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GIS based Site Suitability Analysis for Wastewater Treatment Plant in Upper Ponnaiyar Watershed, South India

Shanthi S[1], Suresh R[2]

[1,2]Department of Geology, Periyar University, Salem – 636011, Tamil Nadu, India

Abstract

The management of water resources is a major challenge for most of the dry land areas, as the demand for water are increasing and the quality are being compromised due to a number of natural and economic factors. The water pollution issue has gotten worse recently, in order to solve the water pollution issue, building a wastewater treatment plant is a good way to treat polluted water. If the proper location for the treatment plant is not selected, then it may lead to soil degradation and groundwater pollution. This study was conducted by using GIS techniques for selecting suitable wastewater treatment plant sites.There are seven parameters considered in the analysis consists of land use/land cover, elevation, road proximity, a slope of the ground, drainage density, geology, and soil. The weighted index overlay analyses of the final map with final weighted factor map were integrated and produced the final suitable wastewater treatment plant site map using ArcGIS Spatial Analyst tools. As a result, 73.88 km^2 (6.90%), 359.55km^2 (33.59%), 441.08km^2(41.21%), 180.71km^2 (16.88%), 15.05 km^2(1.41%) of the total study area was found to be unsuitable,low suitable, moderate suitable,high suitableand very high suitablerespectively. The area of very high suitable is preferable for wastewater treatment plant sites, because of their minimum effect on the environment, public health and cost effective than other parts of the study area. Therefore, the study will help the concerned authorities to formulate their development strategies according to the selected suitable wastewater treatment plant site available to the area.

Keywords: GIS,Weighted Overlay Analyses,Wastewater Treatment Plant.

INTRODUCTION

Wastewater also knows as waste water is the water-carried waste both in solution or suspension that is intended to be disposed from a community. Wastewater consists of mixture such as water and whatever that is liquid wastes from domestic and industries flushed into the sewers. It is necessary to collect, treat and safely dispose of the wastewater, because if it is let into the environment without treatment, it will be naturally drained by the existing ground slope and will reach the nearby water bodies such as lakes and rivers. The main water supplies for the dry land come from non-renewable groundwater aquifers, local marginal rainfall or far distant discharges from seasonal and perennial river systems. The organic waste present in the wastewater will undergo decomposition in the water bodies causing depletion of dissolved oxygen in it and causing unhygienic condition leading to the spreading of water borne diseases. Wastewatercarries pathogenic organisms that transmit diseases to human. It contains organic matter that causes odor and nuisance problems. It carries nutrients that cause eutrophication of receiving water bodies and leads to ecotoxicity.

The water pollution issue is getting worse recently, the safe disposal of wastewater is one of the key issues facing several countries, as large quantities of municipal waste and industrial effluents are being produced due to increased urbanization and industrialization respectively. In order to solve the water pollution issue, building a wastewater treatment plant is a good way to treat polluted water.Wastewater Treatment Plant is a facility designed to receive the waste from domestic, commercial and industrial sources and to remove materials that damage water quality and compromise public health and safety when discharged into water receiving systems.However, discharge from the wastewater treatment plant also poses a threat to the ecosystem (Smith et al. 1999, Hughes 2004), making it very crucial for the planners and decision makers to take a suitable decision on the location for the wastewater treatment plant (Fraschetti et al. 2006, Milnes and Perrochet 2007) so that its footprint on the ecosystem can be minimized. Proper collection and safe disposal of the wastewater are legally recognized as a necessity in an urbanized, industrial society.

Wastewatermanagement is referred to as the disciplineassociated with the control ofgeneration, storage, collection,transfer and transport, processing and recovery, and finalwastewater treatment plant in a manner that is in accordancewith the best principles of public health, economics,engineering, urban and regional planning, conservation,aesthetics, and other environmental considerations which are also responsive to public attitudes (Water resources research centre 2008).The wastewater treatment problem is one of the primary issues in Krishnagiri and Dharmapuri districts. The River Ponnaiyaris the major supply of water needed for drinking, irrigation, industry, and other applications.Thisrivershows decreasing quantity and quality of water because of the rapid growth of industrial, urbanization and municipal activities. This matter makes this river more susceptible to pollution easily. Therefore, wastewater water should dilute from its pollution before throwing it in this river, it through an efficient treatment plants. The Remote Sensing/GIS applications give a simple way of integrating and analyzing this environmental data for efficient and successful implementation of an environmental project (Usman 2013).Hence, this research attempted the relevant database in a spatial framework to evolve a wastewater treatment plant site map for Upper Ponnaiyar River basin with the application of Remote Sensing and GIS techniques. This wastewatertreatment plant site map based on administrativeunitsis particularly handy for the planners and administrators for formulating remedial strategy and implementation of the adopted wastewater management strategy.

THE STUDY AREA

The study area, Upper Ponnaiyar watershed, from part of Krishnagiri and Dharmapuridistrict of Tamilnadu which has been selected for the study lies between 12°24'36.42" to 12°52'37.73"N latitude and 77°41'18.25"E to 78°12'54.13"Elongitude (Figure 1). It covers a geographical area of 1070.27 sq.km andfall in parts of survey of India toposheet Nos. 57H and 57L. ThePonnaiyarRiver originates in the Chikkaballapur district ofKarnataka at an elevation of about 900m above Mean Sea Level and then flows towards south eastdirection for a distance of 400 km through Karnataka and Tamilnadu and finally emptying into Bay ofBengal.The district headquarters are well connected with other towns in the neighbouring districts, as well as with the towns in the neighbouring States of Andhra Pradesh &

Karnataka. Bangalore to Chennai and Bangalore to Salem National Highways pass through the study area.

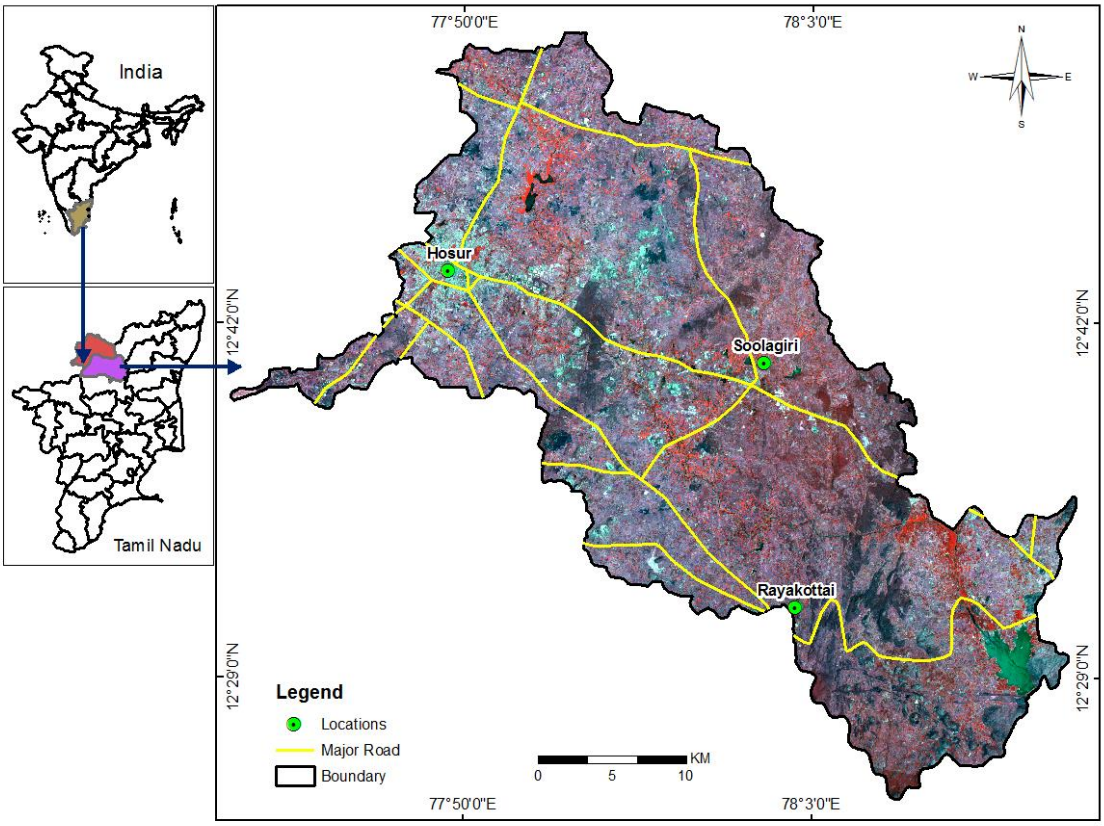

Figure 1- Location map of the study area

DATA USED AND METHODOLOGY

In the present study, there are seven land suitability factors have been chosen for sitesuitability assessment such as land use, geology, soil, drainage density, road proximity, elevation and slope.Thematic maps of the study area can beprepared by integrating survey ofIndiatoposheet of 1:50000 scale, existingmaps, IRS LISS III satellite image and SRTM image by using the software ArcGIS 10.8. These maps were verified in the field through extensive ground truth and necessary corrections were made wherever required.

The methodologies mainly based on GIS-based weighted index overlay analysis.The IRS LISS III image has utilized for preparation of land use/land cover patterns in the study area.From the SRTM DEM 90m resolution satellite data utilized for preparation of slope degrees and elevation map.Geological features have prepared from the GIS published map and soil information gathered from the Soil Survey of India map. The drainage line digitized from Survey of India toposheet and drainage density was generated from ArcGIS tool. Theroad information also gathered from toposheet and road proximity maps by using the buffer tool in GIS software.Theranks and weightageswere assigned to all the thematic data depends on theimportance of influence for locating the plant. The weightage assigned for different themes is shown in the table 1.Then, all the thematic layers wereintegrated; the weightages of each parameter addedand finally, the study area has been divided into very high suitable, high suitable, moderate suitable, low suitable and unsuitablefor concluding the site suitability.

Generation of Thematic Maps

Elevation

The elevation is an important parameter in designing plants and wastewater networks. During the construction of STP (Wastewater Treatment Plant), the path of the main collector of the wastewater was considered. In optimum design, the wastewater flows to the treatment in an open channel using gravity. The elevation of the site STP should be lower than the lowest parts of the area (below the local datum). These features along with other parameters were determined for selecting the final sites.The elevation map was generated from the SRTM DEM with 90m resolution data and shown in Figure 2. Very suitable class belongs to the sites with lower elevation of 463 to 576 meters, as areas with higher elevation are undesirable.

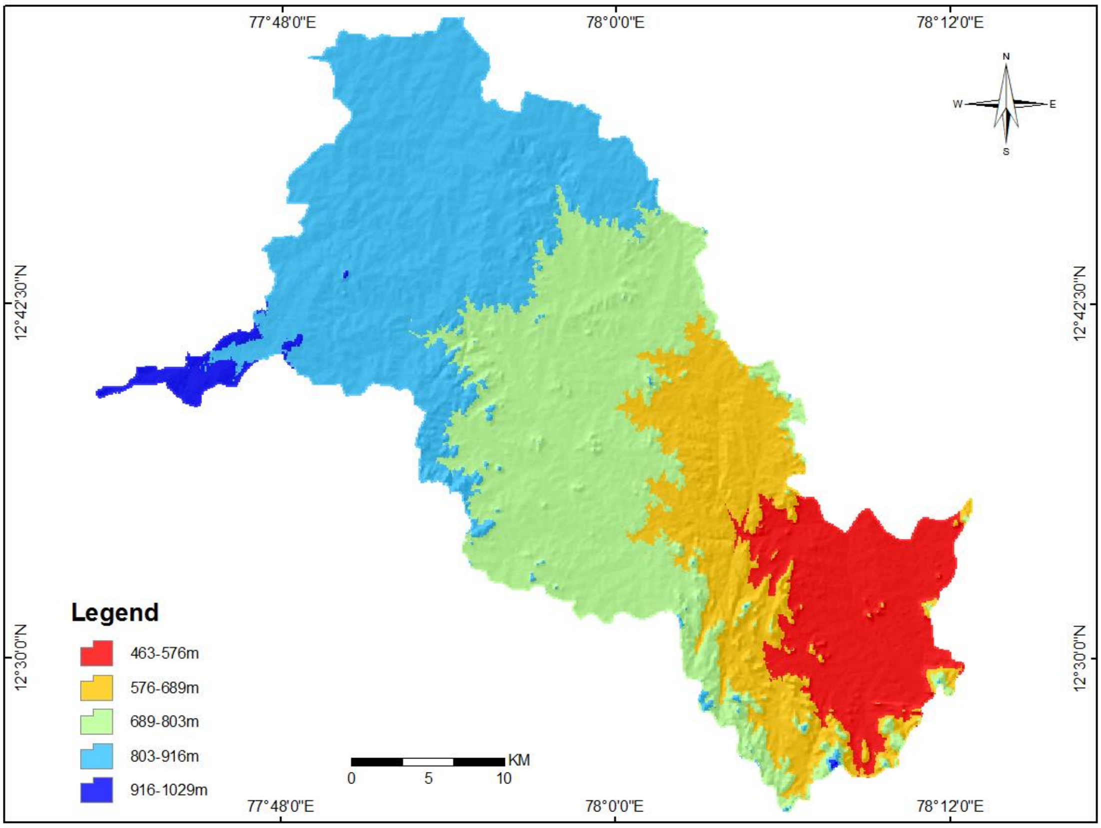

Figure 2 - Elevation of the study area

Slope

In site selection studies, the slope is an important component, both environmentally and economically. Construction of STP on steep sites will increase the cost of excavation and embankment and also intensify the wastewater flow to surface and underground water resources (Omer and Sami 2017).Lin and Kao (1999) stated that slopes that are less than 12% steep prevent the runoff pollution. Slope layer was obtained from Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) 90 m-resolution (Fig 3). The slope of the area is classified into four classes, and appropriate slope for the construction of STP is between 0-3^{o}, which is placed in the very suitable class. The low angle of the slope to get good gradual flow of wastewater collection and to avoid over land flow during rainy seasons. Slopes that are more than 16^{o} prevent the runoff, wastewater inappropriate way and not suitable for civil construction.

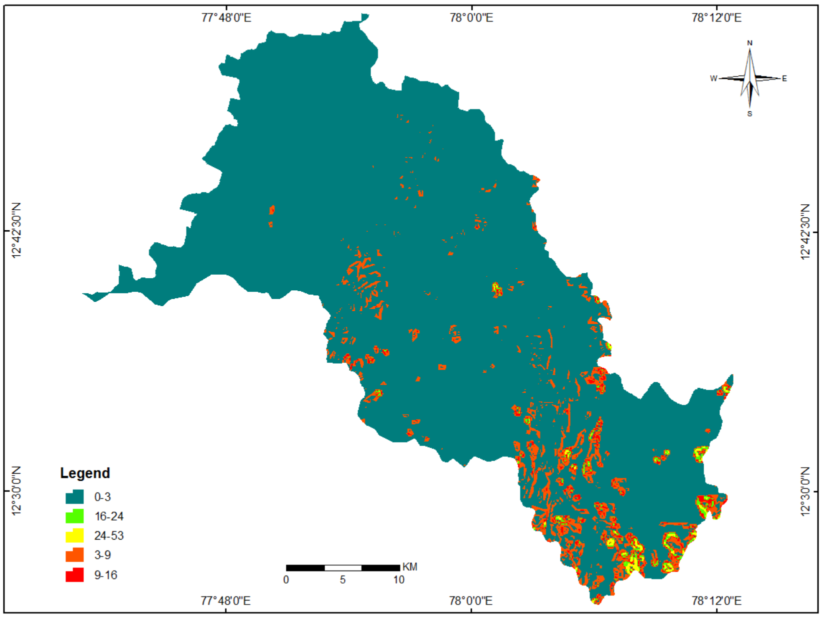

Figure 3 - Slope (degree) in the study area

Land use/Land Cover

Land use/land cover plays a vital role as it is used for identifying the suitable site. Thedumping site should not be selected close to the built up area to avoid adversely affecting the land value and future development and to protect human beings from environmental hazards created from dumping sites (Clark et al 1974). It should be selected at a suitable distance far from the residential area. Scrub land and barren land are most suitable for the dumping site. The land use/land cover map was prepared from IRS LISS IIIsatellite image using interpretation key elements and shown in Figure 2. River and water bodies, built-up, agricultural land, forest land and barren land are major land use/land cover classes in the present study. The rank assigned for land use is based on MSW rule 2016 and other important criteria. In land use, ranks are assigned based on the importance of the feature. Rank 5 indicates the very highest priority; rank 3indicates medium priority and the rank 1 indicate the low priority. Based on the feature importance the rank is assigned from 1 to 5 in land use classification.

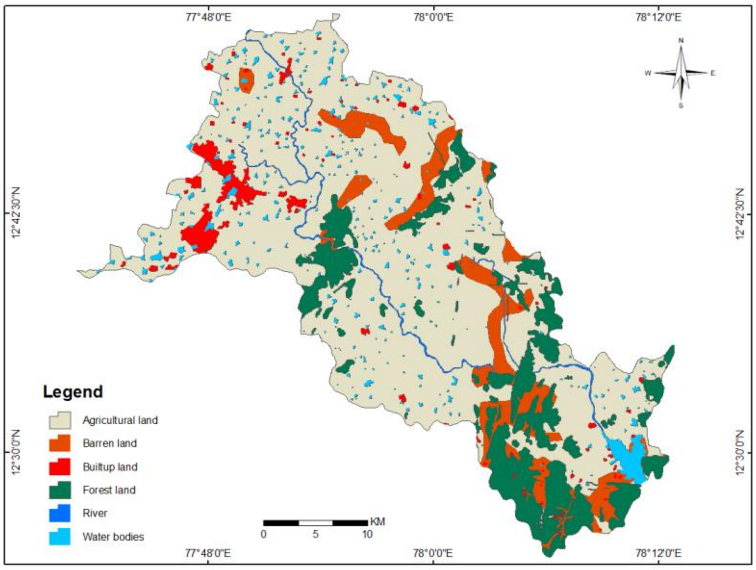

Figure4 - Land use/land cover map of the study area

Drainage Density

All the drainages were drawn from Survey of India topographical map of 1:50000 scale. The drainage network consists of the major river – Upper Ponnaiyar as it cuts across the study area and the surrounding tributaries. The map was reclassified into five classes, viz; 0.25-1.5, 1.6-2.7, 2.8-3.9, 4.0-5.1, and 5.2-6.4 km/sq.km. Similarly, ranks were assigned to drainagedensity; based on surface infiltration and runoff. The area near high drainage density is suitable for STP which is related to low permeability, which leads to low infiltration and increased runoff.

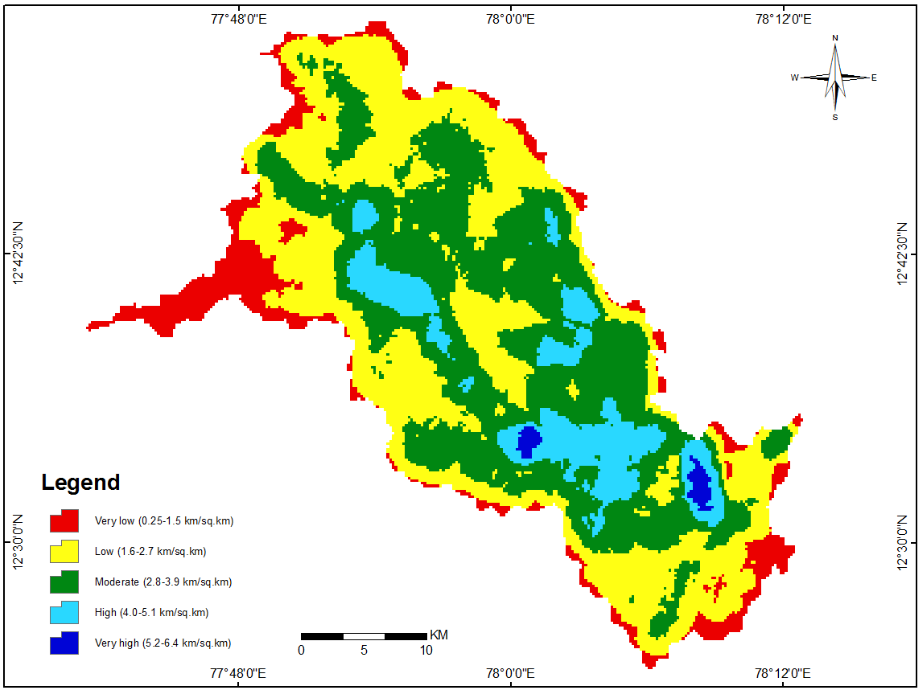

Figure 5 - Drainage density

Road Proximity

The map indicates the national highways, district road and village roads. Road map isPrepared from Survey of India toposheets and shown in Fig 5. The national highways NH-7 and NH-207 passes in the study area. Ideally, the wastewater treatment plant should be away from major roads. Distance from the roads increases the cost of wastewater treatment plant construction and maintenance; however, the presence of the wastewatertreatment plant close to the roads affects the landscape, climate, and the public health (Omer and Sami 2017). In this study four categories of buffer zones express the distances from the roads were used, these are: <250m, 250 - 500m, 500 - 750m, 750-100m and >1000m.In this case, higher rank was given to away from the main road and gradually low and very lowest ranks were assigned closer to the road networks.

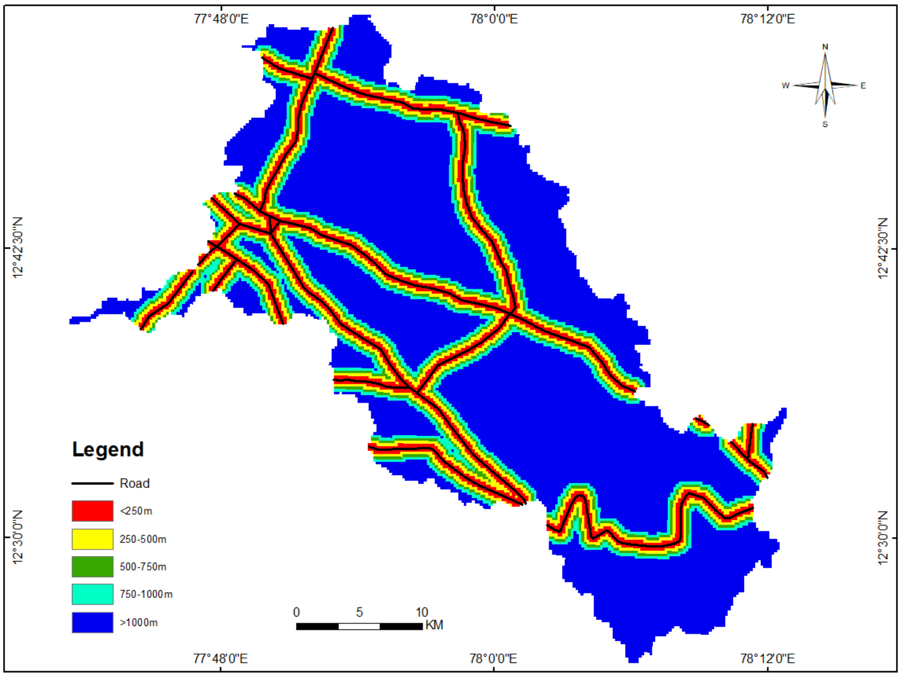

Figure 6 - Road proximity

Geology

The geological settlements play an important role in land suitability site selection. The geological settlements in the study area were identified as granitic gneiss, migmatitic complex, gneiss, charnockite, basic rocks, amphibolites and acidic rocks (Fig 7). The study area forms part of the polymetamorphic and multi-structural Archaean Complex of Peninsular India and is underlain by crystalline formations. Therefore, the lowest ranks were assigned to the geological features in the study area.

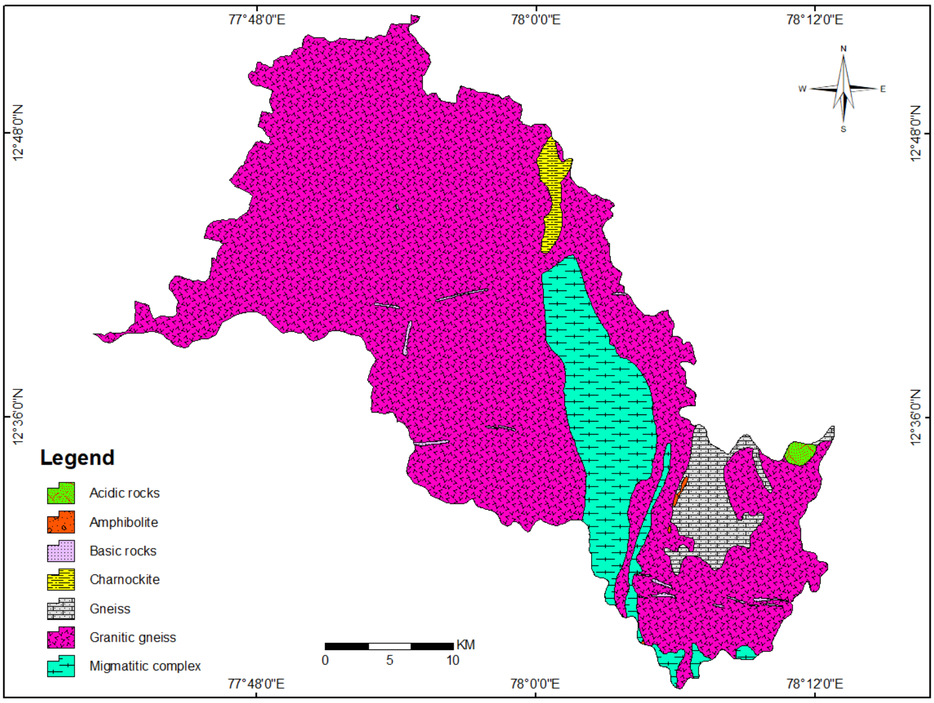

Figure 7 – Geological setting

Soil

The soil's characteristics play an important role in the eventual removal of the waste.Soil texture controls the seepage of wastewater, absorption of pollutant, and surface water penetration into landfills (Thoso 2007). Soil with intermediate to heavy surface texture, pebbles ratio, salinity, and low alkalinity are beneficial for the wastewater treatment plant construction. The soil orders of the watershed are broadly grouped into alfisols, entisols, hill soil and inceptisols. The gravelly clay type of soil is found predominantly in the study area. The clayey soil is found towards the north, northwest and central portion whereas the slightly unconsolidated soil like enthusiastic seen distributing on the east and the southern portion of the study area.Over-permeable soil may result in contaminants reaching the water table, while impermeable soil may cause water to accumulate or run off the surface. Based on the infiltration rate of the soil characteristics rank has been assigned from 1 to 5.

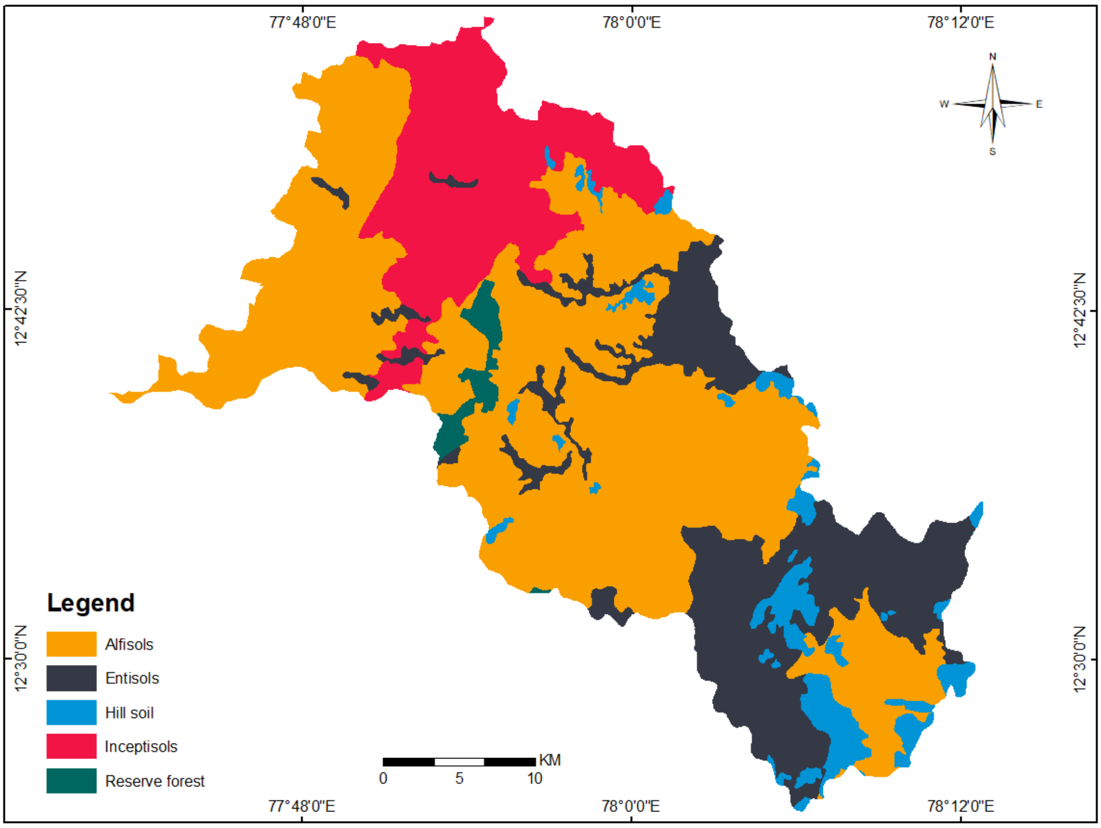

Figure 8 - Soil order in the study area

RESULTS AND DISCUSSION

Weighted Index Overlay Analysis

The weighted index overlay analysis was performed on a GIS platform to identify the suitable location for a land suitability site. The prepared various thematic maps such as land use/land cover, slope, elevation, road proximity, drainage density, geology, and soil were used for weighted overlay analysis. The selection of criteria for identifying the suitable land suitability site is based on the requirement in the particular region; it may not be a universal standard (Makan et al 2012). Based upon the importance of the each feature weight has been assigned (Table 1). Weighting is used to express the relative importance of each factor to another (Subramani et al 2014). The larger the weight, the more important is the factor in overall utility. In a weighted overlay analysis, GIS-based model was created to identify the suitable site for wastewater treatment plant can be found out and classified as good, moderate and poor as shown in fig.8. The weighted index overlay was calculated using the formula sum (weights × ranks) for every factor.

WIO = ∑ [(25×Elevation ranks) + (20×Slope ranks) + (20× Drainage density ranks) + (15×land use/land cover ranks) + (10×Road proximity ranks) + (5×Geology ranks) + (5×Soil ranks)]

Table 1 - Features in each theme and weight factors

S.No.	Theme	Classes	Ranking	Weight	Level of site suitability
1	Elevation	463-576	5	25	Very high
		576-689	4	25	High
		689-803	3	25	Moderate
		803-916	2	25	Low
		916-1029	1	25	Unsuitable
2	Slope	0-3.10	5	20	Very high
		3.10-8.69	4	20	High
		8.69-15.73	3	20	Moderate
		15.73-23.81	2	20	Low
		23.81-52.80	1	20	Unsuitable
3	Drainage density	0.25-1.5	1	20	Unsuitable
		1.6-2.7	2	20	Low
		2.8-3.9	3	20	Moderate
		4.0-5.1	4	20	High
		5.2-6.4	5	20	Very high
4	Land use/land cover	Barren land	4	15	High
		Forest land	3	15	Moderate
		Agricultural land	3	15	Moderate
		Builtup land	2	15	Low
		Water Bodies	1	15	Unsuitable
		River	1	15	Unsuitable
5	Road proximity	<250	1	10	Unsuitable
		250-500	2	10	Low
		500-750	3	10	Moderate
		750-1000	4	10	High
		>1000	5	10	Very high
6	Soil	Entisols	4	5	High
		Reserve forest	3	5	Moderate
		Hill soil	3	5	Moderate
		Inceptisols	2	5	Low
		Alfisols	2	5	Low
7	Geology	Gneiss	2	5	Low

		Granitic gneiss	2	5	Low
		Basic Rocks	2	5	Low
		Amphibolite	2	5	Low
		Charnockite	1	5	Unsuitable
		Migmatitic complex	1	5	Unsuitable
		Acidic rocks	1	5	Unsuitable

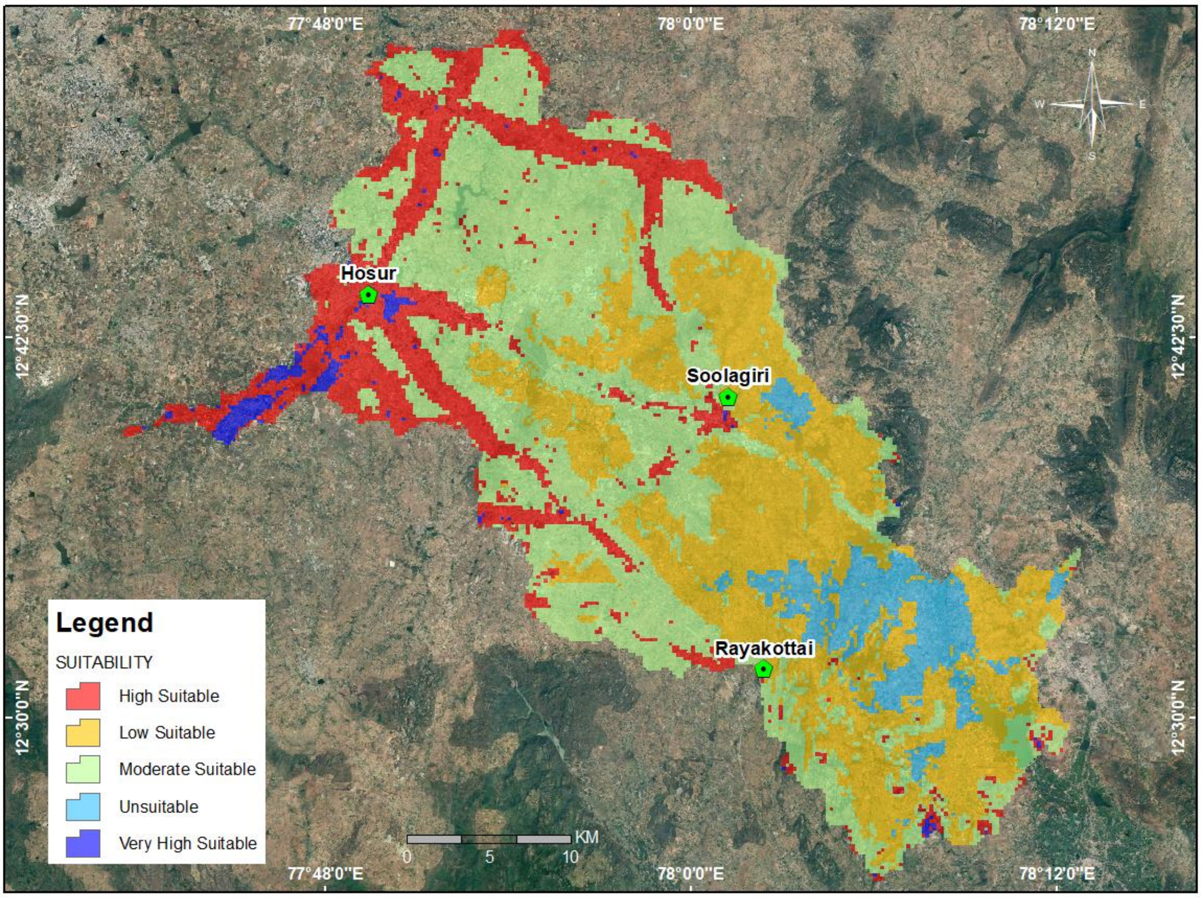

Figure 9 - Site suitability for Wastewater Treatment Plant (WTP)

The area coverage of each suitability index of the sites was calculated in ArcGIS environment showed that 15.05km^2(1.41%) of the study area is unsuitable (restricted)for wastewater treatment plant site as the areas are environmentally unfavourable and economically impracticable to be proposed as wastewater treatment plant site. This unsuitable (restricted) site include, areas with steep slope (>16%), areas with higher elevation (>916m), areas with close to road networks and far from road networkswith a 250m buffer zone. The main advantage of theseareas restriction was to minimize their negative effects ofon environment and public health as well as to minimizethe cost of construction and maintenance of thewastewater treatment plant site. However, 180.71km^2(16.88%) of the area was low suitable for wastewatertreatment plant site and the area of 441.08km^2(41.21%) moderately suitable. Out of the remaining area, 359.55 km^2(33.59%) and 73.88 km^2(6.90%) of the area was very high suitable and high suitable, respectively, these areasare preferable for wastewater treatment plant, because oftheir minimum effect on environment, public health andcost effective than other parts of the study area, shown in(Table 2), with different suitability indices**.**

Table 2 - Area coverage and identification of suitable areas

S.No.	Suitability	Area (km^2)	Area (%)
1	Unsuitable	73.88	6.90
2	Low	359.55	33.59
3	Moderate	441.08	41.21
4	High	180.71	16.88
5	Very high	15.05	1.41
Total		1070.27	100

CONCLUSION

Wastewater treatment plant is great in demand due to the increasing population, urbanization and industrialization. The methodology employed in this study described the GIS and weighted index process techniques for the selection of suitable sites for the wastewater treatment plants in the Upper Ponnaiyar watershed. Theresult of this study indicated that, out of the total area, 73.88km^2(6.90%) and359.55km^2 (33.59%) of the area was very highly suitable and highly suitable, respectively. It has been identified the location in the Southeast part of the study area which full fill all the criteria for a land suitability site. Theseareas are preferable for wastewater treatment plant, because of their minimum effect on the environment, public health and cost effective than other parts of the study area, with different suitability indices. Thus, this study demonstrated the capability of GIS to select the most suitable site for wastewater disposal in an area.

REFERENCES

1. Clark, R.M., and Gillean, J (1974) Systems Analysis and Solid Waste Planning. Journal of the Environmental Engineering Division, 7-25.
2. Fraschetti S, Gambi C, Giangrande A, Musco L, Terlizzi A, and Danovaro R (2006) Structural and functional response of meiofauna rocky assemblages to wastewater pollution. Marine Pollut Bull 52(5):540–8
3. Hughes K.A (2004) Reducing wastewater pollution in the Antarctic marine environment using a wastewatertreatment plant. Marine Pollution Bulletin 49, 850–853.
4. Lin H.Y., Kao J.J., (1999) Enhanced spatial model for landfill siting analysis. Journal of Environmental Engineering, ASCE 125 (9): 845–851.
5. Makan A, Malamis D, Assobhei O, Loizidou M, and Mountadar M (2012) Multi-criteria decision analysis for the selection of the most suitable landfill site: case of Azemmour, Morocco. Int J Manag Sci EngManag 7(2):96–109.
6. Milnes E and Perrochet P (2007) Simultaneous identification of a single pollution point-source location and contamination time under known flow field conditions. Adv Water Resour; 30(12), 2439–46.
7. Omer O. A. Abdalla and Sami O.H. El Khidir(2017) Site Selection of Wastewater Treatment Plant using RS/GIS data and Multi- Criteria Analysis (MCA): Case Study Omdurman City, Khartoum State, Sudan. Alneelain Journal of Geosciences, 1 (2), 94-107.

8. Smith AK, Ajani PA, and Roberts DE (1999) Spatial and temporal variation in fish assemblages exposed to wastewater and implications for management. Marine Environ Res; 47(3), 241–60.
9. Subramani T, Subramanian A, Kathirvel C, and Bharathi Devi S. K (2014) Analysis and Site Suitability Evaluation for TextileWastewater Water Treatment Plant in Salem Corporation, TamilnaduUsing Remote Sensing Techniques, Research Article, P. 96.
10. Thoso M., 2007. The construction of a Geographic Information System (GIS) Model for landfill site selection", A dissertation submitted in partial fulfillment for the requirement for the degree of Magister Atrium in the department of geography at the university of the free state. 17-25.