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LAND SUITABILITY ANALYSIS FOR URBAN AND AGRICULTURAL LAND USING GIS: CASE STUDY IN HVITA TO HVITA, ICELAND

Gerlee Puntsag
Administration of Land Affairs, Geodesy and Cartography
Government building-12, Barilgachdiin talbai-3
Ulaanbaatar, Mongolia
gerlee414@yahoo.com

Supervisors:
Sigríður Kristjánsdóttir, PhD
Agricultural University of Iceland
sigridur@lbhi.is

Brynja Dögg Ingólfsdóttir
EFLA Engineers
brynja@efla.is

ABSTRACT

One of the global environmental problems is that the population is growing fast in the world. Unfortunately land is a limited resource. GIS technology can be used to identify and analyse land suitability for all kinds of land-use planning. In this study the weighted overlay method was used to identify land suitable for urban and agricultural use, using geographic data on roads, volcanic areas, geothermal areas, mines, wetlands, forests, industrial areas, soils, water, built area, slope, agriculture and protected areas. This land suitability analysis will be valuable to land managers in land-use planning. The main aim of the case study was to identify the technology and methods to use GIS tools for analysis to support location decisions with respect to the implementation of agricultural and urban planning. GIS was used based on a set of criteria derived from the spatial and environment aspect.

Key words: Urban land, Agricultural land, Land Suitability Analysis, Mongolia, Iceland

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1. INTRODUCTION

1.1 Background

The rapid population growth and urbanization as well as increased demand for agricultural land are some of the problems in the world and suitable land for urban and agricultural use is a limited resource. Mongolia has this kind of problem.

Mongolia is divided into 21 provinces (administrative units); the municipality of Ulaanbaatar is the capital city. The total area of the territory is 1,564,411 sq. km.

Mongolian land is classified into six main categories: agricultural land; towns, villages and settlements; transportation and utilities; forest; water; and special (state) needs areas (Fig. 1) (ALAGaC 2012).

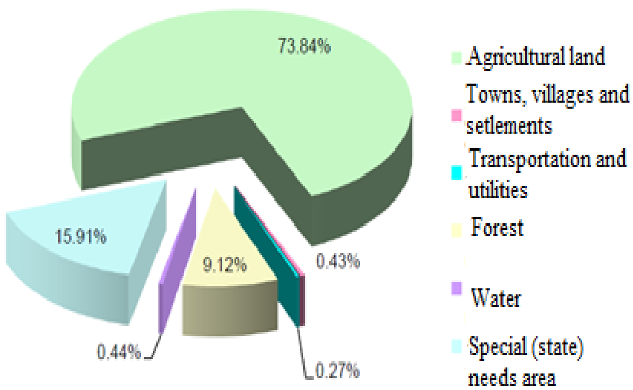

Figure 1. Mongolian land use classification (Source: ALAGaC, 2012)

Traditionally land-use in Mongolia is for pasture and animal husbandry (Byambadorj et al. 2011). Urban planning development began in the 1950s (Chinbat 2004). Since 1990 economic growth has been rapid and the political system has changed. As a result, land policy and land tenure have also changed.

Mongolia has a population of 2.8 million, with over 1.2 million people living in the capital Ulaanbaatar (World Bank 2012). It means almost half of the Mongolian population lives in 470,444 sq.km urban areas. The urban population in the capital Ulaanbaatar is growing at a faster rate due to migration from the rural areas to the capital in hopes of a job and to access other facilities that are absent in the rural areas. A study carried out by NOSM (2012) has shown that over the past two decades the urban population increased from 0.5 million to 1.2 million NOSM (2012). This has brought about congestion and put too much pressure on facilities such as housing and water, and the associated effects of this are environmental pollution, sanitation and slums.

Enkhmandakh (2011) reported that Ulaanbaatar is beset with many problems as a result of the rise in population including air and soil pollution, and traffic jams. This problem is further exacerbated by the unplanned urban settlements, not only in Ulaanbaatar but also in the other district capitals.

For example, in the traditional Ger district (which is neither connected to a heating system nor a drinking water supply) is growing very quickly in Ulaanbaatar and causing urban sprawl. Ger district residents use coal for heating and cooking, causing the increase in air pollution. Cinder from the combustion of the coal is becoming garbage (Guttikunda et al. 2013) causing environmental problems. Also, the ash from the coal is blown by wind in spring into the air, causing air and soil pollution (Batjargal et al. 2010). Figure 2 shows pollution (red colour) mainly generated from Ger districts, especially in winter and autumn (Guttikunda 2007).

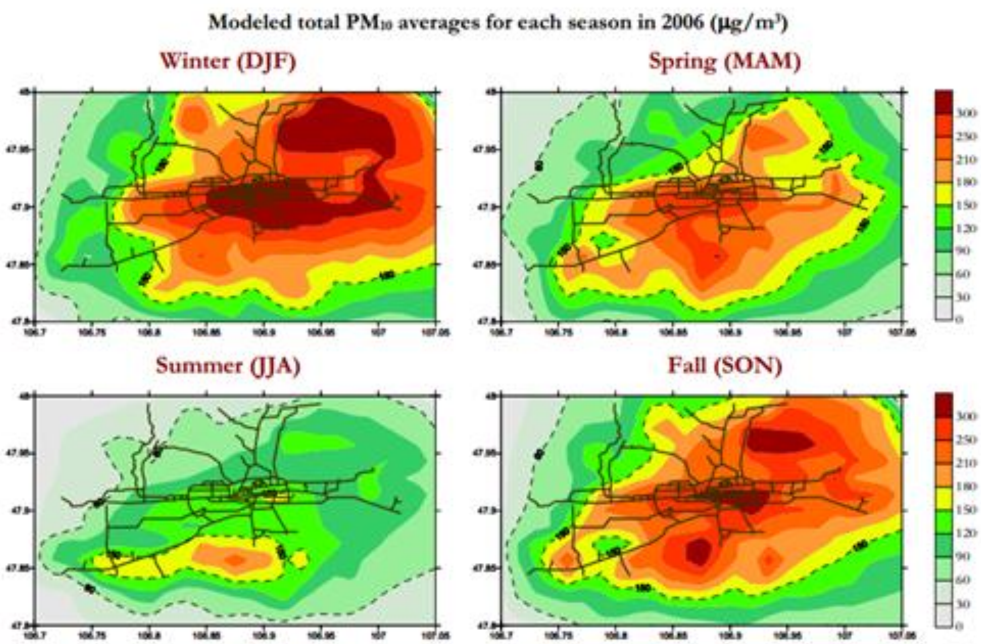

Figure 2. Seasonal air pollution in Ulaanbaatar (Source: Guttikunda, 2007)

The overcrowding of the capital has resulted in many people being confined to small areas, making planning of the area difficult. Most cities in Mongolia are not planned according to land-use and it is possible to find all kinds of land-uses within a small area. It is therefore necessary to classify land-use types within the cities, thus identifying the needed spaces for urban development using land suitability analysis. Additionally, land suitability analysis is valuable not only for urban planning but in all land management problems in Mongolia.

According to Kaiser et al. (1998) the main goal of land suitability analysis is to identify areas within a planning area that are best suited to particular land-use such as settlement, agriculture, national park, and other uses.

Land suitability analysis is beneficial to land managers and urban planners as it can be used to develop a master plan or land-use plan of an area. (Steiner 1991).

According to Steiner et.al (2000, p. 200) "Suitability techniques are essential for informed decision-making. Main valuable decision an analyst makes when using this tool is the determination of how relative values, or weights, are to be given to two or more combined factors".

In addition, GIS (Geographical Information System) is a useful tool for land-use suitability mapping and analysis for urban, agriculture, mining and all land-use projects (Brail and Klosterman 2001; Collins et al. 2001). Hopkins (1977) and Collins et al. (2001) defined land-use suitability analysis as identifying the most suitable spatial pattern for future land uses according to specific requirements, preferences, or predictors of some activity.

GIS has been used to analyse land-use suitability in many situations for ecological approaches for animal habitat and plant species (Store and Kangas 2001). Bonham-Carter (1994) used GIS to analyse geographical favourability, Cambell et al.1992 and Kalogirou (2002) also employed GIS in landscape evaluation and planning. GIS can also be used in private and public property planning. For example, Eastman et al. (1993) and Church (2002) used GIS to select the best sites for public and private sector facilities, whilst Janssen and Rietvelt (1990) used the same GIS for regional planning. This makes GIS a very important tool for all planning activities.

Land-use suitability may mean different things to different experts based on the intended purpose for which the land is desired. For the agriculturist, it would mean the suitability of the land for cultivation of crops, animal husbandry and pasture, and to the urban planner the suitability of the land for building houses, landfill sites, etc. No matter what the intended purpose or which expert is involved, the rule of thumb, according to Cova and Church (2000a), is to differentiate between the site selection problem and site search problem. Site selection analysis will best identify a specific site for a suitable activity based on its known potentials such as location, size, and other attributes. Different sites are ranked based on their potentials and the best site is chosen.

A site search problem on the other hand arises when there is no predetermined site for suitability analysis. According to Malczewski (2004) the goal of a site search is to identify the boundaries of the best site. Both the site search and suitability analysis as stipulated by Malczewski (2004) is that there should be a given study area and the area subdivided into a basic unit of observations such as polygons and rasters. According to Cova and Church (2000a), as well as other researchers (Aerts 2002; Xiao et al. 2002), site search analysis in addition to its ability to identify site suitability, also determines the spatial characteristics of a site, including its shape, contiguity and compactness.

1.2 Land suitability analysis

Land suitability analysis is more than just a Geographical Information System (GIS) based procedure; it also can be used to locate the most suitable location for a project (Birch 2009).
According to a study conducted by Joerin et al. (2001), land suitability analysis is one of the significant contributions of ArcGIS. The ArcGIS program is useful for analysing the scope desired to determine the suitability of land.

There are two kinds of methodologies which are related to land quality and index. It is an important tool for an ArcGIS database for data compilation. Data on several parameters such as soil, slope, flood, water, and road are used for spatial analysis that could enhance land suitability analysis. The planning related to each different type of land-use is based on ArcGIS including information about land suitability analysis, which has recorded significant increases within the last 20 years (Malczewski 2004). For example, a land-use suitability map can be used to show future development of an area. Also it is beneficial to land managers and urban planners for the development of area master plans or land-use plans (Fig. 3) (Joerin et al. 2001).

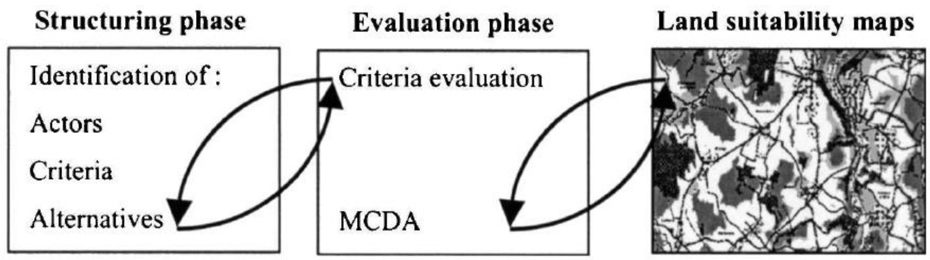

Figure 3. Main steps used to build a land-use suitability map (Source: Joerin et al. 2001).

The purpose of this study focused on mapping urban and agriculture land suitability so as to use prior information regarding the present state of different units of the land which will be highly important when applying site specific management interventions. This is done by linking data on socio-economic organizational factors and geophysical conditions of the land for decision making in identifying land management using geospatial techniques. This requires application of geospatial technologies through the Geographic Information System (GIS) which will provide the capability to analyse and interpret land suitability modeling on various scales, time and cost effectively. In land suitability modeling all the factors of environmental conditions will be weighted based on their level of influence using multicriteria evaluation to produce a land suitability map. Mapping urban and agricultural land is thus vital to locate and rank which areas are highly suitable and less suitable, so that coherent managing measures could be suggested and implemented immediately to plan, protect and use the valuable land planning in a sustainable manner.

Moreover, land suitability mapping using GIS provides a classification of the urban and agricultural area into zones each of which has a different likelihood, or risk, of experiencing specific land using processes. Such maps are fundamental to land-use planning aimed at the urban and agricultural land. The procedure is based on the processing of directly mapped and interpreted data, is easy to apply, and allows frequent updating of the land-use planning.

1.3 Aims and objectives

The overall purpose of this project was to develop my own capacity in conducting land suitability analyses for later use in Mongolian contexts. However, currently I do not have the Mongolian data I need in order to do this; therefore I did an Icelandic case study.

Mongolia and Iceland have many similar environmental conditions, and it would be beneficial to learn from the Icelandic experience in land suitability analysis as this would help mitigate some of the land and urban problems in Mongolia.

The aim of the case study was to locate a new site for an urban and agricultural land are in South-West Iceland.

For the purpose of this project, an area reaching from the River Hvítá in Borgarfjörður in the west to the River Hvítá in Ölfus in the south was used as a case study. The area is considered to be the potential growth area for the capital. This area is about one hour's drive from Reykjavík in each direction (Fig. 4). The study area covered about 538,023 ha.

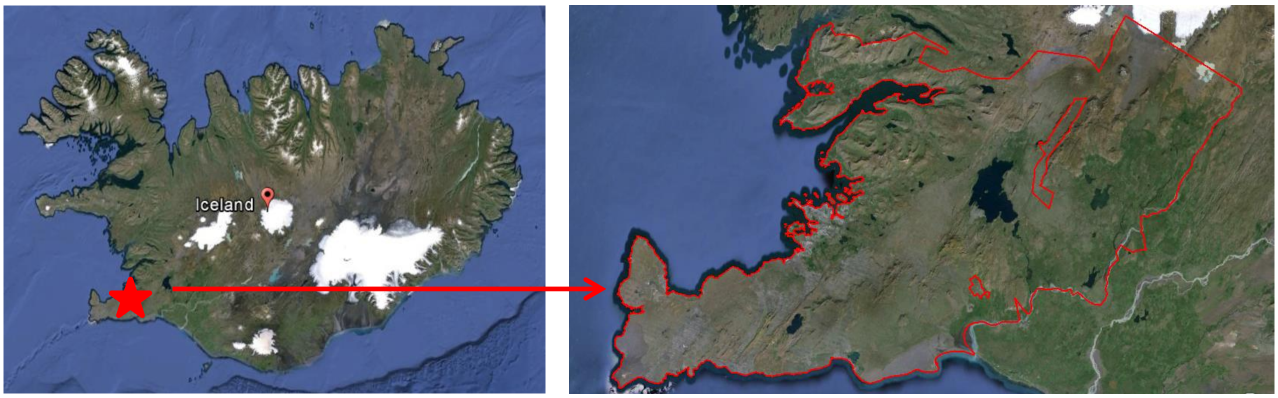

Figure 4. Map of case study area Hvitá to Hvitá (Source: Google earth map 2014).

For this, locations suitable for urban and agricultural use respectively were classified through land suitability analysis. The objectives were:

1. To identify available land based on existing land uses
2. To create suitability map layouts
3. To discuss the adaption of the analysis approach used in this study to Mongolian conditions.

2. METHODS AND DATA

2.1 Data collection

Data were collected from Google Earth maps, topographic maps and land-use maps using ArcGIS. Available data on roads, volcanic area, geothermal, mine, wetlands, forest, industrial, soils, water, built area, slope, agriculture and protected area were acquired from the Agricultural University of Iceland, CORINE project and other sources (see Table 3).

The digital analysis was carried out using the Geographical Information System (ArcGIS version 10.1).

To achieve the objectives of the study, the following methodology was developed;

- Input: Data from the case study "Hvítá to Hvítá"
- Process: Calculate composite scores
- Output: A map identifying locations that are suitable for the selected land uses.

2.2 Data and criteria of analysis

The basic key for the GIS plan was the model of the database. The basic database consisted of current data for soil types, transport, sewage, protected area, forest and other land use types. Raster maps were used for weight overlay analysis. When land suitability is used in a raster ArcGIS situation, each criterion in the database is assigned a scored according to its suitability.

According to FAO (1993) the suitability classification standard is famous for land suitability analysis. The standard establishes whether a land is highly suitable or not suitable. It is split into five suitability ratings. This case study used three of the important ratings of land suitability ratings to generate the results. The three ratings are high suitability, moderate suitability, and low suitability, as shown in Table 1 below.

Table 1. Explanation of the land suitability ratings used in the study (Source: FAO, 1993).

Low suitability	**Modarate suitability**	**High suitability**
1	2	3
Land with limitations so severe that benefits are reduced and/or the inputs needed to sustain production are increased so that this cost is only marginally justified	Land that is clearly suitable but which has limitations that either reduce productivity or increase the inputs needed to sustain productivity compared with those needed on highly suitable land	The land can support the land use indefinitely and benefits justify inputs

2.3 Raster and Reclassify

In order to demonstrate the working of GIS suitability for agricultural production, a practical process has been performed by reclassifying the 13 kinds of theme maps. The attributes of each thematic map were ranked on a scale factor of 1-3 based on their suitability for urban and agricultural land (see appendices).

2.4 Suitability Scores

For each criterion, a suitability score was applied using a three-point scale to determine the qualitative scores of the suitability based on each criterion. These scores ranged from 1 (low suitability) to three (high suitability). This “positive direction” Joshua et al. (2013) presented to keep the scores clear since the higher the score, the more suitable the case study area is. The analyses of the suitability types are shown in Table 2.

2.5 Weighted Overlay

The weighted overlay process is based on the GIS of a land suitability model that includes management of an evaluation scale. The influence value of criteria based on suitability for land use types was resolved using the criteria rating displayed in table 2.

The main aim was to identify land that is suitable for urban use and for agriculture; the first objective was based on existing data/information from Iceland. Existing data/information was divided into 13 environmental conditions. These environmental conditions determined how suitable the land is for road, volcanic areas, geothermal, mine, wetlands, forest, industrial, soils, water, built area, slope, agriculture and protected area for urban or agriculture land.

Table 2. The all stage summary is shown in the weighted overlay of spatial analysis (using data from CORINE and IS50V)

Weight-influence (%)	Criteria	Rank		Source
		For urban area	For agriculture	
1.Soils				CORINE, Local plan
20	Brown Andosol	1	3	
	Brown Andosol-Histic Andosol-Gleyic Andosol	1	3	
	Gleyic Andosol-Brown Andosol	1	3	
	Histic Andosol	1	3	
	Leptosol	3	1	
	Cambic Vitrisol-Arenic Vitrisol	2	2	
	Cambic Vitrisol-Leptosol	2	2	
	Arenic Vitrisol	2	1	
	Arenic Vitrisol-Leptosol	2	1	
	Water	0	0	
	Glaciers	0	0	
2. Roads, distance from				IS50V
15	< 1000 m	3	0	
	1000-5000 m	2	0	
	>5000 m	1	0	
3. Topography map (slope)				IS50V
10	0-5 %	3	3	
	5-15 %	2	2	
	>15 %	1	1	
4. Volcanic areas				-
1	Volcanic area	0	0	
	Other land	3	3	
5. Geothermal				-
5	Geothermal	0	0	
	Other land	3	3	
6. Mine				IS50V
1	Mine	1	0	
	Other land	3	3	
7. Wetlands				CORINE, Local plan
2	Wetlands	1	1	
	Other land	3	3	
8. Forest				IS50V
10	Forest	0	0	
	Other land	3	3	
9. Agricultural areas				IS50V
2	Agriculture	1	3	
	Other land	3	2	
10. Built areas				IS50V
2	Built area	3	0	
	Other land	2	3	
11. Industrial areas				IS50V

2	Industrial area	3	1	
	Other land	2	3	
12. Protected areas				IS50V
10	Protected area	0	0	
	Other land	3	3	
13. Water, distance from				CORINE, Local plan
18	< 1000 m	3	3	
	1000-5000 m	2	2	
	>5000 m	1	1	

Soil: Soil is the most important criterion for determining an area's suitability for urban construction or for agriculture. Joshua et al. (2013) identified which soil types have high fertility, nutrient deficiency and high water holding capacity and can be used for agriculture or urban areas. The soil types in the case study area are Brown Andosol (249320.50 ha or 46%), Leptosol (77391.10 ha or 14%), Brown Andosol, Histic Andosol and Gleyic Andosol (67468.38 ha or 12%), Cambic Vitrisol and Arenic Vitrisol (47782.29 ha or 9%), Arenic Vitrisol-Leptosol (30012.54 ha or 6%), Gleyic Andosol-Brown Andosol (25873.19 ha or 5%), Histic Andosol (17193.43 ha or 3%), Water (16277.04 ha or 3%), Arenic Vitrisol (6645.17 ha or 1%), and Cambic Vitrisol-Leptosol (5978.43 ha or 1%). These soil types belong to different suitability classes for urban or agricultural use.

The soils high suitable for agriculture are Brown Andosol, Brown Andosol-Histic Andosol-Gleyic Andosol, Gleyic Andosol-Brown Andosol and Histic Andosol. Cambic Vitrisol-Arenic Vitrisol and Cambic Vitrisol-Leptosol have moderate suitability for agriculture, and Leptosol, Arenic Vitrisol and Arenic Vitrisol-Leptosol have low suitability for agriculture.

Leptosol has high suitable for an urban area, whereas Cambic Vitrisol-Arenic Vitrisol, Cambic Vitrisol-Leptosol, Arenic Vitrisol, Arenic Vitrisol-Leptosol have moderate suitability for an urban area. Brown Andosol, Brown Andosol-Histic Andosol-Gleyic Andosol, Gleyic Andosol-Brown Andosol and Histic Andosol have only low suitability for urban land. On the other hand, heavily fertilized soil is good for agriculture.

Roads: Proximity to roads is one of the criteria that should be considered from economic and social points of view during urban and agricultural site selection processes. However, proximity to a road network is recommended for urban land use as well as for agricultural land due to high transportation costs. Therefore, to minimize such problems, the land selected must be sited very close to roads. Proximity to roads was reclassified based on the fact that very distant sites are not suitable. Accordingly, sites more than 5000 m from existing roads were excluded. But more weight was assigned for suitable areas 0-5000m.

Slope: Areas with a slope of 0-5% were scored in the first place and high rank (3) because of its optimum suitability. Areas with a slope of 5-15% were scored in the second rank (2) and the third rank was given to areas with more than a 15% slope because an increase in steepness will increase operation and construction costs and create difficulties. Lastly areas with >15% slope were excluded as having low suitability.

Volcanic areas: This study has ranked weight (0) to a volcano. Volcanic areas are possible for urban or agricultural uses. But an active volcano presents risk from volcanic eruptions and earthquakes for the population. Volcanic soils have a high phosphorus level due to the presence of Al and Fe compounds (Ping 2000), hence high fertility, and are therefore highly suitable for agriculture.

Geothermal: This study ranked weight (0) to geothermal areas. Geothermal areas are possible for urban area or agricultural uses. Especially some facilities in urban areas can be suitably located near geothermal areas for the purposes of space heating and generation of electricity. During winter, pavements near these areas can be heated to control ice formation or snow build-up at low cost.

Mine: Reclaimed mined-out areas have low suitability for urban or agricultural use because mining companies use chemicals in their mining activities.

Wetlands: This case study prefers to preserve wetlands. Wetlands are of international importance and are not allowed to be drained according to the Ramsar Wetlands Conversion: "Wetlands provide many ecological, economic, and social benefits, such as habitat for fish, wildlife, and a variety of plants. They serve as nurseries for saltwater and freshwater fishes and shellfish of commercial and recreational importance. Wetlands also prevent flooding by acting as sponges to hold flooding water. Because of the important roles wetlands play,we should all be concerned about the substantial loss of this diminishing resource, which helps ensure good water quality for local communities and provides vital habitat for a diversity of important wildlife species." (Ramsar Wetlands Conversion 2014).

Forest: This case study prefers to preserve forest land because there are very few forests in Iceland and Mongolia. Trees are natural air conditioners and oxygen cylinders. Trees stabilize the soil. Trees retain moisture in the soil. Forest also absorb the greenhouse gas carbon dioxide. As such, cutting down forests releases huge amounts of carbon, while regrowing them combats climate change and slows the extinction crisis we are facing. Forests emit oxygen, which all animals including humans breathe. Trees are a source of inspiration for many pharmaceuticals (the cure for cancer may be out there still) and are habitat for much of the world's plants and animals. The more we fragment forests, the less chance species have of finding each other, breeding and surviving as a species, and the less chance animals and trees have of migrating to the poles as a shift in climate forces them to. Forests also perform ecosystem services such as pollination and pest control and are a source of materials for indigenous and modern societies, such as for food and fibre - we could yet get new agricultural crops from forests (Rainforest action network 2014).

Agriculture: Agricultural land is based on soils with high fertility. These soils should be preserved for agriculture. According to Pimentel & Giampietro (1994), ninety percent of the food of the world is derived from just 15 plant and 8 animal species. It means agricultural land is the most important thing in the world and that agricultural soil is unique.

Built areas: This case study prefers to keep built areas. A built area has low suitability for agriculture. It is expensive to build new cities and the purpose of the project is to add to built areas.

Industrial areas: Industrial areas are highly suitable in urban areas but have low suitability for agriculture. For that reason, industrial areas are marked as polluted areas.

Protected area: This case study prefers to preserve protected areas. According to UNEP-WCMC (United Nations Environmental Programme-World Conservation Monitoring Centre) (2008), Protected areas or conservation areas are locations which receive protection because of their recognised natural, ecological and/or cultural values. These areas protect the biodiversity of plants and animals that need natural habitats in order to survive and would become extinct if their habitats were destroyed. Laws are enacted to protect these areas, preventing people and companies from chopping down trees and bulldozing large areas. Protected areas also have aesthetic values for tourism such as natural areas where people can go and relax. They also have cultural and spiritual importance. There are also ethical reasons. Some people just like to know that a certain area has been preserved even if they have not been there.

Water: In this research, a 1000 m buffer distance was used as a minimum distance from a water source that urban and agricultural land can use. Agricultural processes and urban areas are based on water. Accordingly, analysis tools were used to prepare multiple polygons around each stream and river within the following distances: 0-1000, 1000-5000 and >5000m. The proximity map was reclassified into three classes and weights were calculated using data analysis. Accordingly, more weight (3) was assigned for more suitable areas 0-1000m. To minimize the effect of water a >5000 m buffer area was used.

3. RESULTS

The results of this study were contained in two sections, land suitability analysis for agriculture and land suitability analysis for urban area. One of this study's concerns was to preserve forest, protected area and wetlands for future generations, which also contributes to the protection of the world's environments. The results indicated that some areas are suitable for both urban and agricultural land use. For example, these areas are located near water and a road and also have good soil.

Table 3. Land suitability analysis summary table by hectare (ha) and percent (%)

Land use types	Built area		Forest, protected area and wetlands area		Moderate suitability		High suitability (%)	
	Ha	%	Ha	%	Ha	%	Ha	%
Agricultural land	24263	4.51	91271	16.96	118038	21.94	304451	56.59
Urban land	24263	4.51	87886	16.34	286578	53.26	139296	25.89

3.1 Land suitability analysis for agriculture

The result of the land suitability analysis for agriculture includes built area 24,263 ha, forest, protected area and wetlands area 91,271 ha. No area with low suitability was found, the moderate suitability area covered 118,038 ha, and the high suitability area 304,451 ha (Figure 5, see Table 3).

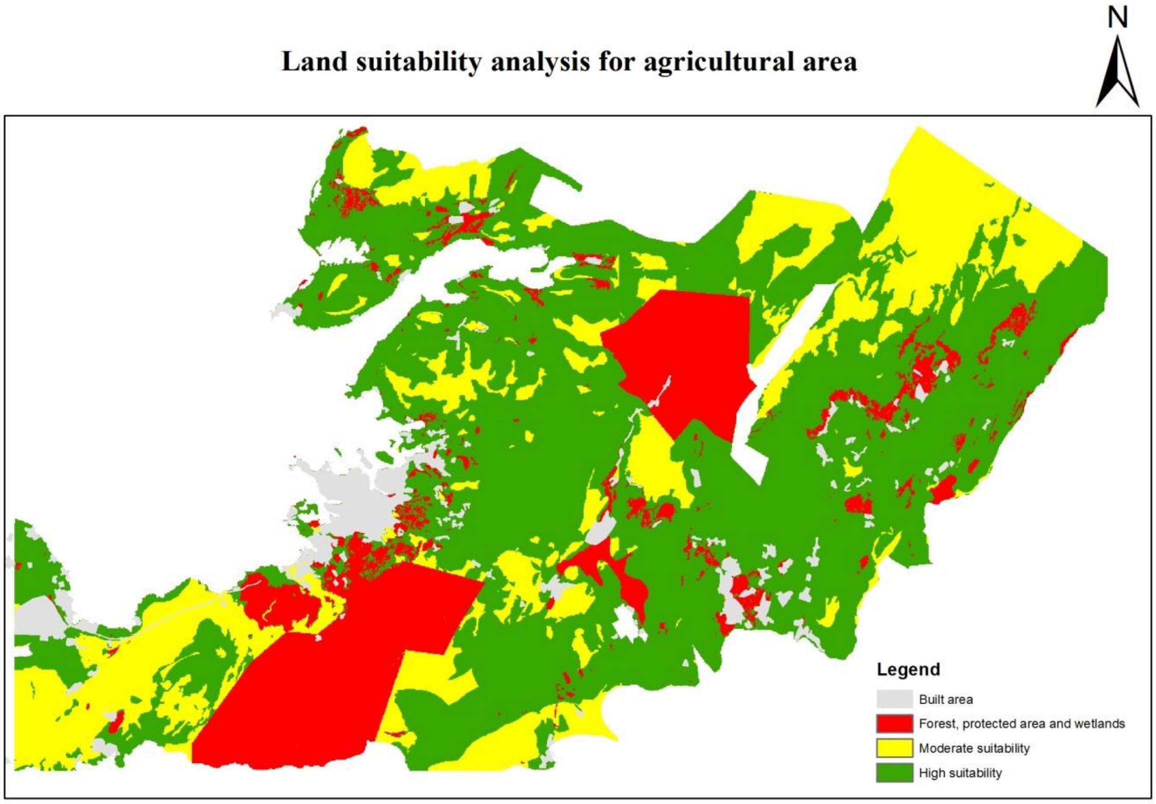

Figure 5. Land suitability analysis for agriculture.

Low suitability: No agricultural land with low suitability was found.

Moderate suitability: Those areas identified as being moderately suitable included road, volcanic area, geothermal area, mine, wetlands, forest, industrial, coastline, soils, water, built area, slope, agriculture and protected area for agriculture land use. They have limited uses that will need some investment, for example the cost to increase soil fertility.

High suitability: Those areas identified with the most suitable road, volcanic area, geothermal, mine, wetlands, forest, industrial, coastline, soils, water, built area, slope, agriculture and protected area for urban and agriculture land use type.

3.2 Land suitability analysis for urban area

The result of land suitability analysis for an urban area includes built area 24,263 ha, forest, protected area and wetlands area 87,886 ha. No area was found with low suitability, the area with moderate suitability covered 286,578 ha, and the high suitability area 139,296 ha (Figure 6 see Table 3).

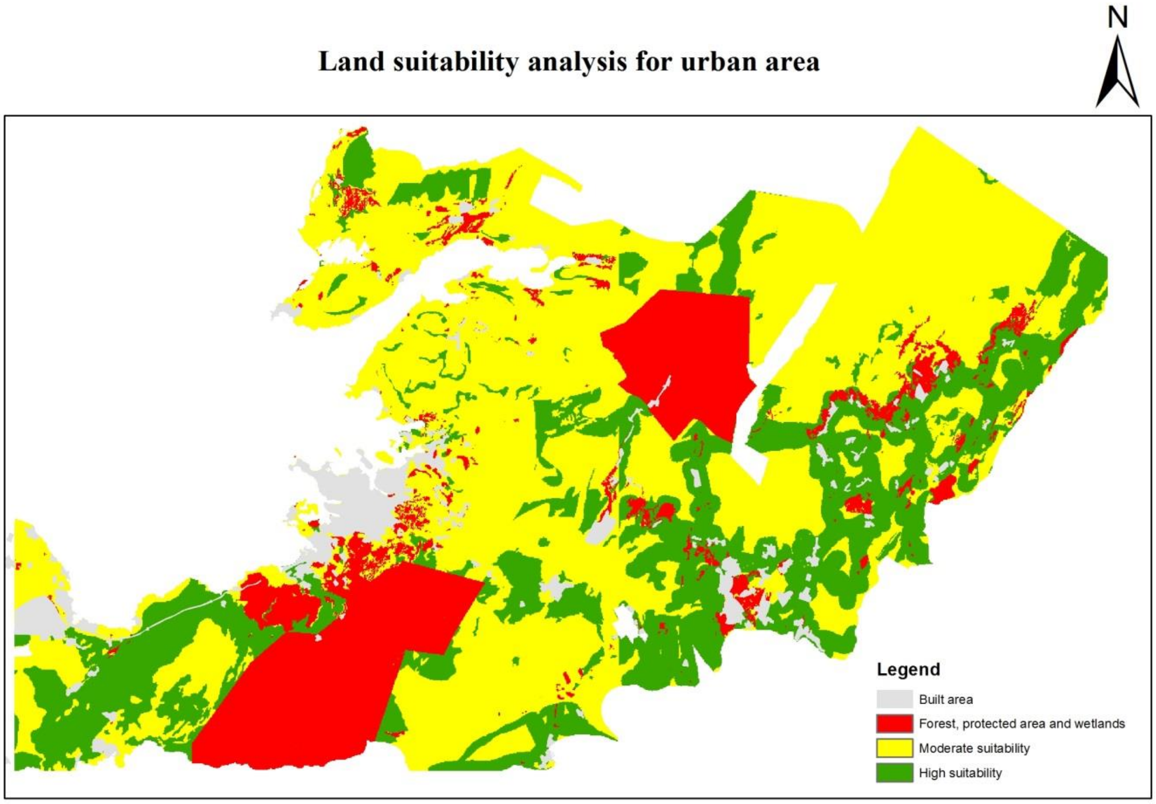

Figure 6. Land suitability analysis for an urban area.

Low suitability: No urban land with low suitability was found.

Moderate suitability: Those areas identified by moderate suitable road, volcanic area, geothermal, mine, wetlands, forest, industrial, coastline, soils, water, built area, slope, agriculture and protected area for urban land use. They have limited uses that will be needed by some cities. This site showed some high mountain moderately suitable for urban area.

High suitability: The areas identified with the most suitable road, volcanic area, geothermal, mine, wetlands, forest, industrial, coastline, soils, water, built area, slope, agriculture and protected area for urban and agriculture land use type. This site located nearby road and water. It means location is the best for urban area.

These two maps show 2 different results. related to data rank. Soils, road and water were the most important criteria in this study.

Table 4. Mongolian and Icelandic environmental conditions checklist (+ condition is present, - does not have this condition)

No	Condition	Iceland	Assess ment	Mongolia	Assess ment
1	Road	Various road types	+	Various road types	+
2	Volcanic area	Many	+	Very few	+
3	Geothermal	Many	+	Very few	+
4	Mine	Very few	+	Many	+
5	Wetlands	Same	+	Same	+
6	Forest	Very few	+	Very few	+
7	Industrial	Fishing, fish processing and agriculture	+	Agriculture and mining	+
8	Soils	Various soil types	+	Various soil types	+
9	Water	Pure water	+	Salty and pure water	+
10	Built area	House, apartment and construction, which are connected to heating system and water supply	+	House, apartment, construction and ger which are connected to heating system and water supply except ger.	+
11	Slope	Low elevation	+	High elevation	+
12	Agricultural land	Farm, greenhouse, hayland and open access	+	Pasture, arable land and hayland	+
13	Protected area	National park	+	National park	+
14	Ocean	North-Atlantic ocean	+	Landlocked	-
15	Territory (sq. km)	103,000	+	1,564,411	+
16	Air pollution	None	-	High	+

Iceland and Mongolia have these types of environmental conditions. However, Iceland is located in the North Atlantic Ocean, whereas Mongolia is a landlocked country. Also Mongolian territory is bigger than Iceland. Mongolian total territorial area is 1,564,411 sq. km. whilst the Icelandic total territorial area is only 103,000 sq. km. The highest elevation in Mongolia is 4374 metres; the lowest elevation is 518 metres. In Iceland the highest elevation is 2,110 metres. Iceland has 44 dormant and active volcanoes. Mongolia has 5 extinct volcanos**.** Iceland has many hot springs which are used for the heating and generation of electricity. Mongolia has 42 hot springs which are usually used for medicinal purposes. Iceland has very few mining sites. Mining is common in Mongolia where 1241 mining sites are registered (in August, 2013). In Iceland 1.3% of the total area is covered with forest, whereas in Mongolia 7.0 % of the total area is covered with forest. It means Iceland and Mongolia have very few forests. Iceland has mainly 7 types of soils with Andosol especially common. Mongolia has 10 main types of soil, where brown desert-steppe and grey brown desert soils are common. But Mongolia has no Andosol. Iceland has very pure water from glaciers and pericipitation. Mongolia has 2 types of water, fresh water and salty water from lakes, rivers and groundwater. Iceland has apartment houses or blocks and free-standing houses which are connected to heating systems and a water supply. Mongolia has apartments, houses and gers. Apartments and houses are connected to heating system, water supply and electricity. But gers are not connected to a water supply or heating system. Iceland and Mongolia have very similar agricultural land. However Iceland has farming activities and greenhouses. Mongolia has, in contrast, a nomadic lifestyle. For example Mongolia has winter, spring-autumn and summer camps and the herders move during the four season. Sedentary farming activities are not much developed.

4. DISCUSSION

The results showed that land-use suitability analysis is a useful tool for land managers and urban planners as it can be used to develop a master plan or land use plan of an area (Steiner 1991) for urban and agricultural use. But next time, we should for example add elevation to the evaluated criteria because some parts of high mountains are marked as moderately suitable for urban areas on the result map for land suitability analysis for urban area, but we know that in Iceland land over 300m is not suitable for urban areas because of the climate. Also we should rank urban areas again. For example, some urban areas look like empty land.

I think this case study missed data on climate, vegetation and geology from this analysis. But the results mostly fit the site. For example, this analysis preserved the forest, protected area and wetlands. Also I took a GPS point on the field trip where I imagined it should be urban area and it was matched.

When we do land suitability analysis on Mongolian data, we should add some important data related to Mongolian environmental conditions, such as geology, vegetation and sewer lines.
Also the discussion on the results will be based on how the findings from this study can be applied in Mongolia. The discussion will be based on what data are available and what data are needed to be produced. Data from Mongolia are available for natural zones, hydrogeology, geology, vegetation, forest, road and cadastral map.

However, data from soil, streams, floodplains, drainage boundaries and sewer lines are not available for analysis and have to be collected for this type of project. Since 2010, the Mongolian Administration of Land Affairs, Geodesy and Cartography have been working to create a Mongolian National Land Information System (NLIS). The completion of information gathering by 2015 will make it easier to analyse land use suitability for all land use types.

5. CONCLUSION

Land suitability is a critical versatile process which can considerably affect the benefits that can be derived from the land. In the context of application, this case study identified the land with high suitability land for urban and agriculture use. It is more expensive to use land that is categorized as moderately suitable. This case study demonstrates that GIS based methods can be used in urban and agricultural land-use planning. The Icelandic case study would have been more accurate if the urban land-use had been restricted to land below 300 meters. The analysis could be strengthened if applied in combination with other methods. The outcome of the study is a process for identifying land suitability for particular uses. This method can be applied e.g. in Mongolia in order to improve urban and agricultural land use planning.

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APPENDICES

APPENDIX 1-A: Soil

APPENDIX 1-B

APPENDIX 2: Road

APPENDIX 3: Slope

APPENDIX 4: Volcanic area

APPENDIX 5: Geothermal

APPENDIX 6: Mine

APPENDIX 7: Wetlands

APPENDIX 8: Forest

APPENDIX 9-A: Agriculture

APPENDIX 9-B

APPENDIX 10-A: Built area

APPENDIX 10-B

APPENDIX 11-A: Industrial

APPENDIX 11-B

APPENDIX 12: Protected area

APPENDIX 13: Water