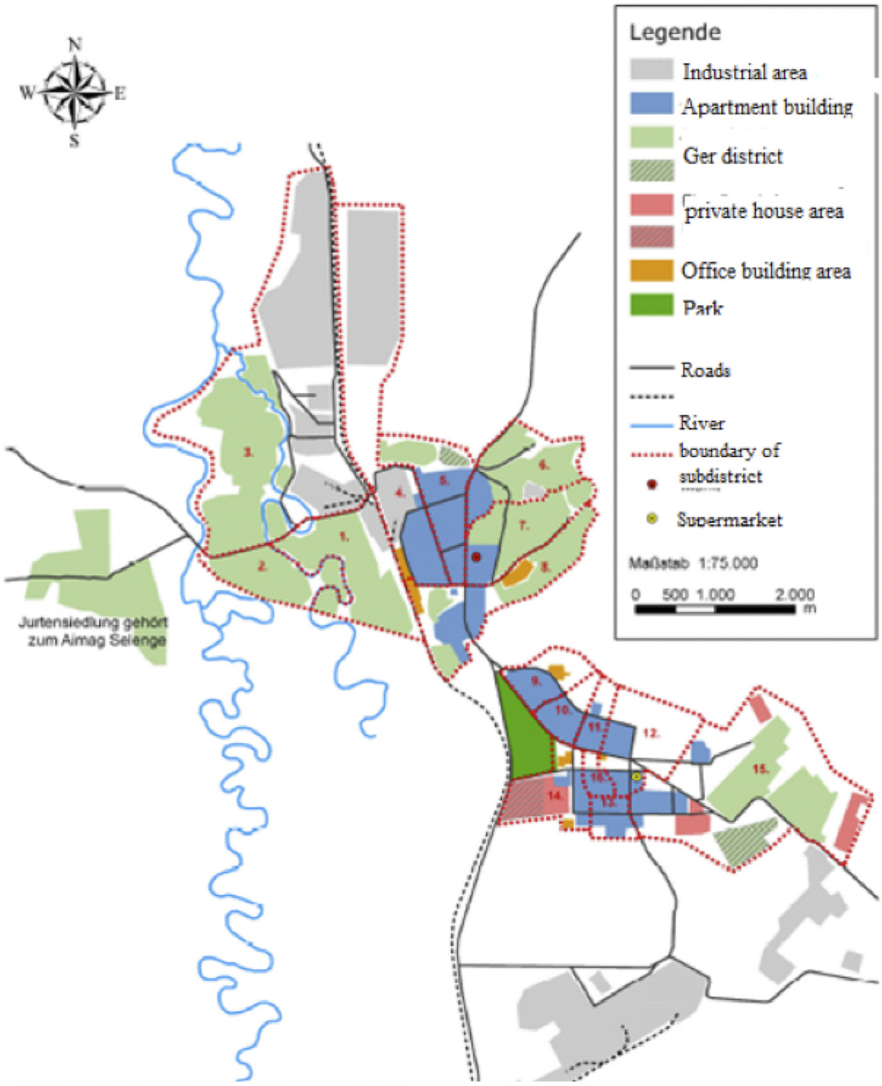


Fig. 5. *Map of Darkhan city (Source: Römer as cited in and translated from IWAS & UFZ, 2010).*

4. ANALYSIS OF CURRENT CONDITIONS

4.1 Land use

Land cover and land use in an urban area are key aspects of the urban dynamic. All of the land uses and processes mentioned above have a significant influence on local hydrology and land degradation, resulting both urgent scientific, political and management tasks.

The spatially most important land use activities in Darkhan city are industrialization, settlement and grazing. However, mainly in Darkhan the area taken up by heavy industries and blocks of flats is large compared to other secondary cities. In Darkhan city the main types of land cover are built-up land (67%), agricultural land (25%) and roads and network lines (7%) (Fig. 6).

The rural population is resettling in and around towns and small cities at the moment, driving increasing fractionation of settlement. The uncontrolled spread of informal *ger* settlements is

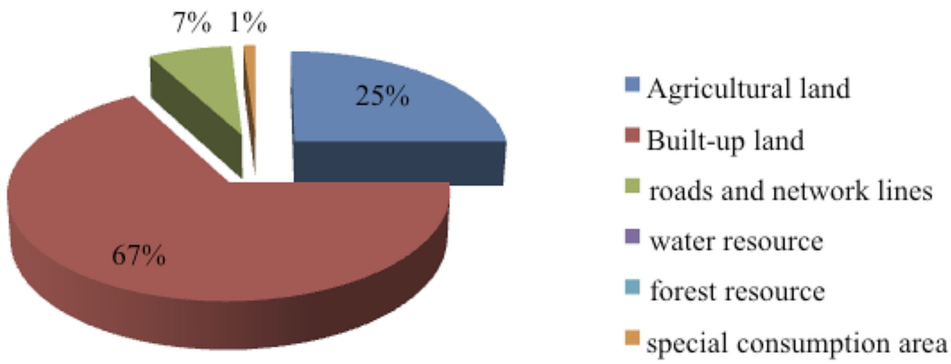


Fig. 6. *Land cover of Darkhan (Data from land registration document of Darkhan city).*

common, mostly with inadequate supplies of water, energy and other services (MOMO, 2009). Table 3 shows more detailed information on land use. In the last few years the built-up area has increased due to the increase in *ger* settlements around the city, with in-migration the main source of population growth. The on-going urbanization leads to considerably higher private water consumption, air pollution, and land degradation in the urban environment.

Table 3. *Land use in Darkhan city (Data from land registration report of Darkhan city, 2007).*

	Land use types	**Capacity (ha)**	**%**
1	**Agricultural land**	2583.63	67
	Pasture (grassland)	2480.06	
	Arable land (potato and other vegetables)	103.57	
2	**Urban area**	6949.63	25
	Resident area	391.57	
	Recreation area	40	
	Common area (road, street)	1402.57	
	Waste water treatment plant	25	
	Cemetery area	40	
	Landfill	270	
	Open space	3467.9	
	Industrial area	379.25	
	Mining area	287.9	
	Ger district	645.44	
3	**Roads and network lines area**	699.95	7
	Roadways	402.05	
	Network line area	108.9	
4	**State special consumption area**	81.79	1

4.2 Housing conditions

In Darkhan city three distinct types of housing can be identified: blocks of flat, private houses and *gers*. In the *ger* areas people live in *gers* and/or in private houses. The *ger* areas comprise approximately 3,750 households living on 444 hectares of land. Over 30% of Darkhan's population live in *ger* areas without access to basic services available to flat dwellers, including heating, sewerage and solid waste services. Most households use simple coal or wood-burning stoves for heating and cooking, and there are no solid waste collection or sewerage services. There are also no paved roads or street lighting, limiting access particularly in winter, and disrupting water delivery when roads become impassable (PADCO, 2005). Potable water is available through 30 kiosks, which are mainly supplied by trucks. Of 2,000 Darkhan households (12.5% of total households) living below the poverty line 1,875 or 94% live in *ger* communities (PADCO, 2005). Table 4 shows the distribution between the three types of housing in Darkhan city where about a half the residents (49.5%) live in *ger* areas.

Table 4. *Housing situation in Darkhan city (Source: IWAS & UFZ, 2010).*

Total number		Apartment blocks		Private houses		Gers	
households	residents	households	residents	households	residents	households	residents
20,345	75,006	10,795	37,847	5,337	20,415	4,213	16,744
		53.1%	50.5%	26.2%	27.2%	20.7%	22.3 %

4.3 Air pollution

Air pollution has become a serious problem in urban areas in Mongolia in the past decade. Sources of air pollution include emissions from mobile sources or vehicles; stationary sources-combined heat and power plants, industry, household stoves, refuse burning, road dust, sandstorms. There are many agents such as poisonous gas, dust, biological agents, and noise to indicate air pollution, but the stations which control air pollution in urban areas measure only nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and emitted dust. Darkhan's atmosphere is believed to contain all the major air pollutants today. It has damaged the urban environment as well as depressed land soil.

Perhaps the single largest problem pollutant in the city is particulate matter. The case of Darkhan is particularly alarming due to suspended particulates that are generated by wind-blown dust, the incomplete combustion process of industries and traffic, household stoves, as well as limestone quarrying, nearby cement factories, and again the burning of rubbish, all contributing to high rates of pollution in the urban atmosphere. The mean particulate concentration in Darkhan as shown in Fig. 7 is between 30–533 $\mu g/m^3$ and is two to three times higher than the AQS[2] and even international accepted standards (US-EPA[3]). Suspended particulate matter measurements show that pollution peaks in the winter time. In recent years, health studies have established a direct relationship between the concentration of particulate matter and premature deaths and excess morbidity (World Bank, 2004).

[2] *Notes: AQS - Mongolian air quality standard from MNS 4585-97*
[3] *US-EPA - US Clean air act of 1999*

During the winter, each household in the *ger* area consumes approximately 5 tons of coal and 4.7 m^3 of wood for household heating and cooking which contribute approximately half the air pollution in the city (World Bank, 2004). The means for SO_2 and NO_2 in the winter months are already higher than the air quality standards (AQS), as shown in below figures (Fig. 9). The maximum NO_2 concentration (Fig. 8) has been between 30–52 μg/m^3 during the winter months or almost twice the AQS. NO_2 is usually caused by vehicle emissions and the power

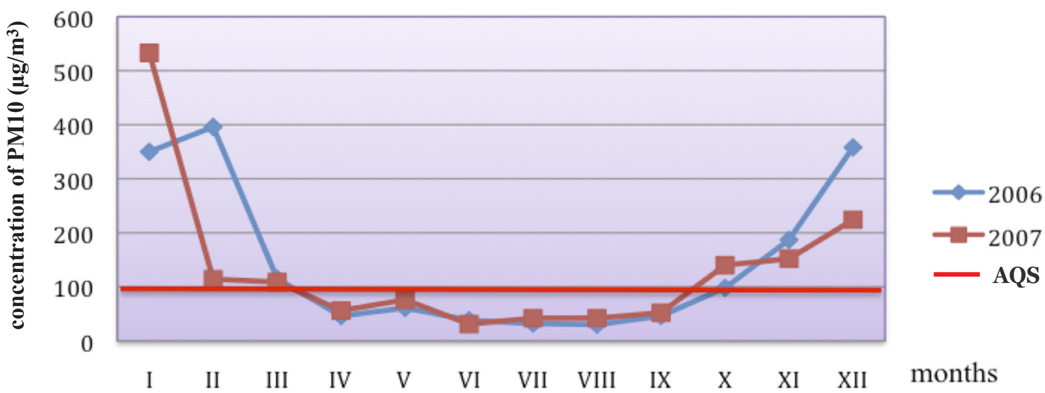


Fig. 7. *Particulate matter (PM10) based on data from Institute of Meteorology (2006, 2007).*

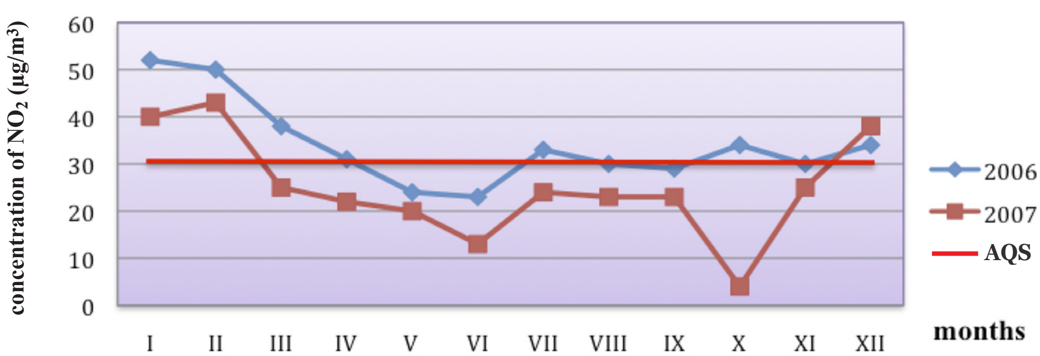


Fig. 8. *Emission of NO_2 based on data from Institute of Meteorology (2006, 2007).*

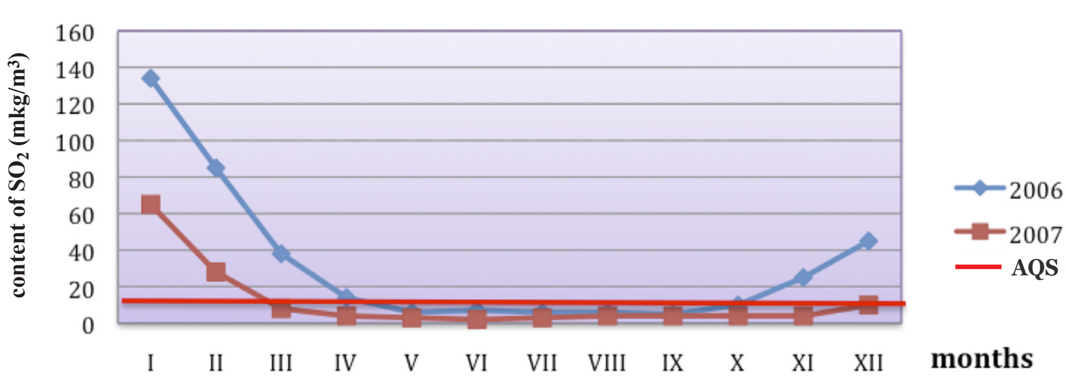


Fig. 9. *Emissions of SO_2 based on data from Institute of Meteorology (2006, 2007).*

plant. Maximum SO_4 components came to 25–134 µg/m^3 or 13.4 times higher than the AQS and emitted from local heating sources and power plants (Fig. 9). Currently around 30% of the land use in Darkhan includes the *ger* districts, according to the planners grant of the land within the framework of the new Land Law which named Mongolian Citizens´ Ownership of Land, and it surrounds the city centre. It provides 60% of the pollution in the city during the heating season, originating for example from coal-burning (World Bank, 2004). It is clear that the pollution in Darkhan city is as high as in Ulaanbaatar and confirmed that air pollution has a strong seasonal pattern, being much worse in the winter months when SO_2 and NO_2, and dust concentrations are many times higher than in the summer.

The higher concentrations of nitrogen dioxide (NO_2) are emitted from vehicles. In addition more than 200 poisonous gases and chemicals such as carbon monoxide, nitrogen and sulphur and lead, are emitted from vehicles when driving at low speeds and stopping at road crossings and traffic lights. Cars average 15000 km annually.w During this time the car has burned 4350 kg O_2 and emitted 3250 kg H_2CO_3, and 7 kg NO_3 (Kravchenko, 2006). For these reasons, measurement of the main road´s traffic intersections can help pinpoint the source of pollution. There are a total of 623 vehicles included 511 cars, 55 trucks and 57 public transportation vehicles measured in Darkhan streets (Table 5). Around 70% of vehicles are 7–10 years old (Nyamtseren, nd) which might be part of the reason for the pollution in Darkhan.

Table 5. *Intensity of transportation of Darkhan (2010).*

City	Cars /number/	Trucks /number/	Public transportation /number/	Total /number/
Darkhan	511	55	57	623

Air pollution influences human health as well as damaging and depressing land quality. Two studies, conducted in 1996 and 2001, have noted that physical growth of children has been negatively impacted by air pollution (World Bank, 2004). The aftermath affects our physiology, such as breathing, eyesight, shock and asthma and heart problems. The primary cause of children´s deaths is bronchitis and for old people pneumonia and asthma. Such diseases among children under 5 years old are 2–3 times higher than in rural areas (Nyamtseren, nd). If this continues, the reasons for death will increase along with the disease rates.

These figures indicate “a significant risk to present and future generations” for standard of living of the people, “but the government has yet to implement any efficient pollution-reduction policies or measures to alleviate the situation.” (“Green Star” Project, 2008, p. 5).

4.4 Water quality

According to the emissions from point sources (direct discharges from wastewater treatment, industrial zones, etc.) and emissions from diffuse sources (diffuse emissions from agriculture, mining industries, atmospheric deposition, etc.) surface water quality has worsened (MOMO, 2009).

The Environmental Survey´s central laboratory to control water quality uses sensors to determine water quality and components and takes and analyses samples using 30 indicators based on how human are impacted (Ochirbat, 1999). In Darkhan, the Institute of Meteorology takes samples and surveys to physical property, temperature, floating substances, solute gases, saline-ion and other micro-elements. The "MOMO" project developed in Mongolia between 2006 and 2009 under the "Research for Sustainability" Programme of the German Ministry of Education and Research has identified the impacts of human pressure in Kharaa river basin and Darkhan city.

The "MOMO" project (2009) noted that mean discharge of the Kharaa decreased from around 21.5 m^3/s for the years 1990–1995 to 8.6 m^3/s in the period 1996–2002 (Fig. 10), mainly driven by less precipitation and higher potential evapo-transpiration. These effects may also be partly due to anthropogenic water use.

In terms of water pollution the analysis was based on data from water censors (point 1, point 2), showing the water pH was alkaline (8.31–8.40) and nitrate levels were NO_3 0.213–0.521 mg/l, and though not too high above a standard level nevertheless giving an annual high (Table 6).

The location of point 2 is near an industrial zone and drinking water supply system in the south part of Darkhan, and it‘s higher than point 1. This might be one of the reasons for the water pollution. But the discharge of inadequately treated wastewater to surface water resources is a major water-quality concern. The waste water is pumped to an infiltration pond in the centre of the town (MOMO, 2009).

The waste water from the industrial zone of Darkhan is discharged to the WWTP (Waste water treatment plant) of Darkhan but the plant has significant problems as it operates with out-dated technology, its cleaning efficiency with regard to the reduction of nitrogen and phosphorus concentrations is comparatively low, the polishing pond cannot be utilized in winter, and the purification provides no denitrification, as the "MOMO" (2009) project noted.

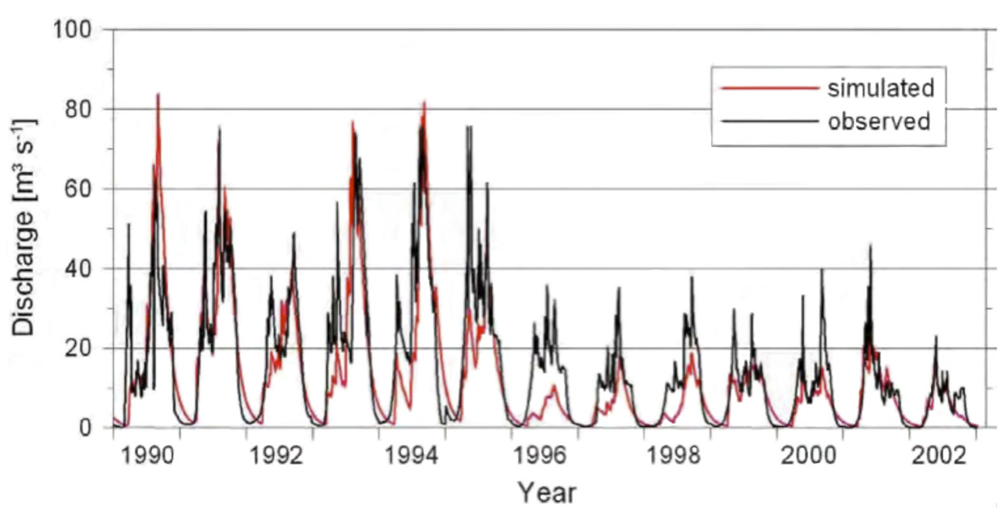


Fig. 10. *Simulated and observed discharge of the River Kharaa near Darkhan (HBV-D Model) (Source: MOMO, 2009).*

Table 6. *Water quality indicators based on data from Institute of Meteorology for 2006 and 2007.*

Year	Sampling point	Na+k	Co	Mg	NH_4	Fe	Cl	SO_4	NO_2	NO_3	HCO	pH	Hardness
2006	Point 1	23.22	28.12	15.68	0.073	0.061	5.74	34.45	0.003	0.213	167.47	8.39	2.68
	Point 2	26.52	29.80	17.46	0.149	0.077	11.21	37.99	0.002	0.521	174.88	8.35	2.86
2007	Point 1	17.14	36.42	13.07	0.081	0.06	6.34	28.00	0.005	0.227	171.88	8.31	2.89
	Point 2	17.75	38.09	13.83	0.143	0.086	9.21	29.76	0.009	0.429	174.35	8.40	3.03
Tolerate level		-	-	-	0.5	-	300	100	0.02	9.0	-	6.5–8.5	-
Annual average		-	-	-	0.261	-	-	-	-	0.295		7.6	1.9

This analysis of industrial water supplement compared to the maximum level of tolerable water component shows that the levels of NH_4 (0.04–6.95 mg/l), NO_2 (0.010–1.181 mg/l), NO_3 (0.029–12.80 mg/l) and P (0.05–2.18 mg/l) are higher than the water quality standards (Table 7) and constitute several of the sources of water contamination of the River Kharaa originating from the city of Darkhan.

In 2007 in Khongor *soum* there was a chemical accident from chloride and boron which caused high concern that the infiltrated waste water had contributed to the contamination of the upper ground water level. Drinking water extraction sites for Darkhan are only 9 km away from this place and this contamination problem has a high priority for the drinking water supply of Darkhan city (Fig. 11) as described in detail by Hofmann as cited in MOMO (2009).

Table 7. *Infiltrated waste water from the Waste Water Treatment Plant of Darkhan to the River Kharaa in years 2006 and 2007 (Data from Institute of Meteorology). Note: cells coloured yellow indicate above standard level.*

Matter	pH		NH_4		NO_2		NO_3		SO_4		Cl		P		Cr		Cleaning process (%)	
Years months	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
1	7.85	7.84	1.14	12.4	0.030	0.215	9.85	8.70	71.9	48.30	49.88	7.10	1.26	17.2	0.007	0.012	81.7	91.7
2	7.70	7.75	4.98	0.140	0.24	0.035	5.70	11.44	54.45	49.55	29.78	63.8	2.18	1.86	0.012	0.008	91.8	84.2
3	8.24	7.56	3.96	0.15	1.68	0.010	8.44	12.80	8.23	60.0	41.83	86.8	1.14	1.66	0.008	0.007	83.2	85.1
4	7.62	7.50	3.31	0.12	0.285	0.17	4.40	12.1	105.2	59.5	6.74	57.5	1.10	1.74	0.008	0.011	90.8	89.3
5	8.08	8.52	1.178	0.44	0.835	0.295	3.99	10.34	44.75	49.94	48.57	48.0	1.56	1.47	0.011	0.011	93.9	85.8
6	8.48	8.41	0.440	0.60	0.005	0.315	0.985	8.90	43.71	38.0	9.57	12.4	0.05	1.73	0.005	0.004	91.7	94.1
7	8.17	7.79	0.082	0.04	1.181	0.150	0.029	0.665	26.6	42.35	25.52	44.5	1.44	2.11	0.008	0.011	90.4	97.2
8	8.53	8.36	0.205	0.05	1.135	0.815	8.55	10.25	35.85	33.5	22.6	17.8	1.52	1.24	0.009	0.006	92.9	85.7
9	8.02	7.98	0.020	0.69	0.655	0.050	10.3	7.10	43.4	11.45	8.94	10.0	1.14	1.60	0.007	0.004	89.1	83.6
10	7.86	7.59	2.345	0.10	0.060	0.335	4.36	14.7	59.05	11.0	88.5	32.0	1.64	1.89	0.010	0.010	91.5	91.7
11	7.66	8.24	1.92	0.15	0.075	0.020	3.68	3.60	70.0	19.5	87.0	48.0	1.64	1.98	-	0.010	96.3	85.0
12	7.86	7.97	5.12	6.95	0.060	0.120	8.76	6.05	52.7	18.0	108.1	79.5	1.34	1.39	0.006	0.020	92.8	85.9
Tolerate level	6.5–8.5		0.5		0.02		9.0		100		300		0.1		0.05		-	

__Fig. 11__. Khongor (A) site of a chemical incident in 2007. The drinking water extraction sites of Darkhan (B) are only 9 km away from Khongor (Source: MOMO, 2009).

The drinking water extraction for Darkhan comes from 18 ground water wells 8 km south of the city Darkhan near the River Kharaa. The drinking water supply system (DWSS) is distributed to 3 zones (Old Darkhan, New Darkhan and Industry) and 558 consumptions points, as MOMO (2009) noted.

For urban *ger* residents drinking water is predominantly supplied from private wells and water kiosks. The ground water level is only 2 to 4 m below the surface of the flood plain west of the railway line where residents have private wells. Ground water is the only source of drinking water available for larger cities but there is no data on ground water level and no information about the ground water resources situation and no measurement of heavy metals in the project area. The quality of the water is not controlled and contamination from the pit latrines cannot be ruled out. It is a significant problem that the population is exposed to high health risks (IWAS & UFZ, 2010; MOMO, 2009) and that the water doesn´t meet sanitary requirements.

4.5 Soil degradation

The soil is a natural resource and it is very difficult to renew and expensive to reclaim or improve when its properties have been subjected to chemical or physical deterioration (Van Lynden & Oldeman, 1997). The number of land degradation problems includes loss of the topsoil which indicates heavy degradation of the land. The loss of the productive rhizosphere is not only caused, but soil pollution leads to degradation by limiting plant cover (Castro Filho, Cochrane, Norton, Caviglione & Johansson, 2001).

Soil pollution is measured by several indicators such as physical, chemical, and biogeochemical defined as the combined negative effect of chemicals and chemical processes on those properties that regulate the life processes in the soil and which can be caused either by natural processes or by anthropogenic activities (Singh et al., 2009). In the organic topsoil organisms are the most active and pollutants accumulate in this section first, so it is essential to assess the risk of soil pollution (Glasovskaya, 1990). The main source of soil pollution in an urban area is air pollution, in Mongolia from vehicular exhaust (Ochirbat, 1999). During the flooding in spring time, most of the pollutant matter remains in the soil but other pollutants move to the ground water and surface water (Kravchenko, 2006).

Because of the high air pollution observed in winter time and in view of the paucity of information about soil pollution of study area, snow pollution data have been used. Snow pollution analysis has shown a pH of 10.95, or highly alkaline around the central hospital, and NH_4 was measured at 9.510 mg/l over the Meteorological Office, after sampling at 20 points, or higher than is tolerable (Appendix 3). High concentrations of NH_4 can lead to eutrophication and loss of biodiversity.

Other sources of soil pollution in Darkhan city are solid waste, the *ger* district's latrines, air pollution and sewage drains. Some urban *ger* settlements are contaminating soil due to breeding pigs, chickens, fixing old machinery, and gathering building materials such as cement (Land monitoring of urban ger district, 2000).

Soil erosion in Darkhan city has led to loss of the topsoil, soil compaction, gullies caused by off-road driving, windblown and flood borne materials, and chemical pollution of the soil also has occurred. The soil around the town and districts has no more vegetative cover, which is why the top 20–30 cm of soil in some parts has been eroded by the wind and even subsoil has been exposed down to 40–70 cm. According to the soil monitoring results the amount of soil lost from the ravines or gullies differed depending on their depth and width with; on average 10.62 tons/ha lost annually (Nyamdorj, 2004). The amount of the soil lost from the gullies and topsoils is increasing every year. Odonchimeg (2008) measured the amount of soil lost through water erosion in Darkhan using GLASOD (global assessment of human induced soil degradation). There were 23 points of active gullies determined during the first monitoring in Darkhan and 5 points of active gullies were measured to ensure results for several criteria (Table 8).

Table 8. *Measurement of active gullies of Darkhan (Source: Odonchimeg, 2008).*

Number of the research point		**Width of top of the gully [m]**	**Width of bottom of the gully [m]**	**Depth [m]**	**Total length (m)**	**Amount of lost soil (tons/ha)**
I	1.	4.03	1.42	2.55	1035	94
II	2.	6.2	1.8	1.44	41	3.11
	3.	2	1.08	1.44	21	0.61
III	4.	4.92	4.84	2.27	96	13.9
IV	5.	4.8	2.56	5.4	771	200.7
	6.	5.92	2.72	1.94	536	58.8
	7.	6.1	2.32	2.96	75	12.2
V	8.	26.9	22.4	2.5	597	482.8
Total						**866.12**

Mijiddorj (2004) noted that when the amount of the soil lost is less than 2.5–5 ton/ha, there is no negative impact on ecosystem resilience. From Table 8, the length of the gullies is up to 1035 m and amount of the soil lost up to 482.8 ton/ha which came from off-road driving (30%), surface run-off (30%) and sand pits (20%) (Table 8). It is shown that the soil lost has been 90 times higher than the ecosystem resilience level (Odonchimeg, 2008) and human induced activities generated this type of land degradation due to disturbing the land cover and vegetation.

5. RESULTS

5.1 Result based on the Russian experience

Based on the indicators developed by Kravchenko (2006), the calculations of the values of each indicator are shown in Table 9 and Table 10.

The results of the assessment based on baseline conditions in Darkhan, the total value of both natural and anthropogenic impacts was 1.35. It is indicated that conditions in Darkhan are unsustainable and both sets of impacts adversely affect the urban land use system in Darkhan. The main processes involved are air and soil contamination, sanitation effluent from households, gully erosion, land degradation due to off-road driving, and sand pits.

Table 9. *Natural indicator system of urban land quality in Darkhan.*

	Natural impacts	value	coefficient
Geology-geo-morphological condition			
1.	Surface slope: 3–7 °	1	0.125
2.	Depth of ravine: 10–20 m	2	0.100
3.	Density of ravine: less than 1 km	2	0.100
4.	Mechanical components of ground soil: slight and medium clay	2	0.150
5.	Depth of groundwater: 3–15 m	1	0.100
6.	Gully erosion: active gully	1	0.050
7.	Landslide and subsidence: no data		
8.	Coastal plain erosion: less than 10 m width	1	0.025
Soil and hydrological condition			
9.	Soil: lea and brown soil	1	0.050
10.	Land degradation: intensive, for little area	1	0.075
11.	Infrequent flood out area: less than 10%	2	0.025
12.	Flood out period: no data		
13.	Stagnant water and marshy land: hard to dry	0	0.025
Microclimate condition			
14.	Protection from wind: non protected area from gale	1	0.025
15.	Pollution source located in town	0	0.025
16.	Sunlit: ordinarily for all year	2	0.025
17.	Aspect of slope: south slope	3	0.025

According to the assessment of land use (Table 11), the **highest pressure** level included the industrial and mining area (667.15 ha or 6.46%) and transportation, communication, and the engineering network area (699.95 ha or 6.78%). In all this embraced 1367.1 ha or 13.25% of the urban land.

The **high pressure** area was for public utility (5245.47 ha or 50.85%), residential areas (391.57 ha or 3.96%), the military and special consumption area (0.79%), and *ger* settlement (645.44 ha or 6.25%). In all this accounted for 6364.27 ha or 61.69% of the total urban land.

The **medium pressure** area included only agricultural land 2583.63 ha or 25.04%. There was no low pressure area in Darkhan.

Table 10. *Anthropogenic indicators of urban area.*

Main anthropogenic impacts		value	coefficient
1. Technogenic depression and sanitation			
1.	Technogenic depression: less than 1–2 m	1	0.125
2.	Surrounding by open mining: local mining with little area	2	0.100
3.	Potential of industry: high	2	0.100
4.	Intensive of transportation: intensity (more than 400 number/hour)	2	0.150
5.	Sanitation: poor	1	0.100
6.	Green cover: 15–20%	1	0.050
2. Social welfare, human well-being and urban planning level			
7.	Population density: less than 5 thousand people/km^2	1	0.050
8.	Built-up area: more than 30 %	1	0.075
9.	Water supply: mixed system	2	0.025
10.	Waste water treatment plant: available WWTP	2	0.025
11.	Sewage drain: available	0	0.025
12.	Household heating system: mixed (power plant and stokehold)	1	0.025
13.	Hot water supplement: 0–40 %	1	0.025
14.	Gas supplement: 0	0	0.025

Table 11. *Anthropogenic pressure of land use.*

Assessment	Land use	Darkhan city	
		ha	Percent
Higest	Industrial	1367.1	13.25
	Transportation, Communication		
High	Public utility	6364.27	61.69
	Apartment complex, residential		
	Administration, commercial		
	Military		
Medium	Special and other urban	2583.63	25.04
	Agricultural land		
Low	Recreation (commercial and public)	0	0
	Water		
Total		10315	100%

To demonstrate the analysis of the data, several thematic maps were created based on indicators using ArcGIS software which included air pollution, soil contamination, housing condition, land use modification, geo-morphological condition, soil erosion, etc. (see maps 1 and 2). Some of the geo-morphological indicators such as slope, aspect, sunlit, prevailing wind and gullies are shown in map 1, based on a topographic map. Other factors were not mapped because of the lack of data and information at the district level. However, the map shows the spatial distribution of natural conditions and suitable land for urban development and planning. In map 2, most of the anthropogenic impacts identified are shown, including how different residential preferences and landscape characteristics shape the development of urban areas, in turn affecting energy use and pollution patterns. A combination of table and maps can show the consequence of land use type and the value of the results. Such information is vital in order to determine policy for land restoration planning, urban planning and development.

5.2 Result based on UK experience

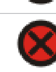
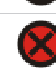
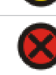
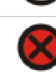
The UK indicators are arranged into environmental, social and economic categories focusing on comprehensive measures of human health and well-being. The method has to be adapted to local circumstances and problems. For instance, urban systems would not include information on countryside characteristics (Therivel, 2006). The indicators are here assessed based on the research proposal and data availability for Darkhan and shown in the following table, as selected from UK framework indicators (Table 12). These are used to assess the urban sustainability and identify problems, which help to develop strategic action objectives.

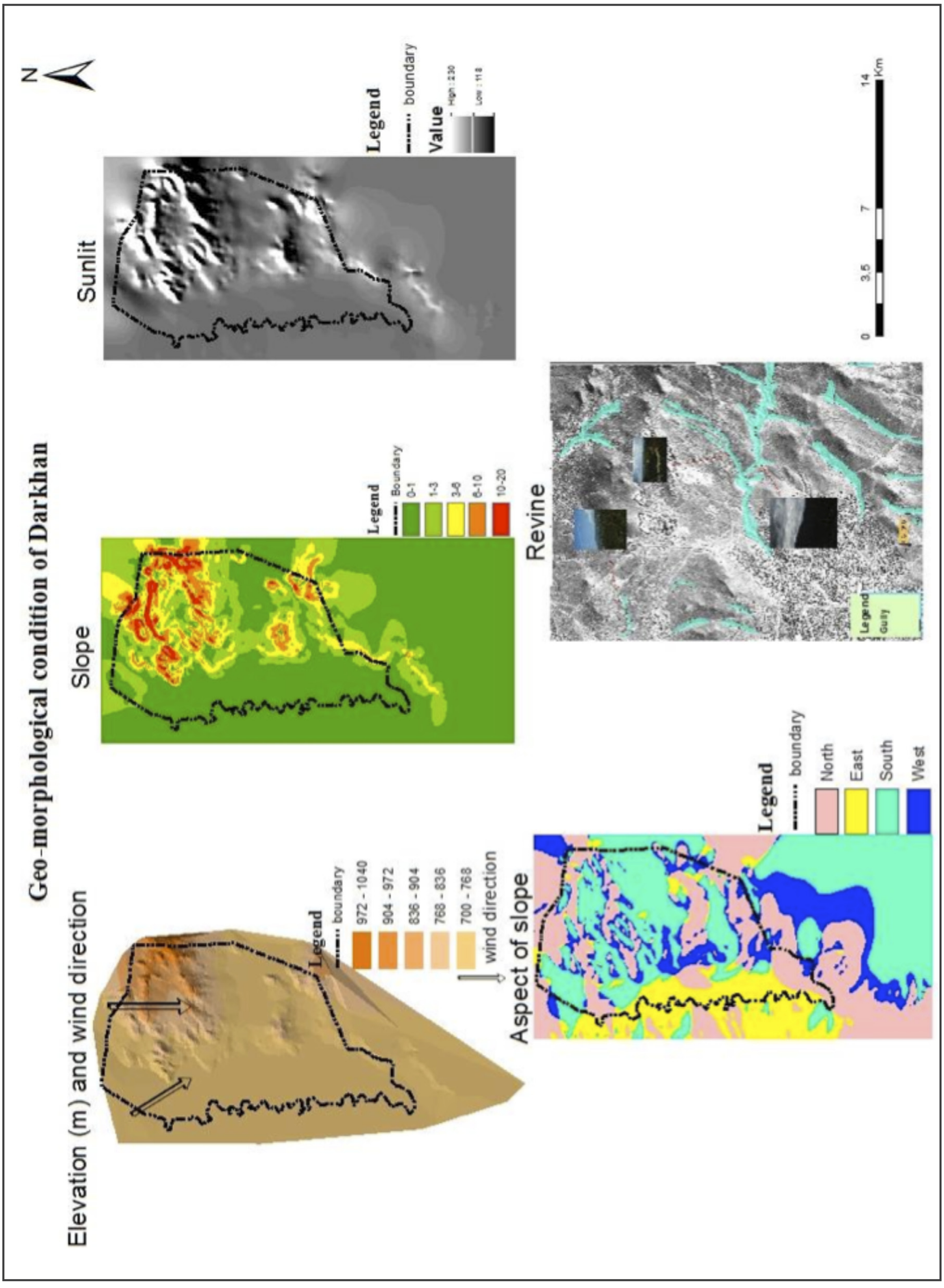
The UK´s approach to assessing sustainable development is based on a different structure to the Russian one. The indicators in Table 12 show whether there has been improvement, deterioration, or no change. Six measures show improvement and seven show deterioration. Those showing improvement include land use, land recycling and flooding. Indicators showing deterioration include local environmental quality and household satisfaction. This assessment highlights similar challenges as the Russian method but also defines trend of urban sustainability.

5.3 A comparison between the Russian and the UK methods

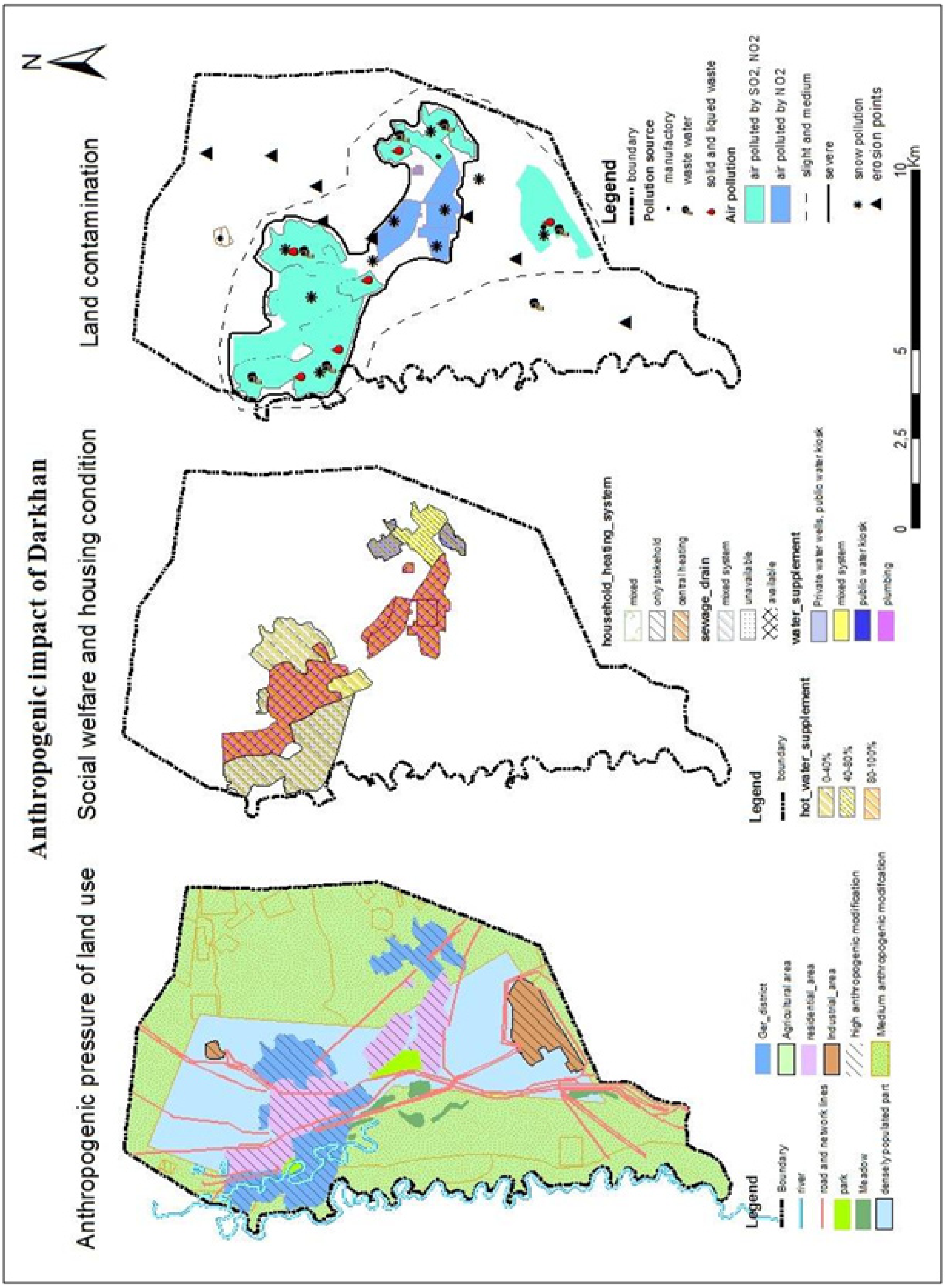
The question arises as to which indicators can be used to bring about urban sustainability. To give an answer to this question, this paper examined two practices selected from developed countries and regions in the world, Russia and the UK. The generalities of each practice are presented in the previous part with the aim to show the purposes, goals, methodology and indicator frameworks applied to urban sustainability assessment. This can help to generate a big picture for each of these practices. The different practices tell us different stories of development of sustainable urbanization, the selection of urban sustainability indicators and their application. These processes were developed at different times, under different circumstances, and for varied purposes but by and large for achieving sustainable urbanization. The differences between practices also reveal the difficulties in applying a set of common urban indicators. In this section a comparison is made between the selected practices.

Table 12. *Sustainability assessment of Darkhan city using UK framework indicators. Note: the meaning of the traffic lights is presented in subsection 2.5 (p. 11).*

Indicator number and title		Measures	Assessment
2.	Carbon dioxide emissions	CO_2 emissions from the burning of fossil fuels	
6.	Household energy use	Domestic CO_2 emissions	
13.	Resource use	Domestic Material Consumption	
18.	Waste arising	Million tonnes of waste produced by sector	
		Percentage of municipal waste recycled or composted, incinerated or landfill	
20.	Bird populations	Number of bird species	
23.	Protected area:	Percentage of surface area protected	
24.	Land use:	Area covered by agriculture, woodland, water or river, residential	
25.	Land recycling:	Percentage of new dwellings and all development built on previously developed land	
29.	Emissions of air pollutants:	Emissions of NH_3, NO_x, PM10, SO_2	
26.	Dwelling density		
30.	River quality	Percentage of classified river length of good chemical and biological quality	
31.	Flooding	Number of properties at risk of flooding	
32.	Economic growth	Gross domestic product per head of population	
35.	Demography	Total population – contextual	
36.	Households and dwellings	Total dwelling stock – contextual	
55.	Mobility	Number of trips made by public transport or taxis, walking and cycling	
61.	Air quality and health	Annual levels of PM10 concentrations	
62.	Housing conditions	Percentage of households below decent homes standard	
		Number of households living in fuel poverty	
65.	Local environment quality	Percentage of population living in households they consider to be suffering from noise	
		Percentage of population living in households they consider to be suffering from pollution	
66.	Satisfaction in local area	Percentage of households satisfied with quality of places which they live; overall and in deprived areas	



__Map 1.__ Description of natural impact of Darkhan using indicators in Table 9. Prevailing wind comes from the north and north-east and over 20% of the area is 900–1040 m above the sea level. Most of the area has a 0–3° slope; however, the northern and eastern areas have from 3° till 20° slope with prevailing aspect mostly south and north. As shown in the sun light maps, in the normal sunlit area, the north and north-east parts have a natural ravine whose depth is about 10 m.



Map 2. *Description of anthropogenic impact of Darkhan using indicators in Table 10. As shown in the land use map, the high pressure of human impact occurs in the built-up area including the ger district, apartment, houses, industry, and transport lines especially contaminate the land; housing conditions are fair in the ger district, which is the main source of the pollution; and there is medium impact outside of the residential zone. More than 30% of the area is "built-up" and 33% is green space..*

According to selected indicators, the Russian evaluation system is more detailed in natural and anthropogenic pressures which include environmental, social and economic dimensions at the local level. But the UK system takes account of global impacts, not just what is happening in the UK and it has high compliance with environmental and social dimensions. Both methods focus on “a better quality of life for everyone, now and for generation[s] to come”, which is the widely used international definition of the WCED (1987).

Indicators can be described or measured in different ways, for instance air pollutants indicators, which can be expressed by PM10 concentration, quantity emitted or CO_2 content. Therefore, for the purpose of proper analysis, the descriptions and units of measurement for the indicators included in urban sustainability indicators must be clear in order to avoid repetitions and to enable a better classification.

There are, for example, different ways of defining and measuring household conditions, of classifying the dimensions: percentage of households below minimum home standard, number of households living in fuel poverty, household energy use (as in the UK system); household heating system, sewage drains, hot water supplements, etc. (as in the Russian system).

A sustainability indicator set based on integration of the two practices is suggested but some criteria had to be adapted (Appendix 4) to better fit the case study conditions and available data. The 21 indicators identified in the indicator set are those which seemed to be the most important to measure sustainability of urban land use (Appendix 5), and land degradation, human well-being, happiness, resource utilization, and risks are outlined.

Table 13 represents the final evaluation results of Darkhan´s sustainability (see also Map 4). The total value of the indicators is 1.28, indicating that Darkhan´s ecological sustainability, water resources and living conditions are fair condition with further environmental and land management moving into an unsustainable trend toward “fair condition”. The following list gives a few problems in urgent need of attention:

Imbalance between natural conservation and economic development

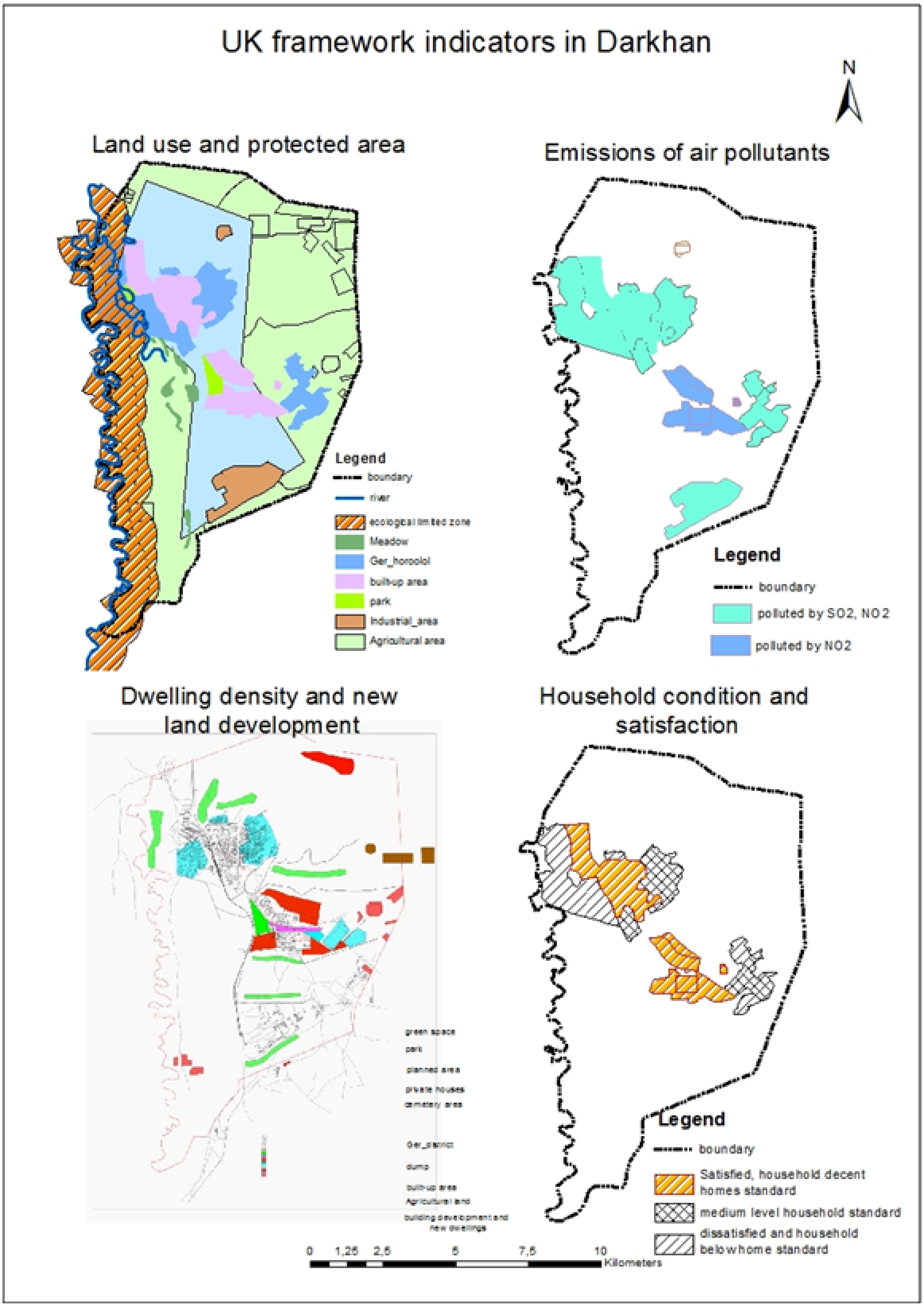
- Depletion of water resources and water quality deterioration
- Land degradation due to off-road driving, surface run-off and soil chemical pollution
- Sanitation due to inadequate development
- Urban green cover meets requirement but aesthetics of scenery lacking

Impact of economic development on the living environment

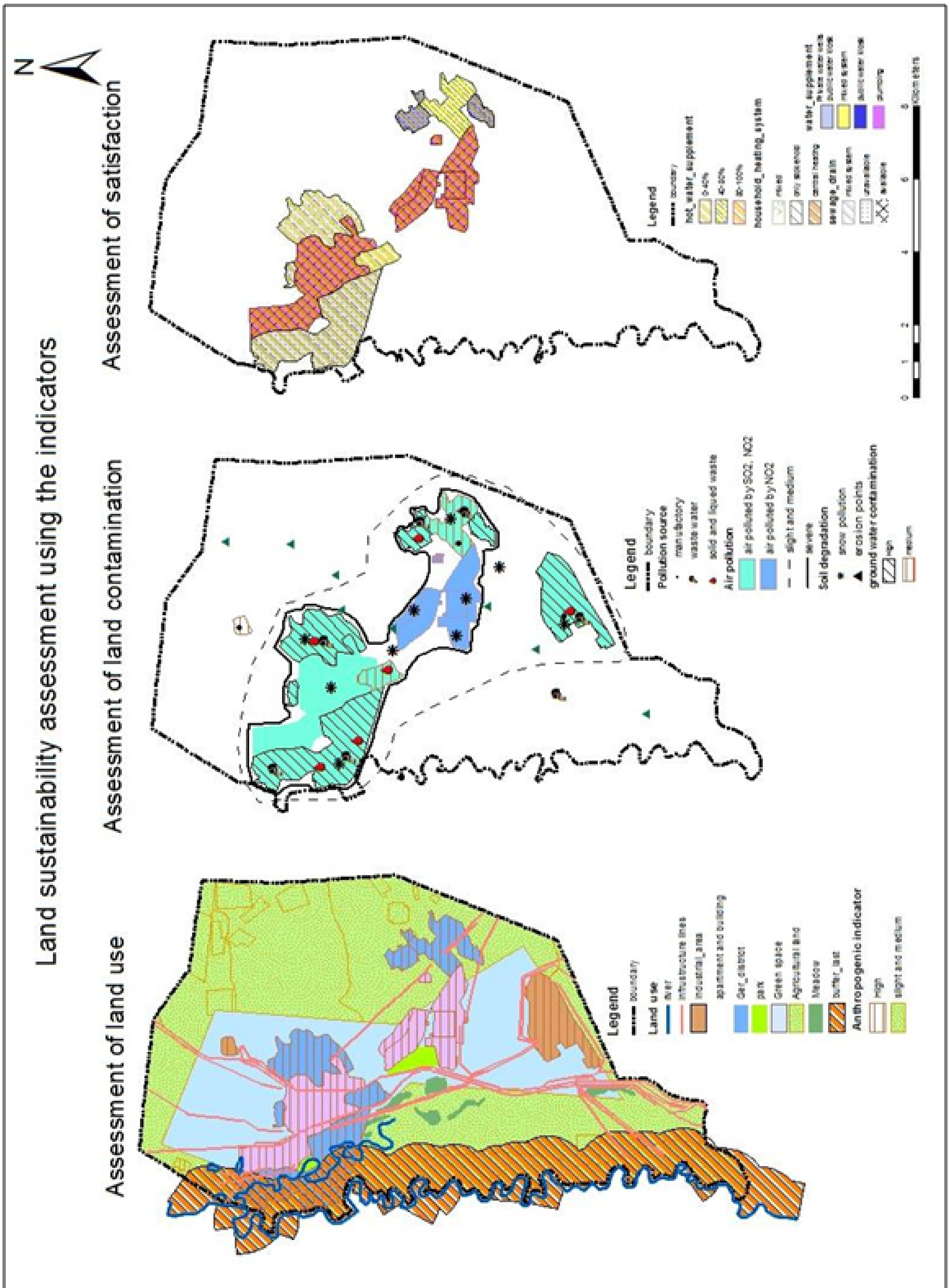
- Air quality problem due to traffic roads, household heating and power plant
- Increase of solid waste and lack of resource recycling
- Lack of recreation areas for amenity and safety as compared to green coverage and open space
- Surrounded households below decent home standard due to inadequate urban land use planning and land mismanagement
- Lack of urban renewal in old town district
- Impact of human activity on the natural environment
- Inefficient land management due to separate urban planning, political, environmental management

Table 13. *The suggestion of land sustainability assessment of urban area in Mongolia.*

№	Indicators	Value	Trend
1. Technogenic depression and sanitation			
1	**Air quality**		
	Polluting day/year > 40	0	↓
2	**Technogenic depression in the landscape**		
	Technogenic depression (Off-road net and geological exploration fields, artificial deposition in the settlement and industrial area, dump and tatter, abandoned land, etc.)		
3	**Bird population (ecological versatility)**		
	More than 7 species	3	→
4	**Ground water contamination**		
	Medium	1	↓
5	**Soil quality**		
	Slight and medium	2	↓
6	**Flood out area of total urban land %**		
	Less than 10	2	↑
7	**Gully erosion**		
	Active gully	0	↓
8	**Surrounding with open mining**		
	Local mining with little area	1	→
9	**Potential of industry**		
	High	0	→
10	**Transport mobility**		
	Intensive (more than 400 number/hour)	0	↑
11	**Waste recycling**		
	No sorting or volume reduction, collected for recycling; once a week every 1–3 times with individual disposal	2	↓
12	**Sanitation**		
	Poor	0	↓
13	**Urban green coverage %**		
	30% < Ratio of Green Cover< 65%	2	↓
14	**Ratio of Park/Green Cover**		
	Park/Total area < 5%	1	↑
2. Social welfare, human well-being and urban planning			
15	**Population density, thousand people/km^2**		
	Less than 5	3	→
16	**Built-up area %**		
	More than 30	0	↓
17	**Water supplement**		
	Mixed system	3	↓
18	**Waste water treatment plant**		
	Available WWTP	2	↓
19	**Sewage drain**		
	Mixed system	1	↓
20	**Household heating system**		
	Mixed (power plant and stokehold)	1	↓
21	**Hot water supplement %**		
	40–80 %	1	↓



Map 3. *Description of UK indicators for Darkhan using Table 12. Some part of the ger district is located in the ecologically limited zone which has high air pollution and household conditions below decent home standards. But other built-up areas satisfied household conditions, though still facing some pollution.*



Map 4. *Integration of Russia and UK indicators in Darkhan using maps 1, 2 and 3. Main land use types are built-up land and agricultural land. Main land contamination including soil and ground water pollution, poor sanitation is in the ger district which has poor household conditions without any infrastructure except electricity. Some part of the ger district is located inside of the ecological limited zone where residents own their land. However, apartments, houses have good household conditions but are located in severely polluted zone.*

6. DISCUSSION

There are various approaches available for sustainability assessment of urban land use reflecting divergent views and interpretations in the various countries where they were developed. The methods fall in three groups on the basis of their methodological foundations: environmental assessment methods, life cycle assessment methods and sustainability indicator assessment methods. Many sustainability assessment methods focus on built environmental and life quality evaluation for sustainability (Adinyira, Oteng-Seifah & Adjei-Kumi, 2007). Sustainability focuses mainly on environmental issues such as resource use, pollution, waste and other aspects of urban development such as social and economic issues, using several methods such as check lists, modelling, and multi-criteria assessment.

The most critical concern of sustainability assessment is how to analyse, integrate and present all the dimensions of information to decision makers. A method based on sustainability indicators is a useful integration tool to combine all this and test sustainability. The main problem was determining which indicators measure actual urban sustainability. This was done by comparison to methods developed in the UK and Russia. Both these methods focus on "a better quality of life for everyone, now and for generation[s] to come" (WCED, 1987) but the Russian method is more detailed. The UK system accounts for global impacts, not just what is happening in the UK, and it has high compliance to environmental and social dimensions.

The basic sustainability indicators have been selected and are reproduced in Appendices 1 and 2. More possible sustainability indicators are shown in Appendix 5. Many criteria were developed in order to provide manageable units of information which help in decision making and these are shown in Appendix 4. This indicator-based method provides for the integration of all the issues that anthropogenic pressure, urban social welfare, land use for dwellings, air, and water, and employs the methods of multiple criteria analysis in one assessment. This methodology established that this is a useful tool for measuring, monitoring, and assessing many urban sustainability issues as well as warning about the risk of lasting social, economic and environmental damage.

7. CONCLUSION

- The method presented here includes establishment of an indicator set that can be integrated over sustainability dimensions and databases and that applies to any urban land use system of Mongolia regardless of type, location, and scale. It can therefore be a basic complete tool for facilitating decision making that is oriented to sustainable development.
- The UK Indicators framework and Russia´s Indicators, when applied to Darkhan, are sufficient to undertake a comprehensive characterization of sustainability and can be included as part of the local set as they characterize relevant aspects of urban sustainability and allow urban development in Darkhan to be compared to that in other secondary cities.
- This study determined that there are a total of 21 sustainability indicators and criteria that can be used to develop urban sustainability assessment and to identify/test the strengths and weaknesses of an urban land use system. Urban sustainability assessment returned a value indicating unsustainability. The main categories of problem causing Darkhan´s unsustainable development are the impact of economic development on the living environment and imbalance between natural conservation and economic development.
- There are some weaknesses in the indicator system developed for Darkhan. Some of the indicators are not measurable and do not have data for evaluation. But I believe that from these existing indicators decision makers may learn and improve policy effectiveness.

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APPENDIX 1

Table a. Geology – geomorphological indicators

№	Indicators	Scores	Coefficients
1.	**Surface slope (degree)**		
	Till 3	2	0.125
	From 3 till 7	1	
	More than 7	0	
2.	**Depth of ravine (m)**		
	10–20	2	0.100
	20–30	1	
	More 30	0	
3.	**Density of ravine (km/km^2)**		
	Less than 10	2	0.100
	Between 10–20	1	
	More than 20	0	
4.	**Mechanical components of ground soil**		
	Lightly clay soil	2	0.150
	Sand, loam, heavy clay soil	1	
	Porosity clay, ground soil	0	
5.	**Depth of groundwater (m)**		
	Up to 3 m	2	0.100
	3–15 m	1	
	More than 15 m	0	
6.	**Gully erosion**		
	Up to 5 m depth	2	0.050
	More than 5 m depth.	1	
	Active gully	0	
7.	**Landslide and subsidence**		
	None	2	0.050
	Available	1	
8.	**Coastal plain modification**		
	None	2	0.050
	Coastal plain erodability less than 10 m width	1	
	Coastal plain erodability more than 10 m width	0	

Table b. Soil, hydro-geological and microclimate indicators.

№	Indicators	Scores	Coefficients
1.	**Soil**		
	Brown soil	2	0.050
	Soil of lea	1	
	Disappear soil crust	0	
2.	**Land degradation**		
	Slight, for little area	2	0.075
	Intensive, for little area	1	
	Intensive, everywhere	0	
3.	**Flood out area of total urban land %**		
	Less than 10	2	0.025
	Between 10–20	1	
	More than 20	0	
4.	**Flood out period**		
	No flood out	2	0.025
	Less than 10 days	1	
	More than 10 days	0	
5.	**Stagnant water and marshy land**		
	None	2	0.025
	Easy to dry	1	
	Hard to dry	0	
6.	**Protection from wind**		
	Protected area from wind	2	0.025
	Non protected area from gale	1	
	Non-wind circulation area for long time	0	
7.	**Location through the pollution source**		
	From upside of wind	2	0.025
	From downside of wind	1	
	Pollution source located in town	0	
8.	**Sunlit**		
	Normal sunlit area	2	0.025
	Protected from the rays of the sun up to 30%	1	
	Protected from the rays of the sun more than 50%	0	
9.	**Aspect of slope**		
	South slope	3	0.025
	East and west slope	2	
	North slope	1	

Table c. Anthropogenic pressure, urban planning and public satisfaction indicators.

№	Indicators	Scores	Coefficients
1. Technogenic depression and sanitation			
1	**Technogenic depression**		
	Less than 1–2 m	2	0.150
	Till 4–5 m	1	
	More than 5 m	0	
2	**Surrounding by open mining**		
	None open mining	2	0.100
	Local mining with little area	1	
	Open mining of manufactured	0	
3	**Potential of industry**		
	Low	2	0.150
	Medium	1	
	High	0	
4	**Intensive of transportation**		
	Low (till 200 number/hour)	2	0.150
	Permanent (more than 200–400 number/hour)	1	
	Intensity (more than 400 number/hour)	0	
5	**Sanitation**		
	Satisfaction	2	0.050
	Adversity	1	
	Poor	0	
6	**Green cover %**		
	15–20	3	0.100
	7–15	2	
	Less than 7	1	
2. Social welfare, human well-being and urban planning			
7	**Population density, thousand people/km^2**		
	Less than 5	3	0.150
	5–10	2	
	More than 10	1	
8	**Built-up area (%)**		
	Less than 15	2	0.150
	15–30	1	
	More than 30	0	
9	**Water supply**		
	Mixed system	3	0.25
	Plumbing	2	
	Public water kiosks	1	
	Private water wells	0	
10	**Waste water treatment plant**		
	Available WWTP	2	0.025
	Unavailable WWTP	0	
11	**Water canal**		
	Available	2	0.025
	Mixed system	1	
12	**Household heating system**		
	Central heating (power plant)	2	0.025
	Mixed (power plant and stokehold)	1	
	Only stokehold	0	
13	**Hot water supplement (%)**		
	80–100	2	0.025
	40–80	1	
	0–40	0	
14	**Gas supplement (%)**		
	80–100	2	0.025
	40–80	1	
	0–40	0	

Table d. Classification of land according to anthropogenic pressure.

№	Type of land use	Value	Assessment
1	Land with industry, transport, infrastructure, degraded land	4	Highest
2	Land of Public buildings and facilities, Apartment complex Administration, residential, Military, Special and other urban	3	High
3	Agricultural land, recreational area (commercial and public)	2	Medium
4	Water body and special protected area and objects	1	low

APPENDIX 2

UK FRAMEWORK INDICATORS

1. **Greenhouse gas emissions:** Kyoto target and CO_2 emissions
2. **Resource use:** Domestic Material Consumption and GDP
3. **Waste:** arising by (a) sector (b) method of disposal
4. **Bird populations:** bird population indices: (a) farmland birds (b) woodland birds (c) birds of coasts and estuaries
5. **Fish stocks:** fish stocks around the UK within sustainable limits
6. **Ecological impacts of air pollution:** area of UK habitat sensitive to acidification and eutrophication with critical load exceedence
7. **River quality:** rivers of good (a) biological (b) chemical quality
8. **Economic output:** Gross Domestic Product
9. **Active community participation:** civic participation, informal and formal volunteering at least month
10. **Crime:** crime survey and recorded crime for (a) vehicles (b) domestic burglary (c) violence
11. **Employment:** people of working age in employment
12. **Workless households:** population living in workless households (a) children (b) working age
13. **Childhood poverty:** children in relative low-income households (a) before housing costs (b) after housing costs
14. **Pensioner poverty:** pensioners in relative low-income households (a) before housing costs (b) after housing costs
15. **Education:** 19 year olds with level 2 qualifications and above
16. **Health inequality:** (a) infant mortality (by socio-economic group) (b) life expectancy (by area) for men and women
17. **Mobility:** (a) number of trips per person by mode (b) distance travelled per person per year by broad trip purpose
18. **Social justice:** (*social measures to be developed*)
19. **Environmental equality:** (*environmental measures to be developed*)
20. **Well being:** (*well being measures to be developed if supported by the evidence*)

APPENDIX 3

№	Sampling point	Ph		NH_4		NO_3		SO_4		Cl	
		2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
1	Gurvan shar	7.38	7.84	0.460	1.695	0.575	0.615	8.020	5.60	2.13	19.50
2	Nekhii	8.79	7.97	0.570	1.490	0.875	0.280	75.05	52.45	3.90	35.45
3	Near the Industrial zone	9.82	7.76	0.740	0.735	0.555	0.260	80.80	35.15	3.54	24.80
4	Mangirt district	9.72	7.91	0.760	0.630	0.855	0.280	67.05	25.40	6.74	19.50
5	PSARTI	9.66	7.95	0.500	0.450	1.175	0.320	95.70	19.5	2.13	15.98
6	Private house	10.60	8.26	0.480	0.815	1.515	0.595	86.50	75.0	2.84	23.05
7	Hotel Darkhan	8.83	7.69	1.710	1.885	1.620	0.280	84.25	29.75	8.15	24.80
8	Toirog	8.90	7.96	2.960	0.715	1.070	0.260	46.40	20.90	5.32	12.40
9	Hospital	10.95	7.90	0.940	0.960	0.640	0.400	92.25	10.50	3.90	8.45
10	Heetei subdistrict	8.80	7.83	1.400	0.530	1.390	0.500	71.35	21.20	4.61	12.40
11	Buyan trade	8.06	7.55	3.620	8.040	2.135	0.420	75.65	78.30	28.36	23.05
12	Ger district	7.47	7.52	2.600	1.675	1.345	0.100	87.10	17.55	5.32	8.85
13	Railway	7.44	7.73	2.960	1.120	2.390	0.080	92.80	9.75	8.15	12.40
14	WWTP	7.40	7.77	2.580	1.470	1.730	0.815	78.50	31.95	4.61	8.85
15	V bag ger district	7.26	7.72	5.720	4.200	2.305	0.360	96.00	77.35	8.86	23.05
16	Tolgoit	7.24	7.75	5.575	1.470	2.220	0.795	96.85	29.50	8.86	15.95
17	Meteorology office	8.04	7.67	9.510	2.980	0.980	0.480	98.55	27.10	15.60	19.50
18	Food industry	8.08	7.36	2.210	6.405	1.045	0.300	29.20	53.90	2.13	35.45
19	Micro district	7.41	7.46	4.010	2.120	1.280	0.180	73.05	41.70	14.89	12.40
20	Central laboratory	7.60	7.76	1.930	3.00	2.240	0.755	43.85	42.45	8.15	8.85
Max		10.95	7.97	9.510	8.040	2.390	0.815	2.390	78.30	98.55	14.89
Min		7.26	7.36	0.460	0.450	0.555	0.080	0.555	9.75	8.020	2.13
Threshold		6.5–8.5		0.5		9.0		100		300	

APPENDIX 4

Dimension	Sustainability indicators	References
Environ-mental impact	Atmosphere quality (air pollution)	ECI (European Commision, 2003), UNCSD (Singh, et al., 2009), IUSIL (Shen et al., 2010), (Xing, et al., 2009), (Wiek & Binder, 2005) (Huang, et al., 2009), (Scipioni, Mazzi, Mason & Manzardo, 2009).
	Land use	ECI, UNCSD, IUSIL, (Putzhuber & Hasenauer, 2010), (Huang, et al., 2009), (Xing, et al., 2009)
	Biodiversity	UNCSD, IUSIL, Huang, et al. 2009), (Xing, et al., 2009)
	Noise	ECI, IUSIL, Huang, et al. 2009), (Xing, et al., 2009)
	Waste	ECI, UNCSD, (Wiek & Binder, 2005), (Scipioni et al., 2009), (Huang, et al., 2009)
	Chemical use for drinking and waste water treatment	UNCSD, IUSIL, (Lundin & Morrison, 2002; Walter & Stützel, 2009), (Murray, et al., 2009), (Milman & Short, 2008), (Danko & Lourenco, n.d), (Scipioni et al., 2009), (Balkema et al., 2002)
	Sludge to landfill	(Lundin & Morrison, 2002)
	Land quality (Soil erosion, Soil loss, compaction, heavy metal accumulation,	USAFE,(Walter & Stützel, 2009), (Huang, et al., 2009), (Wiek & Binder, 2005)
	Greenhouse emission	ECI (2003), USAFE, (Huang, Wong & Chen, 1998),(Walter & Stützel, 2009)
	Fuel use	UNCSD, USAFE, (Putzhuber & Hasenauer, 2010; Walter & Stützel, 2009)
Social impact	Health	UNCSD, IUSIL, (Walter & Stützel, 2009; Xing, et al., 2009)
	Quality of life (poverty)	IUSIL, (Scipioni et al., 2009), (Xing, et al., 2009), (Huang, et al., 2009)
	Housing condition	UNCSD, IUSIL, (Wiek & Binder, 2005), (Xing, et al., 2009)
	Satisfaction	ECI, Xing et.al. 2009
	transportation	ECI (2003), USAFE, UNCHS (1995), IUSIL (2010), (Wiek & Binder, 2005), (Scipioni et al., 2009), Xing et.al. 2009, (Lundin & Morrison, 2002), (Huang et al., 2009)
	Population density	UNCSD, (Danko & Lourenco, n.d; Putzhuber & Hasenauer, 2010; Scipioni et al., 2009; Huang et al., 1998)
	Mobility	ECI, (Putzhuber & Hasenauer, 2010)
Economic impact	Employment	UNCSD, (Wiek & Binder, 2005; Putzhuber & Hasenauer, 2010; Scipioni et al., 2009)
	Whole life cost	(Putzhuber & Hasenauer, 2010; Xing, et al., 2009)
	Income average	(Wiek & Binder, 2005)
	Urban productivity	ECI, IUSIL, UNCSD,(Huang, et al., 2009)

ECI – European Common Indicator
UNCSD – United Nations Commission´s Sustainable Development
IUSIL – International Urban Sustainable Indicators
USAFE – Urban Sustainability Assessment Framework for Energy

APPENDIX 5

№	Indicators	Value
1. Technogenic depression and sanitation		
1	**Air quality**	
	Polluting day/year <10	3
	20<Polluting day/year <10	2
	20<Polluting day/year <40	1
	Polluting day/year > 40	0
2	**Technogenic depression in the landscape**	
	Natural geomorphological process	2
	Technogenic depression (Off-road net and geological exploration fields, artificial deposition in the settlement and industrial area, dump and tatter, abandoned land, etc.)	1
	80 % of total area changed technogenic depression or artificial deposition	0
3	**Biodiversity (ecological versatility)**	
	More than 7 species	3
	5 to 6 species	2
	Less than 3 to 4 species	1
4	**Ground water contamination**	
	Pure	3
	Low	2
	Medium	1
	High	0
5	**Soil quality**	
	Conforms to the standards	3
	Slight and medium	2
	Severe	1
6	**Flood out area of total urban land %**	
	Less than 10	2
	Between 10–20	1
	More than 20	0
7	**Gully erosion**	
	Till 5 m depth	2
	More than 5 m depth.	1
	Active gully	0
8	**Surrounding by open mining**	
	No open mining	2
	Local mining with little area	1
	Open mining of manufactured	0
9	**Potential of industry**	
	Low	2
	Medium	1
	High	0
10	**Transport mobility**	
	Low (till 200 number/hour)	2
	Permanent (more than 200–400 number/hour)	1
	Intensity (more than 400 number/hour)	0

№	Indicators	Value
11	**Gully erosion**	
	Wastes sorted, volume-reduced, and collected for recycling and reuse with toxic substances removed; treated daily	3
	No sorting or volume reduction, collected for recycling; once every 1–3 times with individual disposal	2
	No sorting or volume reduction; once every 1–3 times with individual disposal	1
	No sorting at all, disposed open dump, once a week with individual disposal	0
12	**Sanitation**	
	Good	2
	Fair	1
	Poor	0
13	**Urban green coverage %**	
	Ratio of Green Cover< 65%	3
	30% < Ratio of Green Cover< 65%	2
	15% < Ratio of Green Cover< 30%	1
14	**Urban green coverage %**	
	10% < Park/Total area < 15%	3
	5% < Park/Total area < 10%	2
	Park/Total area < 5%	1
2. Social welfare, human well-being and urban planning		
15	**Population density, thousand people/km^2**	
	Less than 5	3
	5–10	2
	More than 10	1
16	**Built-up area %**	
	Less than 15	2
	15–30	1
	More than 30	0
17	**Water supplement**	
	Mixed system	3
	Plumbing	2
	Public water kiosks	1
	Private water wells	0
18	**Waste water treatment plant**	
	Available WWTP	2
	Unavailable WWTP	0
19	**Sewage drain**	
	Available	2
	Mixed system	1
	Unavailable	0
20	**Household heating system**	
	Central heating (Power Plant)	2
	Mixed (power plant and stokehold)	1
	Only stokehold	0
21	**Hot water supplement %**	
	80–100%	2
	40–80%	1
	0–40%	0