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Assessment of suitable industrial site using GIS and remote sensing: Case study in Assosa Town, Ethiopia

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ABSTRACT

Industrial site selection is an important point in the process of starting, expanding, or changing the location of industrial systems of all kinds. In a site selection process, the analyst strives to determine the optimum location that would satisfy the selection criteria. GIS and remote sensing technologies would provide a variety of options during the site selection process. The overall aim of the study is to identify suitable industrial site locations by using Geographic Information System and Remote Sensing based MCA-analysis. In order to conduct this study, a multi-criteria evaluation system to identify factors that influence site selection was considered. The results show the feasibility of GIS-based MCA as a useful approach for decision-makers to propose the best site selection. Furthermore, it is an effective tool for public administration to create the essential databases to perform spatial analysis. Interestingly, a suitability map is used in this study to identify the most suitable locations for the industry. This in turn investigated possible sites that were divided into four categories; unsuitable, suitable, moderately suitable, high suitability. The important factors that can affect industrial site were analyzed which includes topographic-slope, land use land cover, proximity to the main road, distance from a residential area. The findings of this study showed that land use and land cover factors were highly determined in the selection of industrial sites, and elevation and slope determine minimum compared with other factors. The majority of the study area was suitable and a small portion was less suitable.

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INTRODUCTION

Industrial site selection is an important point in the process of starting, expanding or changing the location of industrial systems of all kinds. One of the main objectives in industrial site selection is finding the most appropriate site with desired conditions defined by the selection criteria. In a site selection process, the analyst strives to determine the optimum location that would satisfy the selection criteria. The selection process attempts to optimize a number of objectives desired for a specific facility. Decisions about industrial location typically involve the evaluation of multiple criteria according to several, often conflicting, objectives (EIdin, 2003). GIS-based process used to determine the appropriateness of a given area for a particular use. Suitability is determined through systematic, multi-factor analysis of the different aspects of the terrain. (Michael, 2016). Model inputs include a variety of physical, cultural, and economic factors.

The results are often displayed on a map that is used to highlight areas from high to low suitability. (LaGro, 2007). Land use planning plays an important role in site development, urban renewal and achievement of sustainable urban development (Wang et al., 2013). Suitability analysis is critical for both marketing and merchandising purposes (Dramowicz, 2005). The GIS has different applications in urban health studies (Dom et al., 2012) and can also be used as a decision support tool to allocate health services so that they are geographically accessible for the population that they intend to serve (Boulos, 2001). GIS plays a vital role in planning for many decades of land-use suitability mapping and modelling (Malczewski, 2004). The problem of industrial use suitability assessment has often been tackled using multi-criteria decision analysis (MCDA) since 1980s (Antoine et al, 2001). Cheng et al., has reported an integrated MCDA linear programming approach to support selection of an optimal landfill site. Nowadays MCDM has been extensively studied and refined in a wide variety of decision situations, in fields such as administration, commercial and industrial activity, public health and education (Boroushaki & Malczewski, 2008) Geographic information systems (GIS) have emerged as useful computer-based tools for spatial description and manipulation. Although often described as a decision support system, there have been some disputes regarding whether the GIS decision support capabilities are sufficient (Jankowski and Richard, 1995). To express the importance of this subject for instance, management and finding a location for urban infrastructure accurately such as landfills, industrial slaughterhouses, are considered as one of the main pillars of sustainable development. (Krizek, 1996).

Multi-criteria decision making with in the GIS environment by integrating various thematic layers, is found to be helpful in determining appropriate sites suitable for industrial development. The environmentally related land uses that can pose an impact on the environment include trade, industry, housing, surface transport, waste and wastewater treatment installations (CPCB, 1997)**.** Number of tools have been used to determine the proper site for capital intensive infrastructure. These tools include Expert Systems (ES), Geographic Information Systems (GIS), and Multi Criteria Decision Analysis (MCDA) techniques. These tools have played an important role in solving site selection problems. However, each tool has its own limitations in addressing spatial data, which is necessary for spatial-decision of problems. Most of the environmental attributes are spatial in nature, and to understand and manipulate these attributes, suitable spatial database management system is required. Geographical Information System (GIS), which is a tool for collecting, storing, retrieving at, transforming and displaying spatial data for a particular set of purposes, can provide all desirable requirements. Industrial site selection is a complex problem which requires multi-criteria decision making involving economic, environmental and social factors. Assigning weights to these different criteria may be attempted using Analytical Hierarchy Process (AHP). Very few studies are based on GIS based approach for industrial site selection. The aim of the present study is to develop a methodology to use GIS and MCDA for industrial site selection. The developed methodology has been checked for Assosa town.

According to (EIdin, 2003), industrial site selection is a complex process for owners and analysts. Therefore, simultaneous use of several decision support tools, such as ES, GIS and multi-criteria decision making (MCDM) methods is required. The integration of MCDM techniques with GIS has considerably advanced the conventional map overlay approaches to the land-use suitability analysis. Assosa is one of the developing towns in

Ethiopia which is situated in Benishangul Gumuz region. Due to this reason peoples migrate to the town for different purpose, for finding jobs and also for better living condition. As the population increases public's demand for industry product service increase. The general public's demand for industry is rising promptly with the improvement of the living standard. However, the limited and unbalanced industry site resources have caused the problems of the society. In Assosa town, Industries have been constructed without considering road network, slope, land use land cover and water body, and there is unbalanced relationship between industries and population numbers of town. Conducting of this research was needed to solve all of those problems relating to inappropriate site for industries in this study area.

OBJECTIVES

The main objective of this study was to assess suitable industrial site through Assosa town and give recommendation. Specifically, it sought to:

1. Assess and analysis, the existing industrial site of Assosa town.
2. Evaluate critical parameters of the location of suitable industrial site structure plan.
3. Propose the best alternative site for industries in Assosa town.
4. Assess critical parameters that affect the suitability of the site for industries.

METHODS

Study Area

Assosa town, the seat of Benishangul Gumuz Regional State, is found in Assosa zone, Assosa Woreda, at a distance of 687 Km from Addis Ababa and 180 km away from Great Ethiopian Renaissance Dam. Based on national grid references, as indicated on the base map of the town, Assosa is placed between 667368 – 672068 Easting and 1110044 – 1116444 Northings. Relatively, Assosa town is bordered by AgushaYekedo and Amba 8 in the north, Mengele 29 and Mengele 30 in the south, Amba 4 and Amba 12 in the east and Sherkole Ahufamidi in the west. The region covers 50,698.3 Km^2 area, and it has three major climatic zones, which are 91.86 percent covers by warm ('Qolla'), 7.91 percent moderately warm ('Woyna-Dega'), and 0.19 percent of the total area covers by moderately cool ('Dega').

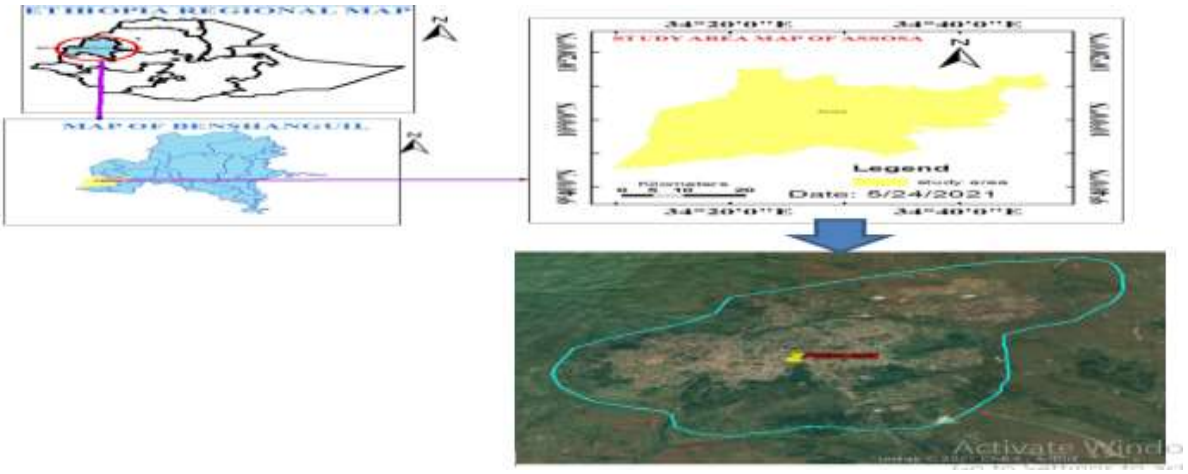

Figure 1. *Location of study area (Source; Extracted from GIS)*

Data Type and Sources

The study employed both primary and secondary data. Primary data (field survey data of the Coordinates of ground water well points collected directly). Whereas the Secondary data (Road network, River line, slope, land use and Town Boundary) has obtained from sketched map of Assosa Town. Slope from DEM downloads.

Table 1. *Data type and source*

No	Data used Land use land cover class	Data type	Source Assosa municipal office	Description To generate land use land cover class map
1	River/stream	vector	Assosa town urban development office	To generate map of Minimum distance of proposed site from
2	Boundary	vector	Assosa town urban development office	To generate Boundary map
3	DEM	raster	download from online sources	To generate elevation and slope
4	Main road (road network)	vector	Assosa town urban development office	To generate Map of closeness distance from the Proposed sites to Road

Software Used for Image and Data Processing

Software used in this study was selected based on the capability to work in achieving the predetermined objectives. USGS Earth Explorer it used to generate DEM, LANDSAT image, ERDAS 2014 was used for image processing activities on satellite images. The factor map development was carried out using ArcGIS10.4.1 Software package.

Table 2. *Software and material used*

No	Types of software we have use	Resolution	Purposes
1	ArcGIS	-----	For creating shape file. For produce the suitability map for all factors.
2	Landsat (8) image	15m	Land use land cover change.
3	USGS Earth Explorer Google earth	-----	For Generating, DEM, LANDSAT image.

Data Analysis

The common specific activities have been used in this study to analyze the spatial data converted from polygon to raster, reclassify and the spatial model involve geographic modeling functions and coincidence modeling was computed in GIS to generate suitable industrial site. In order to conduct the study, a step by step method was followed. Based on preliminary studies the requirement analysis was done for setting data requirements and for getting criteria affecting the industrial site suitability analysis. There are four important steps to produce site suitability map for industry.

RESULTS AND DISCUSSION

The suitability of a site for an industry is influenced by the various characteristics of the site. However, each characteristic only reflects a slope of the overall suitability for the specific industry use. A GIS-based spatial analysing information system for suitable site selection criteria should be identified and integrated in to a GIS database in the form of map layers with associated attribute.

Criteria for Industrial Site Selection

Based on literature review regarding the site selection for different purposes and keeping in mind the sensitivity of different environmental parameters for the purpose, overall four criteria were used for industrial site selection. Different ranking was given to different zones based on their suitability. Suitability was accordingly defined under "high suitable", "moderately suitable", low suitable", and "unsuitable". All the criteria for an area are standardized in the scale of 1-4.1 is assigned to those areas which are unsuitable for industrial sites and 4 are assigned to those areas which are highly suitable. Intermediate values are assigned to different areas with varying suitability. Selection of different parameters for suitability: Following parameters have been considered for the suitability analysis include Existing land use, Slope, River network and Road accessibility

Land Use Coverage Classifications

Based on the GIS and remote sensing image, the land use/cover map of the study area was classified into different categories: agricultural land, barren land, residential area, vegetation and road network. Land use classification have been done for the development master plan of the area. The existing and the land use should be compared to have an in site impacts of development on the industrial area.

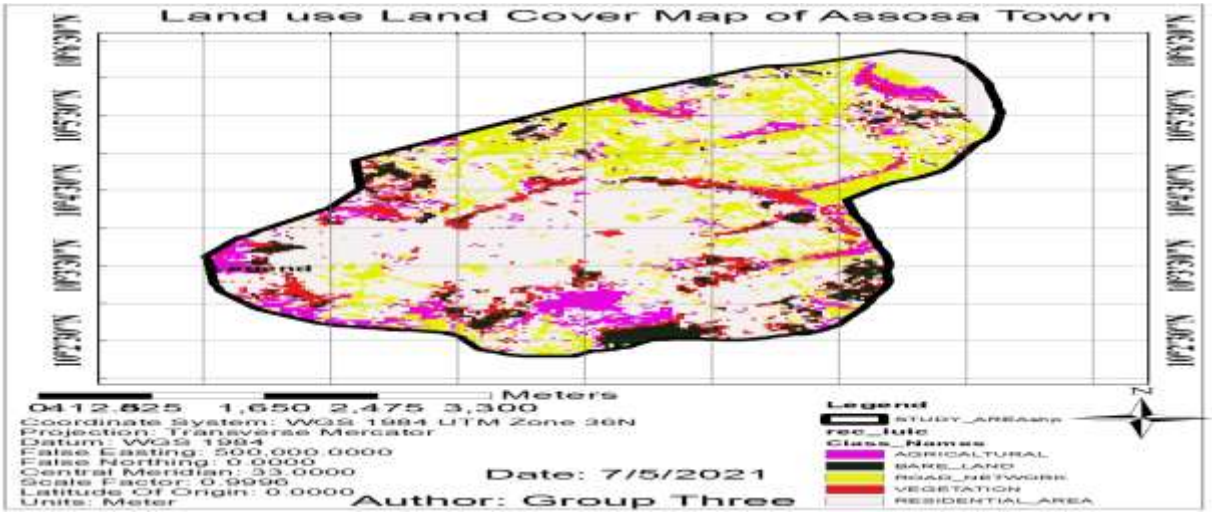

Figure 2. *Land use and cover map*

Raster and Reclassify Map of Land Use and Cover

In order to demonstrate the working of GIS suitability for industrial production, a practical process has been performed by reclassifying the 4 kinds of theme maps. The attributes of each thematic map were ranked on a scale factor of 1-4 based on their suitability for industrial land. These values contain four-character means that 1 refers to unsuitable (vegetation area) area and 4 refers to highly suitable area (agricultural area).

Table 3. *Land use and cover reclassification*

Suitability class	Level of suitability	Rank
Agriculture	Highly suitable	4
Residential area	Moderately suitable	3
Bare land	Low suitable	2
Vegetation	Unsuitable	1

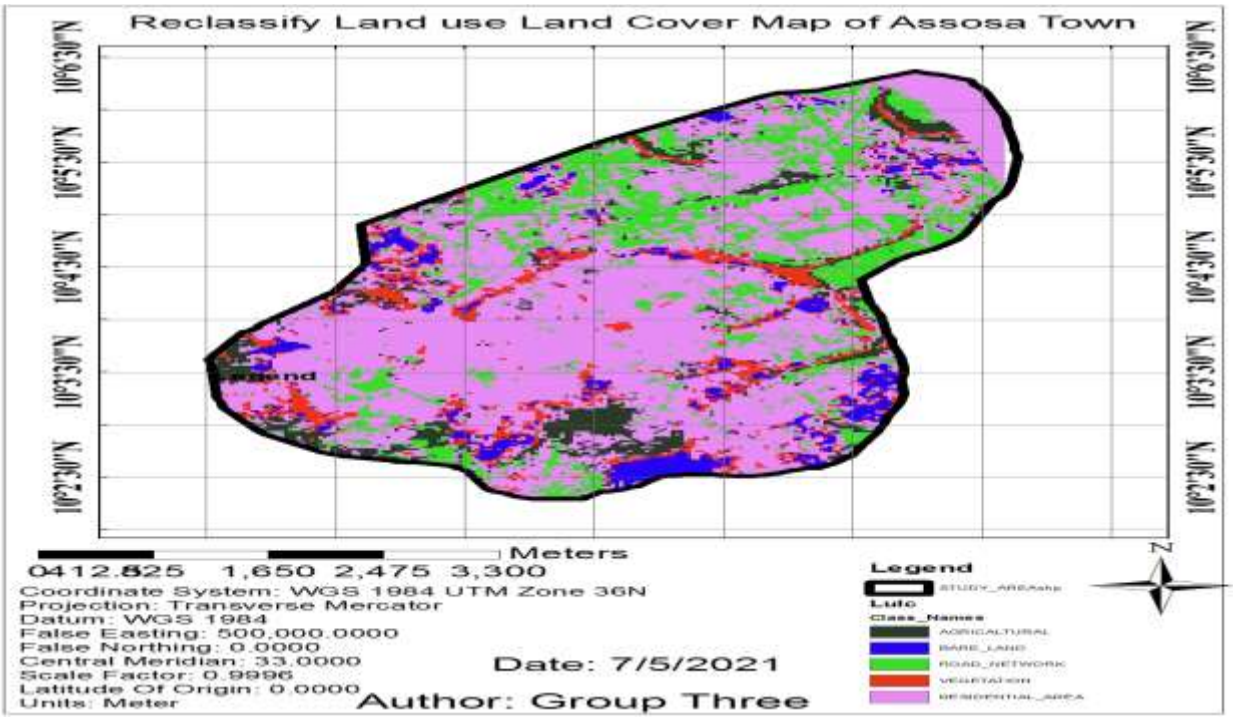

Figure 3. *Reclassify land use land cover map*

Digital Elevation Model (DEM)

The resolution, or the distance between adjacent grid points, is a critical parameter of any DEM. The best resolution commonly available is 30 m and was used in this study. The operators we have discussed here are designed to work on any continuous surface e.g. map elevations, temperature gradients, or cost surfaces.

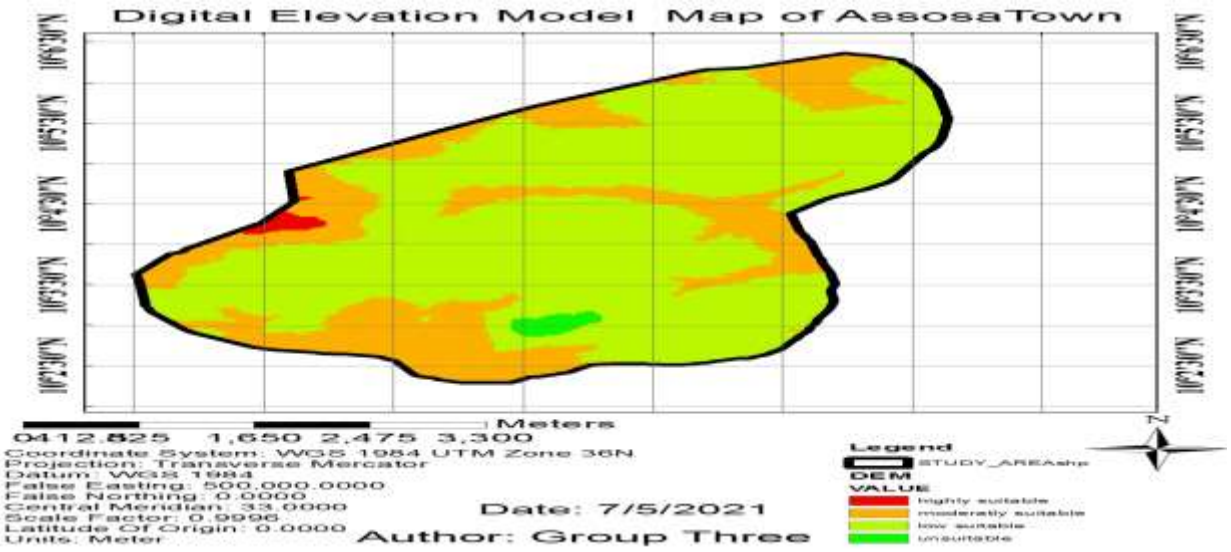

Figure 4. *Digital elevation model map*

Slope

Most of Assosa town's slope can be classified as flat. The maximum slope of the town is 10% which was found around the area so called Selam village and around the Enzi high lands. The minimum slope is about 7% which is covers most part of the town specially the central portion. The topography of the NDP of the site is dominated by flat topography that generally descends towards the steepest slope. In this study slope factor was generated from the digital elevation model (DEM) using the ArcGIS spatial analyst extension of surface module, which enabled to classify the area according to the steepness and the gentleness of the terrain. The lower the slope value, the flatter the terrain was and the higher the slope value the steeper was the terrain. Then the slope raster was reclassified in to four classes of slope percent by examining the value and the frequency of slope percent in the study area.

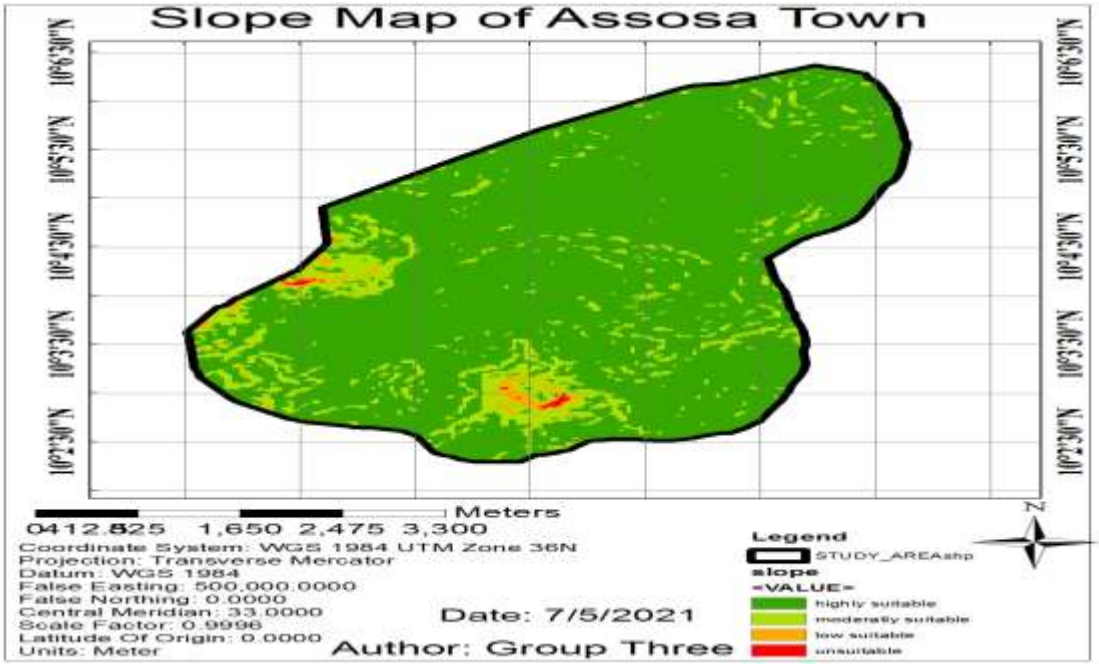

Figure 5. *Slope map*

Raster and Reclassify

The attributes of each thematic map were ranked on a scale factor of 1-4 based on their suitability for urban and industrial land. Industry might be constructed in an area lower than the city level in order to prevent the spread of contamination. Therefore, areas with high altitude ranked as unsuitable, and areas with low altitude ranked as highly suitable for site selection.

Table 4. *The reclassified slope suitability class*

Suitability class in	Level of suitability	Rank
0-2%	Highly suitable	4
2-6%	Moderately suitable	3
6-8%	suitable	2
>10%	Excluded	1

Source: extracted from reclassified slope map.

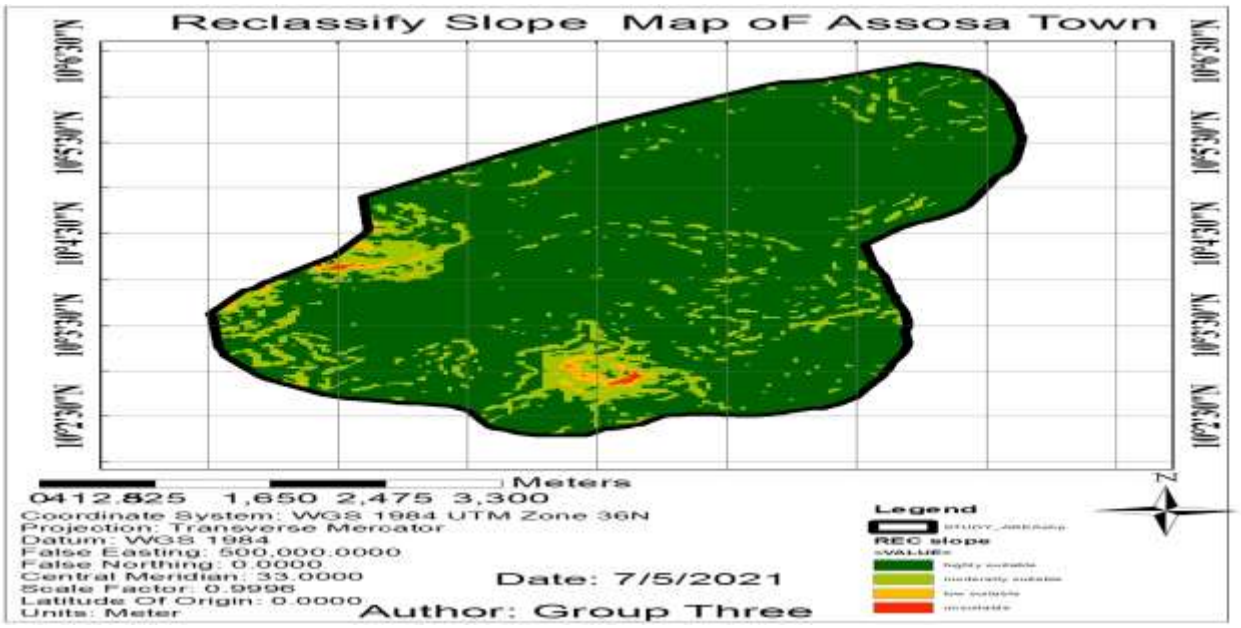

Figure 6. *Reclassify slope map*

Accessibility

Road is also an important criterion in site suitability analysis. The newly proposed areas of the town were not facilitated with sufficient road networks. Moreover, in order to find out better accessibility to the existing road, buffer zones have been created by taking distances between 0 to 400 meters from the existing major roads (EPA, 2000) to generate highly suitable accessibility map.

Spacing of the Road Infrastructure

Standard road infrastructure spacing's were considered for the proper functioning of roads. Spacing is taken to account to make the road network efficient. The standard road spacing urban planning implementation manual is used for decision of road network spacing.

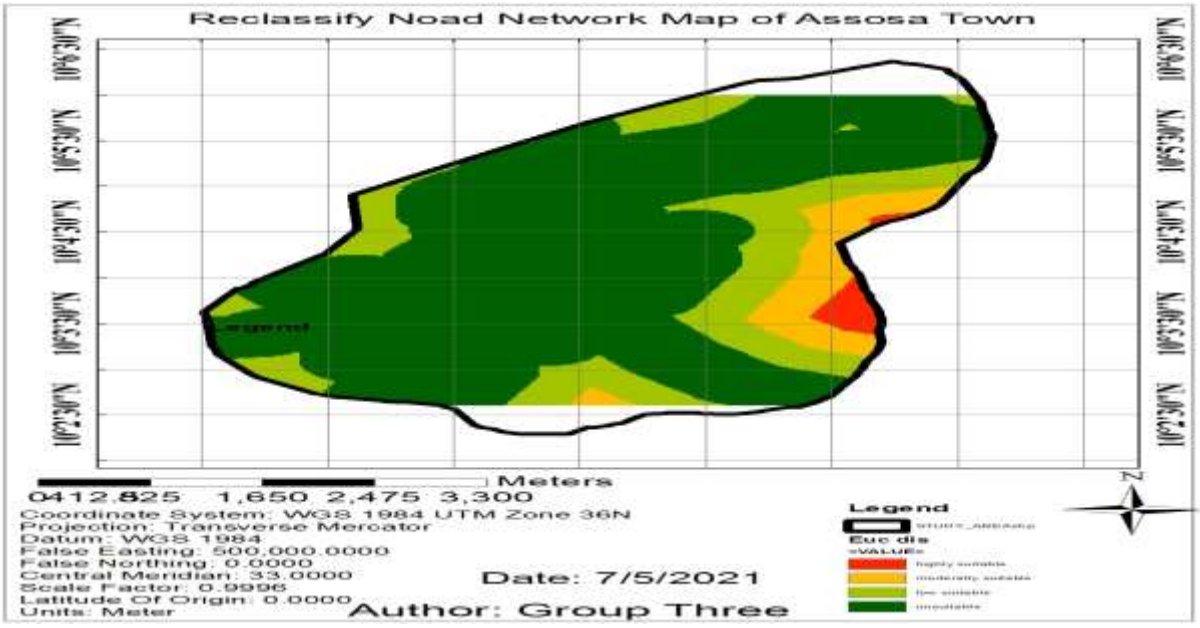

Figure 7. *Reclassify road network map*

The existing road network is assessed and analyzed in terms of coverage, hierarchy, alignment, surface material and associated features of the road system.

Table 5. *Existing road network data*

Road	Counted	Road	Total Length	Sum of width of each	Total Area (Ha)
Asphalt	14		9235.81	116	107
Cobble	29		4064.8	122.52	50
Red Ash	1		176.99	4	.071
Earthen	50		5115.6	116.37	60
Total	94		18593.2		217.071

Proximity (Euclidian Distance): *Euclidean distance tends to under estimate road distance and travel time.*

Proximity to roads is one of the criteria that should be considered from economic and social points of view during industry site selection processes. However, proximity to a road network is recommended for industry site 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. The buffer distance zones have been categorized into four levels based on the level of proximity to industry site.

Table 6. *Reclassified distance from the road network*

Level suitability	Class of suitability	Rank
Highly suitable	500m	4
Moderately suitable	500_1500m	3
Low suitable	1500_2000m	2
Unsuitable	>2000m	1

Source: *Extracted from Euclidian distance map road network*

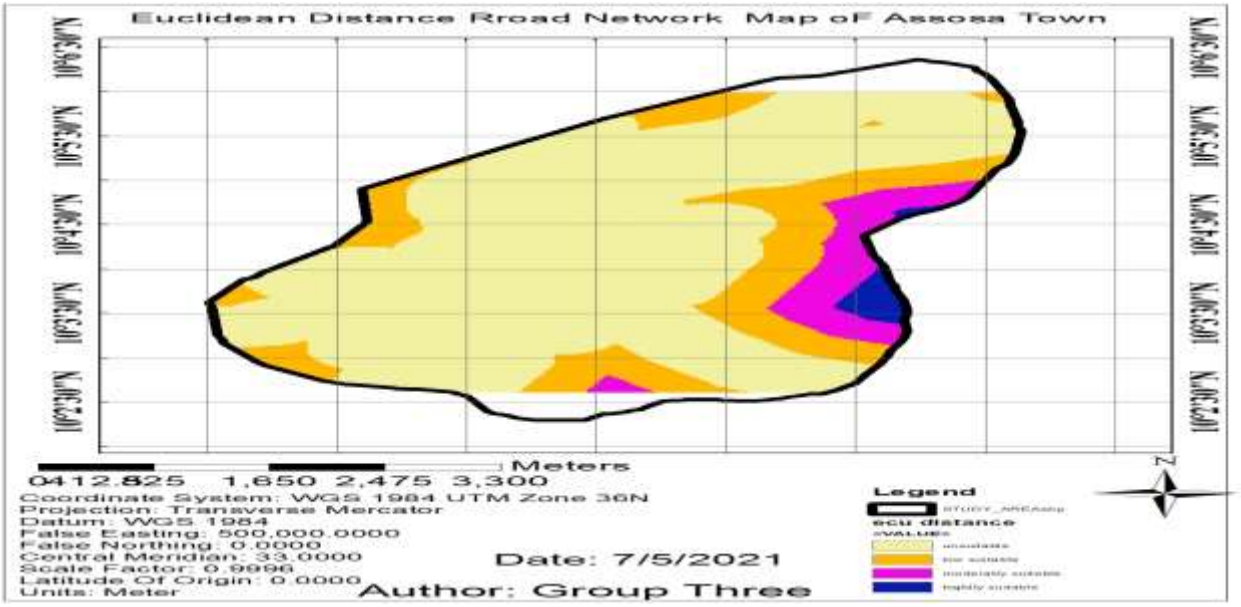

Figure 8. *Euclidean distance map of road network*

Rivers

Most of the surface waters in the study area are in the form of streams that occurred during heavy rains in summer season. Industry site must not be located in close proximity to surface water (streams, rivers, lakes, sea). The criterion is important from the point of view of both environment and economic concerns because in addition to causing pollution problems, it may require an efficient drainage system with high expenses. The streams/river factor was generated from the digital elevation model (DEM) using the ArcGIS spatial analyst extension of hydrology module. Then it was buffered based on the 300m distance standard criteria set by (EPA, 2002) to locate industry site from critical environmental resources such as streams/rivers.

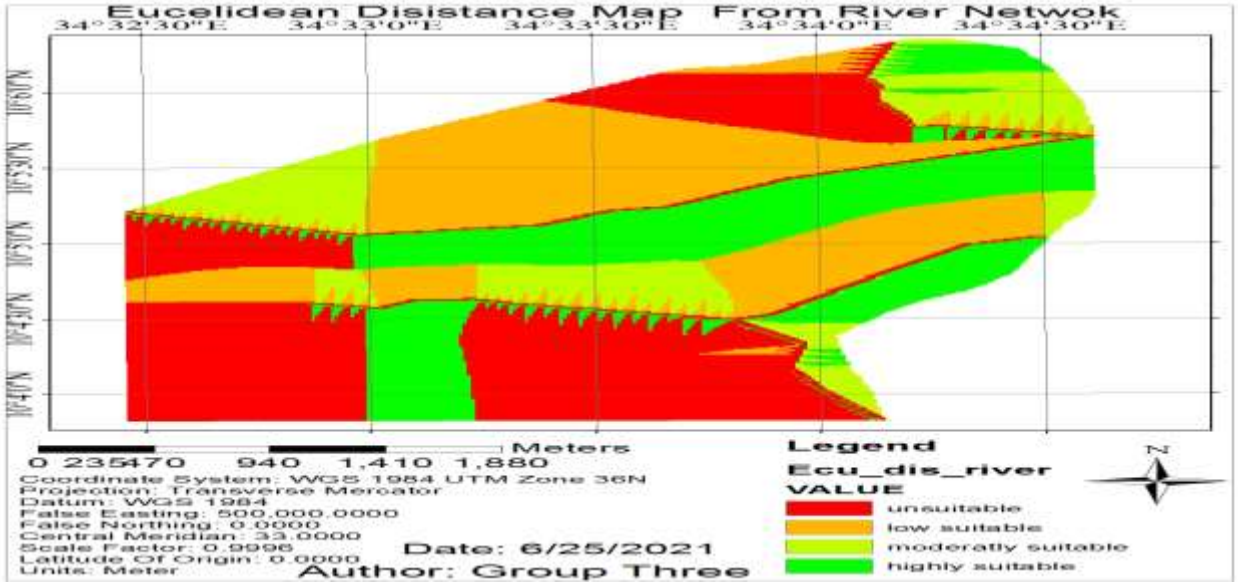

Figure 9. *Euclidean distance map*

Table 7*. Reclassified distance from river*

Level suitability	Suitability class	Rank
Highly suitable	>2000m	4
Moderately suitable	1500_2000m	3
Low suitable	500_1000m	2
Unsuitable	<500m	1

Source: *extracted from Euclidian distance map of river*

Raster and Reclassify River Map

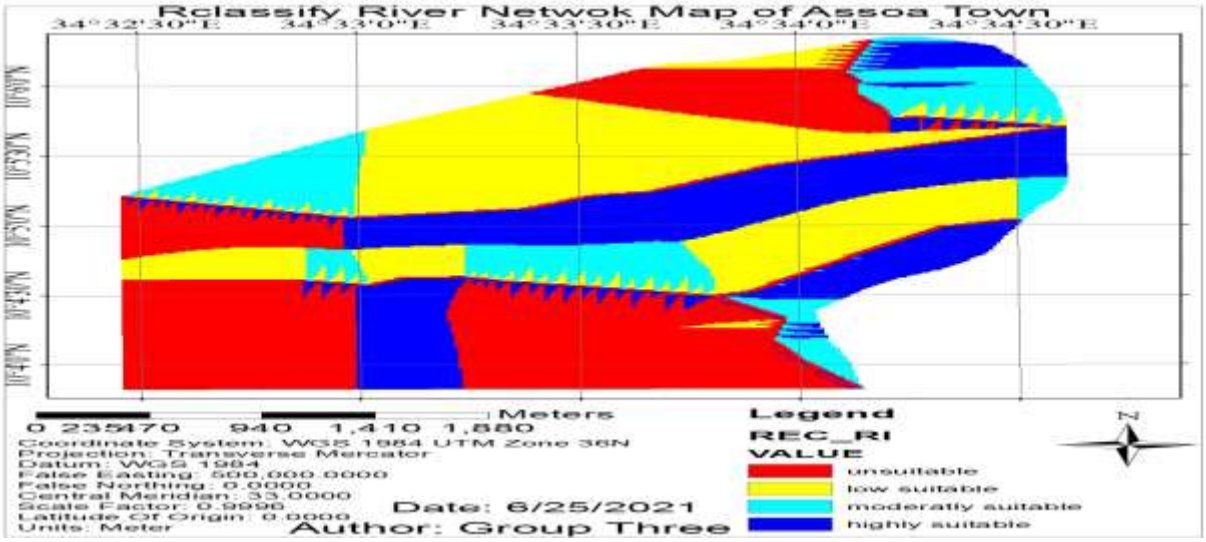

Figure 10. *Reclassify river network map*

Identification and Reclassification

Criteria are variables that justify or explain the environmental impact on making decision to select the most suitable site for our project. During the digitizing process, features from the traced map or image are captured as coordinates in either point, line, or polygon format. Reclassification is important in weighted site selection because it is used to simplify the interpretation of raster data by changing a single input value into a new output value (ESRI). It can also be used to group ranges of cell values into a single value. This simplifies weighted site selection because different types of raster data have different values based on what they show (ESRI). Data extraction is a GIS process similar to vector overlay, though it can be used in either vector or raster data analysis.

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 (unsuitable) to three (high suitability). This "positive direction" (Joshua, 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.

Weighted Overlay

The weighted overlay process is based on the GIS of industrial site suitability model that includes management of an evaluation scale. The main aim was to identify industry that is suitable for urban use and for

agriculture; the first objective was based on existing data/information from Assosa town. Existing data/information was divided into six environmental conditions. These environmental conditions determined how suitable the industry is for road, wetlands, forest, water, slope, agriculture and protected area for urban or agriculture land.

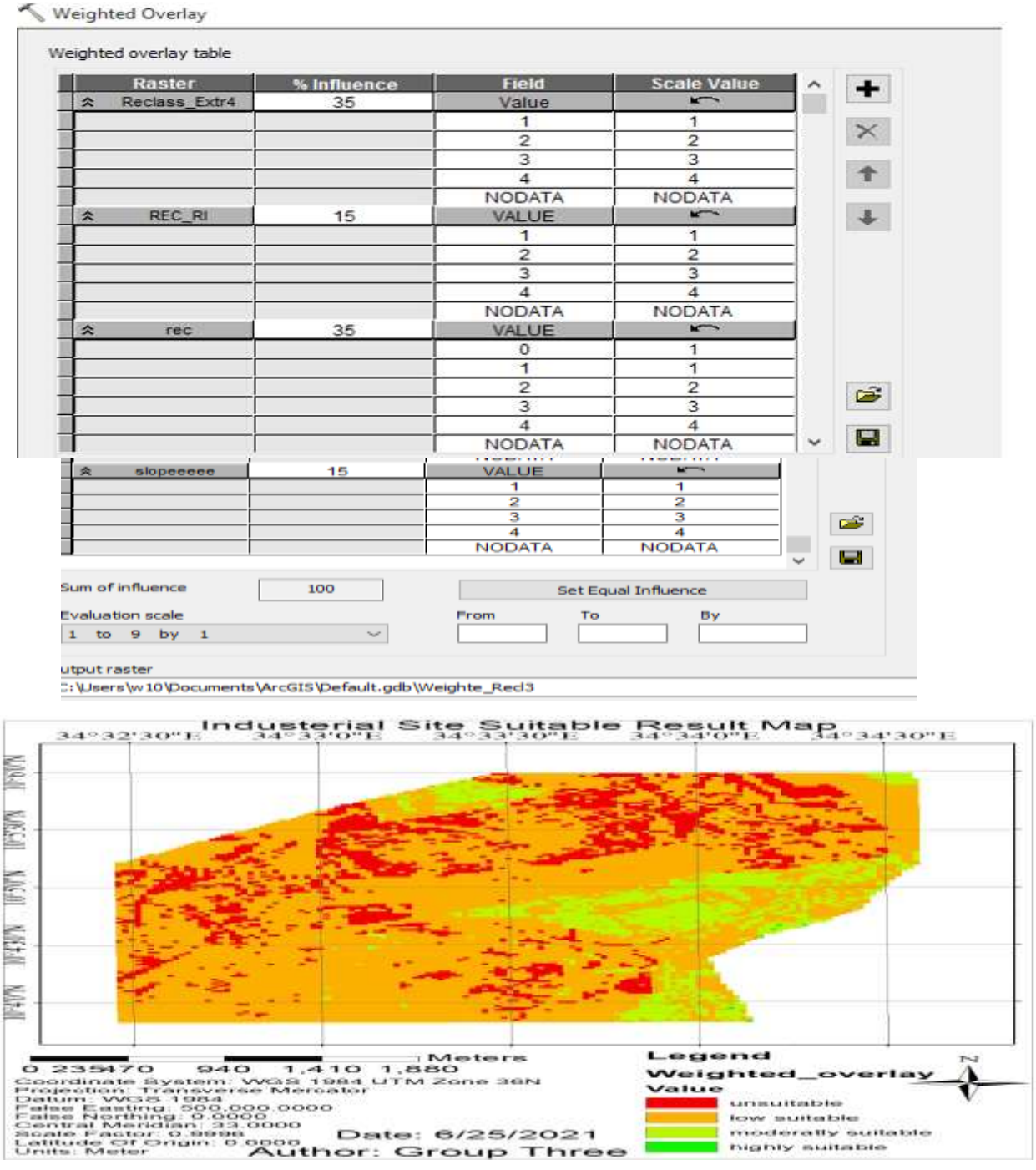

Figure 11. *Final out put industry site suitability map*

Criteria Maps Generation and Classification

The structure could serve as a framework for better understanding of the various specific objectives and spatial entities involved in the overall suitable site designation process for industry. The overall objective (the goal) is to designate suitable site for an industry.

Table 8. *Suitable site selection criteria*

SN	Parameters	Layer Name	Criteria
1	Rivers and Streams	River/Streams	100m away from River/Stream
2	Slope	Slope	between 2-10 per cent slope
3	Road Network(streets)	Road	between 400 and 1000 m from existing road
4	Future Land use	Future Land use	Prioritize
5	Boundary/Assosa Town Area	Boundary	within the municipal boundary

Source: *Environmental protection*

Table-8 represents the criteria identified for the analysis of site suitability for the location of industry by consulting urban planning experts and referring to the review of related previous works.

Assessment and Analysis the Existing Industrial Site of Assosa Town Structure Plan

The field inventory has involved identification of the patterns of spatial and non-spatial features of the study area. It focuses mainly on land use, road network, slope and river network of town. As seen from the existing road network plan the overall road network in Assosa in general and in the NDP site in particular is adequate and in good condition as compared with the situation in another town of Ethiopia. Reclassifications maps of respective thematic layers using a common four-point scale are shown in various maps from figure**.** The most suitable slope falls within 0-2 degrees sown in green colour. It covers a very large area. Steep slope is not suitable for construction purposes but fortunately this is a very small proportion of the study area. The most suitable zone for the roads is shown in figure 4.7. It is between 0m - 500m. This zone is shown in radish colour and covers an area which is sufficient in supporting industrial activities. Areas adjacently close to the rivers are ecologically sensitive hence not suitable for industrial use. Highly suitable areas on the rivers layer are limited and shown in figure 4.9 in light blue colour. The most suitable land use class is agriculture which covers a large proportion of the study area as shown coloured with light green. The most suitable class for the river falls between > 2000m which is farther away to avoid pollution and yet within reasonable distance for tapping the water resources. The result of this research was similar with the research done in Nahan town as the study area (Santosh & Ritesh, 2014). As seen above analysis there are problems they are not to select suitable site in Assosa town some of the problems are; Poor awareness about the potential resources, Inadequate infrastructure and Informal utilization and poor management

CONCLUSIONS

It can be concluded that GIS and remote sensing products play vital role in the preparation of suitable industrial site. With the problem at hand and short listing the important factors necessary for the solution are considered. Main factors being land use and land cover detail, elevation and slope of the region, road network and river network

to make the work easier at least in the initial stages. Evaluation process was conducted with the help of some expert opinions and individual perspective who provided the necessary judgment to fill the comparison matrix.

The current study implemented the GIS- based MCA to select a feasible site for industry in Assosa town. Basically, the study analyzed different possible sites that divided into four categories; high suitability, moderately suitability, low suitable, and unsuitable. This in turn would increase the opportunity to access industry product facilities by the society. Moreover, the study affirmed the successfulness of GIS technology as a primitive technique to estimate an appropriate location for nominated applications.

Finally, suitability maps were generated by MCDA. Finding the potential industrial sites using different techniques gives us a better picture to assess the problems associated in it. Uncertainty is an inherited feature while we deal with real world problems. So, we performed sensitivity analysis by changing the criterion weights to certain percentage to estimate the area changes within the classes of suitability and to decide the suitability area. The conducted analysis is not measure to the method's superiority in that problem solving. A GIS based industry site suitability analysis extends the utilization of overlay operators to the decision maker's preferences. Some of the multi criteria methods have to be investigated later to get a better result. Development of new computational methods in GIS environment makes it interesting for improving the efficiency in evaluating the industrial establishment process. Generally, as seen above in Assosa town there is no so many existing industry site areas but as seen our study there are so many preferable conditions and also comfortable areas which is suitable for industry site.

RECOMMENDATIONS

In this study an attempt is made to develop a model for conducting industry site suitability analysis for a selected town, i.e. Assosa. The study showed that the use of a GIS and remote sensing for industrial site suitability analysis is appropriate. After analysis of the study, certain recommendations can be made. The following can be recommended for suitable industrial site selection. The following can be recommended for suitable industrial site selection:

1. Industrial site-use strategy must take account of industry site suitability in relation to the expected future needs and the possibility of meeting demands. The critical importance of industry for specified uses should be known either physical or economic suitability. This means not only whether it is important that this specific area of industry should be used in particular way but also whether a particular area is physically suitable.
2. The combination of GIS with MCDM is powerful tool for industrial suitability analysis for suitable industrial site. The method requires only little computer skills within a GIS environment. Therefore, GIS-based MCDM for industrial site suitability has proven to facilitate efficiency from the economic point of view as compared to the traditional methods
3. The huge gap between the demand and supply of social and other public services, and their unbalanced distributions, especially industrial service, so these forms of problem should be solved by the government as well as by the communities.
4. Awareness the gap between the natural resource and poor advertisement about the potential of the area and industry sites.
5. In the future study this method can be applied for mapping industry site suitability of other urban development in the town and across the town with additional and more refined parameter.

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