

# GIS Based Area Appropriateness Modeling for Rural Development: A Study of Paktika Province, Afghanistan

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| Hazrat Mohammad Wahdaty<sup>1,\*</sup> | Hameedullah Mohammadi<sup>2</sup> |

<sup>1</sup> Paktia University, Education Faculty, Computer Science Department, Urgun Road, Sharan City, Paktika, Afghanistan

<sup>2</sup> Paktia University, Education Faculty, Computer Science Department, Gardiz City, Paktia, Afghanistan

\*[hazrat.wahdaty58@gmail.com](mailto:hazrat.wahdaty58@gmail.com)

## ABSTRACT

*In order to clearly determine the viability of rural development in Afghanistan's Paktika province, the information on land use planning that the locals may provide is collected. Spatial planning is crucial for the province of Paktika's rural development. Effective spatial planning enables entities including national and state governments, business developers, communities, and people avoid duplication of effort. The structural and basic improvements of their planning systems have made spatial planning possible. This study uses an integrated GIS-AHP model to identify the province of Paktika's best rural growth locations. The outcome demonstrates that the GIS-AHP model is a useful tool for rural planning and location selection. To determine the best location for rural development, seven factors were taken into consideration: slope, road, land use, river, water areas, cultivated areas, and soil. Final results indicate that 13535.3 sq. km was extremely suitable, 4563.2 sq. km was moderately acceptable, 889.5 sq. km was marginally suitable, and 348 sq. km was not suitable for the rural development of Paktika province.*

## KEYWORDS

*rural development; appropriate area; Paktika; GIS; AHP.*

## INTRODUCTION

The article will concentrate on choosing and locating the most suitable region for rural development in the Paktika province of Afghanistan utilizing GIS in conjunction with the Multi-Criteria Evaluation (MCE) method employing AHP, and site suitability modeling for rural development will be examined.

Population growth is placing pressure on rural areas in developing nations. Since gaining their independence, Afghan cities have grown more quickly. The methodology of organized change and organization is now more accessible to technologists and masterminding experts thanks to this.

Impressive rural growth calls for co-ordinate use of remote sensing and Geographic Information System (GIS) for supportable advancement of rural zones. There is a sincere need to grasp Remote Sensing and Geographic Information System approach in rural headway. Moreover, checking process for completing serious plan of rural development.

The strategy must incorporate a combined method of geographical visualization employing GIS and remote sensing data. This aids in the construction of effective and affordable models for the growth and location of businesses, educational institutions, housing, water supplies, and other services like waste disposal systems.

Additionally, the study does not include all pertinent viewpoints, such as land ownership and social-economic factors, for identifying ideal places for rural development. For the investigation of the suitability of rural development, a framework for land evaluation will be used as a guide.

## LITERATURE REVIEW

### General

One of the most beneficial uses of GIS for spatial planning and administration is land use suitability mapping and inquiry (Malczewski, 2004). The GIS-based land reasonableness inquiry generally assumes that a given report region is separated into a set of basic perception units, such as polygons or rasters. At that time, the assessment and arrangement of the areal units according to their suitability for a certain action are included in the land-utilize suitability issue (Mokarram & Aminzadeh, 1996)

The process of grouping land according to appropriateness involves evaluating and combining various land uses according to their justifiability. Based on the purpose, scope, and power of the investigation, the full range of reasonableness orders, classes, subclasses, and units may have been recognized, or the characterization may be limited to the higher a few classifications. The structures of the appropriateness grouping are identical to the images used (Mokarram & Aminzadeh, 1996).

### Using GIS for MCDM

The term linguistic theology or more popularly called grammatical theology was developed by Wittgenstein in 1967 and is the only one that elaborates on theology, linguistics and philosophy. Wittgenstein mentions that *grammatical theology* is a theory that is able to show a human life in relation to God, and uses language and its set of game rules. It seems that the meaning of theology must be related to the life of a religious community, and manifest it in a rule and belief (Kaelan, 2004: 282).

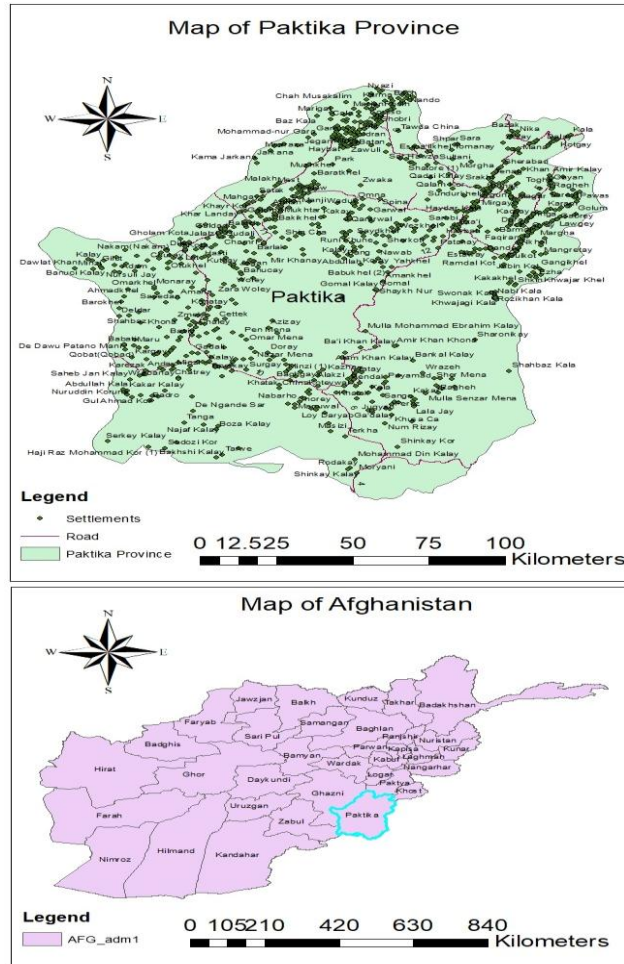
The nature of language in relation to religious life according to Kaelan (2004), and Warami (2014b; 2015) has a special and distinctive function, which must be understood based on the rules of the game that are unique as well. In every religious expression, various linguistic expressions related to the subject and extra linguistic reality will be found. In this connection, reality and extra linguistic subjects are not reached by language symbols related to worldly realities. The expression of language with the nature of God, Soul, Heaven, Hell, Angels, and other extra-linguistic realities, at the beginning of Wittgenstein's concept was a reality outside the boundaries of language, but later placed into a context of language use in a religious life.

## RESEARCH METHODS

### Study Area

Afghanistan's Paktika Province is located in the country's southeast. It shares a border with Pakistan and is encircled by the provinces of Paktiya, Khost, Ghazni, and Zabul. The province has a 19336 km<sup>2</sup> area. Mountainous or semi-mountainous terrain makes up 50% of the province, while flat ground makes up 25% of the total territory (41 percent ). There are 19 districts that make up the province. Sharana, the province capital, is home to approximately 54,416 people. In the province, there are 115,075 households, with 8 people living there on average.

Paktika has a rural population of about 99 percent and an urban population of about 1 percent. Males make up around 51% of the population, while females make up about 49%. More than 96 percent of the population speaks Pashtu. Dari is spoken in five villages with a combined population of roughly 15,000 people, and in four further villages with a combined population of about 5,000 people. The map of the research area can be seen in Figure 1.



**Figure 1.** Map of the study area

### **Statement of the Problem**

The rapid rural development process has put tremendous pressure on various governments. This is apparent in developing nations, particularly in those public institutions that are ill-prepared to manage the expanding change brought on by such pressure. The distribution of land has been one of the issues that the Paktika municipality has experienced. The primary causes of the stated issue were a lack of institutional and legal mechanisms, as well as an ineffective master plan that led to an insufficient distribution of rural land among various uses. As a result, a sizable portion of the population of Paktika resided in substandard dwellings. Housing in Paktika is not the sole issue; infrastructure and access to lawfully partitioned property are also major issues.

### **Objectives**

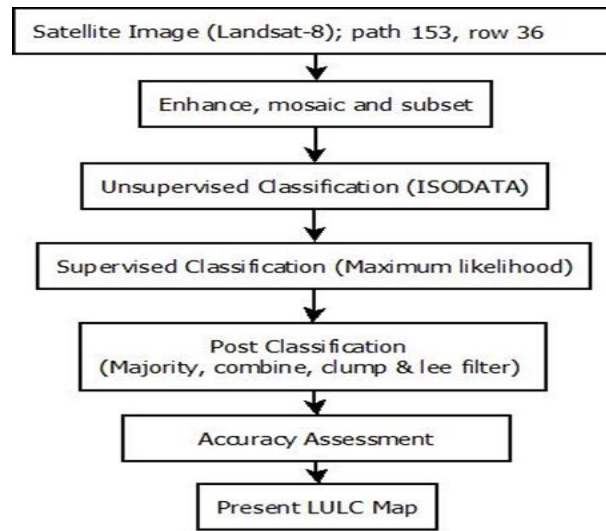
The objective of this article is to use GIS for determining the appropriate area for rural growth of Paktika Province. To get the main objective of the paper, the specified objectives of the paper are listed below:

- To formulate the general methodology for finding the suitable area for rural development
- To select the best factor influenced in rural development and their maps
- To produce the final area suitability map for rural development of Paktika province.

## Methodology

The ideational function

Both primary and secondary data will be gathered for this article from diverse sources. The WGS 84 map projection and UTM map at a scale of 1:50000 were utilized for the land suitability modeling for rural development. Landsat 8 provided the remote sensing data, while Afghanistan Information Management Services (AIMS), the Central Statistics Organization (CSO) of Afghanistan, and the Ministry of Rural Development and Housing provided the GIS and other subordinate data (MRDA). Figure 2 describes the process of those data which are used in this paper.



**Figure 2.** The process of suitability assessment

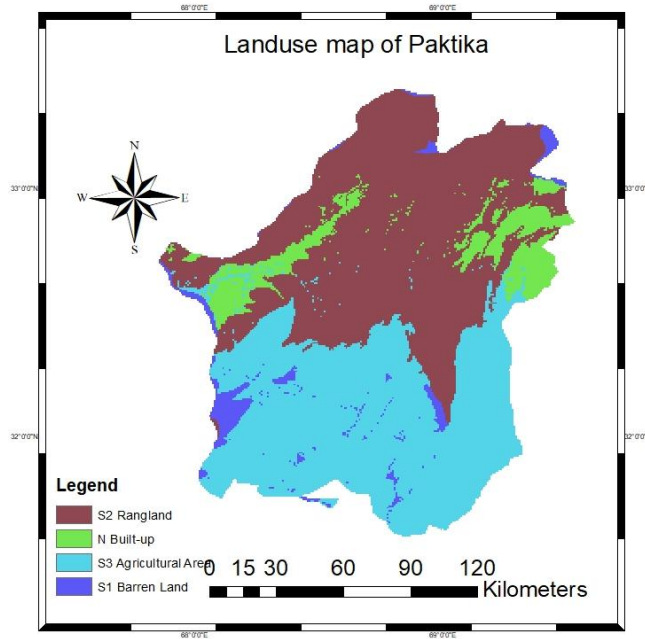
## RESULTS AND DISCUSSION

### *Influenced factors in area selection for rural development*

The three main stages of processing that make up the GIS process are data input, data operation and management, and data output. For additional information, see how the GIS application has grown heavily focused on data preparation and processing, modeling outcome analysis, and planning strategies (Latthachack, 2007). The GIS also functions as an active tool for resource analysis. Data preparation, remote sensing analysis, GIS analysis, and field verification are some of the major processes that are covered in this. The following seven thematic levels are selected to determine whether a piece of land is suitable for rural development:

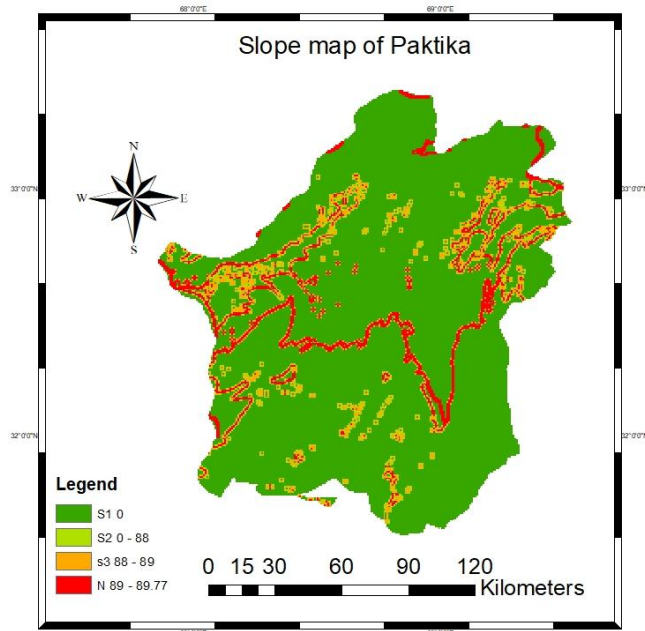
- Land use
- River
- Slope
- Road
- Water area
- Cultivated area
- Soil

Figure 3 Demonstrates Land Cover Land Use distribution map of Paktika Province.



**Figure 3.** Land cover land use distribution map

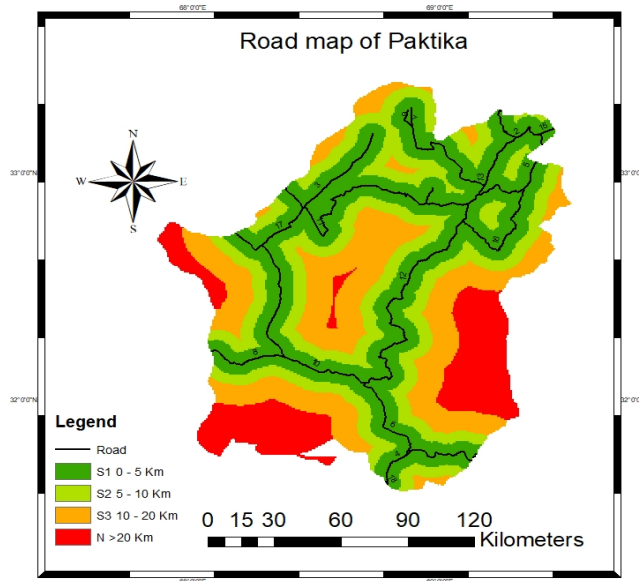
As we can observe from the Figure 3, Land use/Land cover map is classified into 4 classes which are important for planning rural development. The green area depicts the present area covered by rural built up and during the planning process, we cannot consider this because it is ready made rural area. The second class which is a small part of the map covered by water body which is also not suitable. Figure 4 demonstrates Slopes appropriateness distribution map of Paktika Province.



**Figure 4.** (Slope) Topography appropriateness distribution map

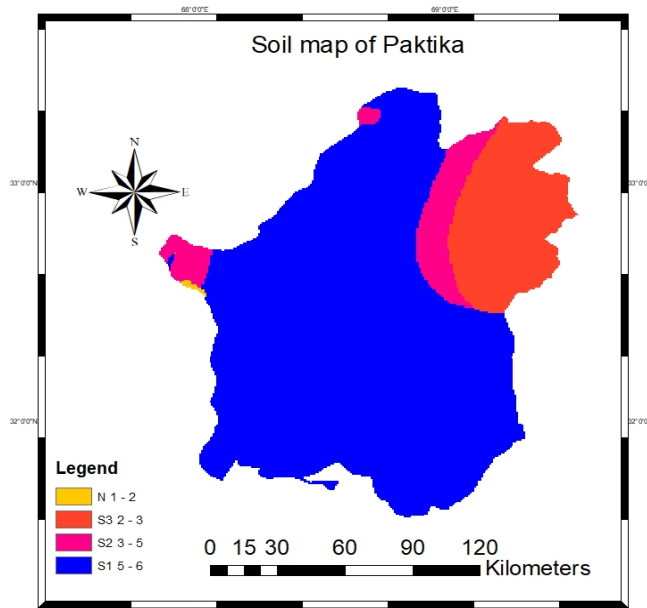
From Figure 4, it shows the slope of the study area. The slope is classified into four categories based on degree. It can be seen that the area covered in red is from 89 to 89.77 degree of the Slopes. The second category which is orange color covers 88 to 89 degree of

the slopes and the last two categories light green and dark green covers the area from 0 to 88 and 0 degree. Figure 5 demonstrates State Highway and National Highway of the Paktika Province.



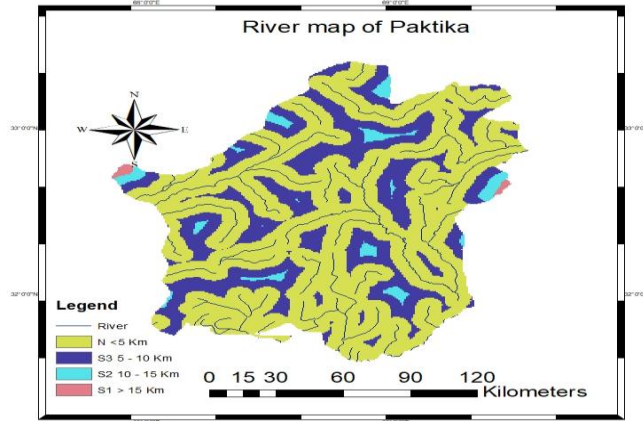
**Figure 5.** Road map appropriateness distribution map

From Figure 5, we can see the distribution of road network in the study area. This map is subdivided into four classes based on their distance from the road. As it is clearly visible from the map, those areas in red are far from the roads which cover more the hilly regions diffidently are not suitable for the rural development. By measuring distances from the road center at intervals of less than 5, between 5 and 10, between 10 and 20, and so on, buffer zones have been formed to determine improved accessibility to the current road. In AHP, proximity to highways is valued more highly, and its value declines the further we get from them. Figure 6 demonstrates Soil Suitability Classification map of Paktika province.



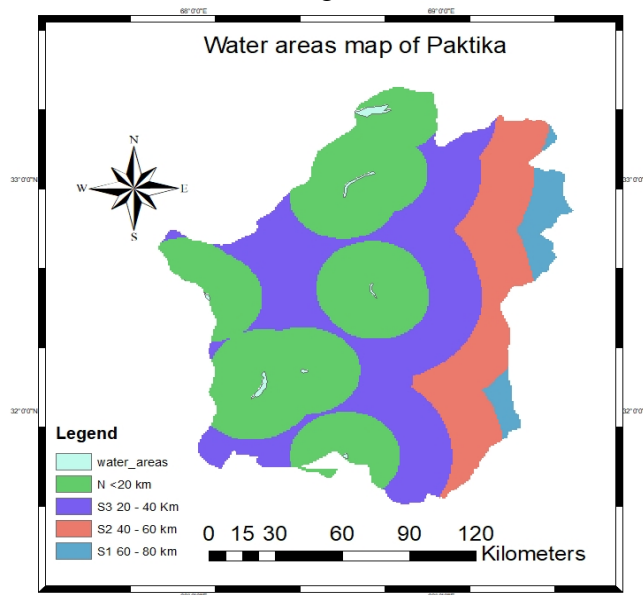
**Figure 6.** Soil suitability Classification

From Figure 6, it illustrates the Soil map of Paktika province. It is categorized into four main classes. Two categories namely N and S1 regions are considered as not suitable and marginal suitable respectively for rural development. And S2 and S3 are more suitable for rural development. Figure 7 illustrates the River Suitability Classification map of Paktika province.



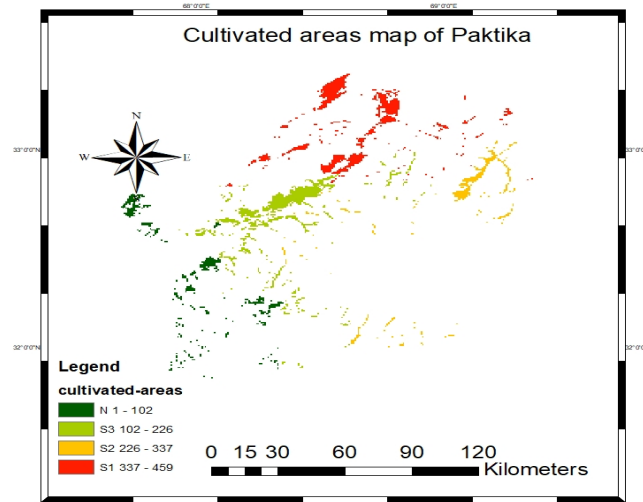
**Figure 7.** River suitability Classification

From Figure 7, it describes the areas which have various distances from the rivers. As from our observation of Paktika, there are more small rivers in each part of the province. As we know that the areas which are near to the rivers are prone to floods hence it is less suitable than those areas located far from the rivers. Due to its proximity to a river, the yellow area on the map is therefore unsuitable for agricultural development. The "Multi ring buffer" of the spatial analyst tool in ArcMap software calculates the evaluation of the distance to the river. Proximity to water areas is shown in Figure 8.



**Figure 8.** Water areas suitability Classification

In figure 8 we can clearly see the distances from the water areas which is categorized into four classes such as: less than 20, 20 to 40, 40 to 60 and more than 60 kilo meters. Figure 9 shows the cultivated areas map of Paktika province.



**Figure 9.** Cultivated areas Suitability Classification

In Figure 9 we can clearly observe the cultivated areas map of the province.

### **Analytical Hierarchy Process**

We have found through selecting certain papers whose references are mentioned at end of each comparative sentences but some factors whose weight was not available in the literature papers were compared based on expert judgment and personal experience obtained from living in the city. For example, considering slope, we have given greater weight to slope as compared to cultivated areas because those areas which have lots of slopes are considered are difficult to access and expensive to carry out building projects while the weight of the cultivated areas factor is more less than slope because those areas where cultivated area are already present, people are trying to construct buildings for extending the present structure. Table 1 demonstrates the scores and weights of classes and factors.

**Table 1.** Scores and weights of classes and factors

N	Factor	Appropriateness distribution	Weight of every factor	Score of every class	Marks of every class
1	Slope	0 degree 0 – 89 degree 89 – 90 degree 90 – 90.77 degree	0.42	9 7 5 2	S1 S2 S3 N
2	Road	<6 km 6 -11 km 11-21 km >21 km	0.24	9 7 5 2	S1 S2 S3 N
3	Land Use	Agricultural Land Barren Land Rangeland Built-up	0.13	9 7 5 2	S1 S2 S3 N

4	River	< 6 km	0.07	9	S1
		6 – 11 km		7	S2
		11 – 16 km		5	S3
		> 16 km		2	N
5	Cultivated areas	340 – 462	0.06	9	S1
		232 – 340		7	S2
		111 – 232		5	S3
		> 1 – 111		2	N
6	Water areas	>62 km	0.04	9	S1
		42 – 62 km		7	S2
		22 – 42 km		5	S3
		< 22 km		2	N
7	Soil	6 – 7	0.04	9	S1
		4 – 6		7	S2
		3 – 4		5	S3
		1 – 3		2	N

**Weights assigning for the influenced factors**

Table 2 illustrates the score of the appropriateness for final suitability map.

**Table 2.** Score for the final appropriateness map

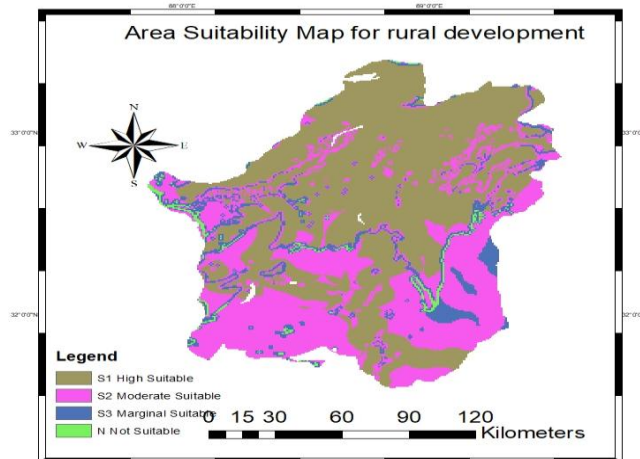
Name of Factors	Weight
Slope	0.42
Road	0.24
LU	0.13
River	0.07
Cultivated areas	0.06
Water areas	0.04
Soil	0.04

How to add the weights in raster calculator?

$$\text{Paktika Province} = (\text{"Slope"} * 0.42) + (\text{"Road"} * 0.24) + (\text{"Land use"} * 0.13) + (\text{"River"} * 0.07) + (\text{"Water areas"} * 0.06) + (\text{"soil"} * 0.04) + (\text{"Cultivated areas"} * 0.04)$$

**Suitability map for rural development of Paktika province**

Figure 10 illustrates the Suitability map for rural development of Paktika province, and Table 3 shows the area of suitability for rural development of Paktika Province



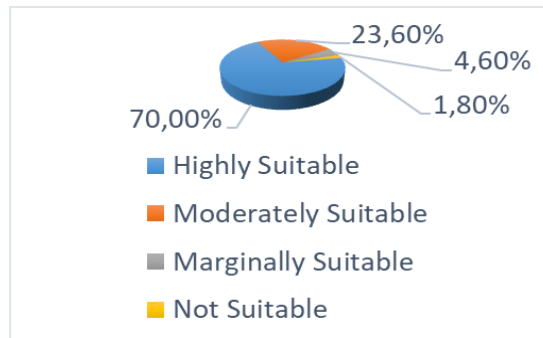
**Figure 10.** Suitability map for rural development of Paktika province

**Table 3.** Area appropriateness for rural growth of Paktika province

Appropriateness Classes	Area SQ. Km	Class percentage	Class Marks
S1	13535.3	70	Most Suitable
S2	4563.2	23.6	More Suitable
S3	889.5	4.6	Little Suitable
N	348	1.8	No Suitable

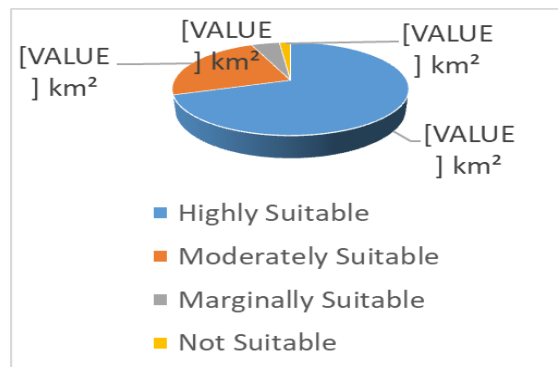
**Appropriateness classes illustration**

Figure 11 demonstrates the percentage of appropriateness classes for rural development of Paktika province.



**Figure 11.** Percentage of appropriateness classes for rural development of Paktika province.

Total study area is 19336 km<sup>2</sup> which categorized into four classes. Figure 12 shows the area of every class of land suitability for rural development of Paktika province.



**Figure 12.** Area appropriateness for rural development of Paktika province

**CONCLUSION**

In order to achieve our first objective which is methodology for finding and selecting suitable areas of rural development. For carrying out research related to suitability analysis such as identifying suitable areas for School, hospitals, Universities etc. this objective is the most important part of the study. For selecting the area suitability whether a particular area is suitable for carrying any project or not, we have selected those factors which affect the most for suitability analysis for that specific area. Then we have compared the selected factors based on their impacts on the research area. After the comparison, we found the weight of each factor using Analytical Hierarchy Process. Furthermore, individual maps

were generated for each factor in ArcMap software and finally, a resultant map was produced considering all the factors and their weights.

To identify suitability maps for locally adaptable rural development. For local adaptability of rural development, we have identified suitability maps we have derived the maps from the seven factors through the literature namely Slope, Road, Land use, River, Cultivated areas, Water areas and Soil respectively. After deriving the map each map was further classified into four classes. These classes make it easy for planners to identify the different areas based on their higher and lower suitability levels

To produce a Land Suitability Index map for Paktika Province. Result shows that highly suitable land was 13535.3 sq. km (70 %), moderately suitable 4563.3 sq. km (23.6 %), marginally suitable 889.5 sq. km (4.6 %) and not suitable land 348 sq. km (1.8 %) were obtained.

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