Preparation of Zoning Atlas for Siting of Industries Using GIS

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ABSTRACT

The present work presents a technique to prepare zoning atlas to classify the environment and risks involved in siting an industry. Based on risks involved in a classified zone, the best suited industries are recommended. Kanpur city has been taken as the study area for the present work. Sensitivity of study area has been checked in terms of air pollution, surface water pollution and groundwater pollution. The study relies upon the database procured for this purpose from Central Pollution Control Board (CPCB) and office of U.P. Jal Nigam in Kanpur. The database mainly comprises of topographic maps, thematic maps and groundwater information. Buffering and overlaying of thematic maps have been carried out as per the guidelines of CPCB.

Overview

1. Introduction

Industrialization is on the increase and so is the environmental pollution due to emissions and waste generated from the industries. The industrial pollution due to its nature has the potential to cause irreversible reaction in the environment and hence is posing a major threat to sustainable development. Since the carrying capacity of the environment is limited and some areas or ecosystems are more susceptible to adverse environmental impacts than others, the unplanned and haphazard location of industries might substantially increase the risk to the environment. Presently, regional plans that suggest suitable sites compatible to the surrounding land use do not exist in India. Hence, the industrial entrepreneur is forced to purchase a site convenient to him and then apply for clearances.

Environmental planning is a proven tool for reducing the impacts from such risks. However, this tool has seldom been used in this country. Proper siting of newly planned industries and industrial estates is a strong pollution preventive instrument that ensures environmental soundness of the industrial development. Site selection based on environmental criteria with the objective of minimizing adverse environmental impacts is, therefore of vital importance. Zoning atlas is a set of thematic maps, which classify an area according to a set methodology to achieve a certain objective. It provides solution for all the problems caused by haphazard industrial siting, and also helps in tackling the problem itself.

2. Objectives of Study

The objective of this work is to present a methodology for preparation of a zoning atlas for siting of industries in Kanpur city using a Geographical Information System (GIS). This zoning atlas is prepared on the guidelines from Central Pollution Control Board (CPCB, 1995), using ILWIS 3.0 GIS environment.

The zoning atlas classifies the environment in the district and depicts the pollution tolerating potential of various sites/zones in the district. It also recommends the possible alternate sites for industries through easy-to-read maps. Thus, objectives of preparing a zoning atlas for siting of industries are:

- To classify the environment in the district.
- To identify locations for siting of industries.
- To identify industries suitable to the identified sites.

3. Methodology

CPCB (1995) gives the general guidelines to be adopted while zoning the suitability of an area as per environmental aspects. It is not a comprehensive draft. Certain aspects, depending upon the study area, are discretionary. The entire methodology has been divided into six steps as follows:

- Acquisition of required topographic sheets, thematic maps and data.
- Converting the topographic sheets and the various maps of the study area into digital form.
- Assigning of ground coordinates to digital database of the previous step by means of georeferencing and resampling operations respectively.
- Digitization of the required themes.
- Performing various overlay operations on the thematic layers as per the guidelines by making use of GIS environment.
- Zoning of area depending upon their sensitivity to air, surface water and ground water.

3.1 Maps and Data Acquisition: Maps and data required were obtained from the concerned government authorities. Maps and data related to air quality and surface water parameters were acquired from CPCB office in Kanpur. Related groundwater data was obtained from office of Uttar Pradesh Jal Nigam in Kanpur.

3.2 Converting Topographic Sheets and Maps into Digital Form: The four topographic sheets, covering the study area at 1:50,000 scale (63 B/2, 63 B/3, 63 B/6, and 63 B/7) published by Survey of India (SOI) were scanned to convert them into digital form and a seamless mosaic has been made. The maps acquired from CPCB were also scanned to convert them into digital form.

3.3 Georeferencing: For carrying out geometric correction, the mosaic map was georeferenced using Universal Transverse Mercator (UTM) with Indian (India, Nepal) datum and Everest (India, 1956) ellipsoid using zone no. 44. In the present study, 48 points were taken and full second order polynomial was chosen and resampling is done by nearest neighborhood interpolation method (Mather, 1987).

3.4 Generation of Thematic Maps: Thematic maps covering air quality, land use, sensitive zone, ground water quality, river pollution stretch, groundwater quality, ground water potential and surface water dependency were generated from the maps obtained from CPCB by process of screen digitization in ILWIS 3.0.

3.5 Overlay Operations on Thematic Maps: Methodology to be adopted for the assessment of air pollution, surface water pollution and groundwater pollution sensitivities has been explained in detail in section 4.0.

3.6 Zoning of Suitable Areas: According to CPCB (1997), every air polluting industry has been categorized into three classes, depending on the air pollution they cause. Similarly, surface water polluting industry and groundwater polluting industries have been classified into three classes. Hence, there are 27 combinations possible, which are explained in section 5.0.

4. Sensitivity Assessment

Sensitivity assessment means determination of the vulnerability of area towards air, surface water and groundwater pollution. This vulnerability is measured in terms of three classes-high, medium and low. The sensitivity of an area due to pollution from industries needs to be evaluated so as to minimize the environmental impacts and risks. In brief, the activities performed in sensitivity assessment are shown in **Figure-1**. The major components of the sensitivity are:

- Air pollution sensitivity
- Groundwater pollution sensitivity
- Surface water pollution sensitivity

Based on the sensitivity as above, the site suitability to receive a particular type of pollution and hence the type of industry can be determined. Sensitive zone map is the map showing all the zones where industries are prohibited due to legal/social reasons. This map is overlaid on each of the air, surface water and groundwater pollution sensitivity map to calculate the risk map that shows the remaining areas available for siting of industries along with their sensitivities. Risk map differs with sensitivity map only in the manner that they also include the areas where industrial siting cannot be done due to legal or social reasons.

4.1 Air Pollution Sensitivity: The sensitivity of the environment due to air pollution depends on the meteorological characteristics of the receiving environment, the topography of the area and the present air quality. The meteorology and the topography of the area have to be studied to analyze how well the area is able to accept or disperse the pollutants. The existing air quality has to be checked so that the areas already stressed with pollution are not further stressed by more industrialization.

4.1.1 Air quality map: The air quality map provides information about the status of ambient air quality in the district. In this map, the ambient air quality is depicted as high, medium and low. The high air quality means that the level of concentration of pollutant in the air is very well within the standards and there is no air pollution problem. The medium air quality means that the level of concentration of pollutants in ambient air is not exceeding the prescribed standard but is very close to the standards. The low air quality means that the air pollutant concentration is exceeding the standards and hence is polluted.

From the available pollution emission data, out of SO_2, NO_x and SPM concentration, it is the SPM concentration, which is exceeding the limits in Kanpur city. The standard SPM concentration is taken to be 260 mg/m^3 (Warner, 1983). Areas having SPM concentration more than 350 mg/m^3 are considered to be exceeding well above the standards and termed as low in terms of air quality. Areas with the SPM concentration less than 200 mg/m^3 are termed as high. Medium quality areas are regions with air quality close to the standards and SPM concentration lie between 200 – 350 mg/m^3.

4.1.2 Dispersion Sensitivity: The dispersion sensitivity

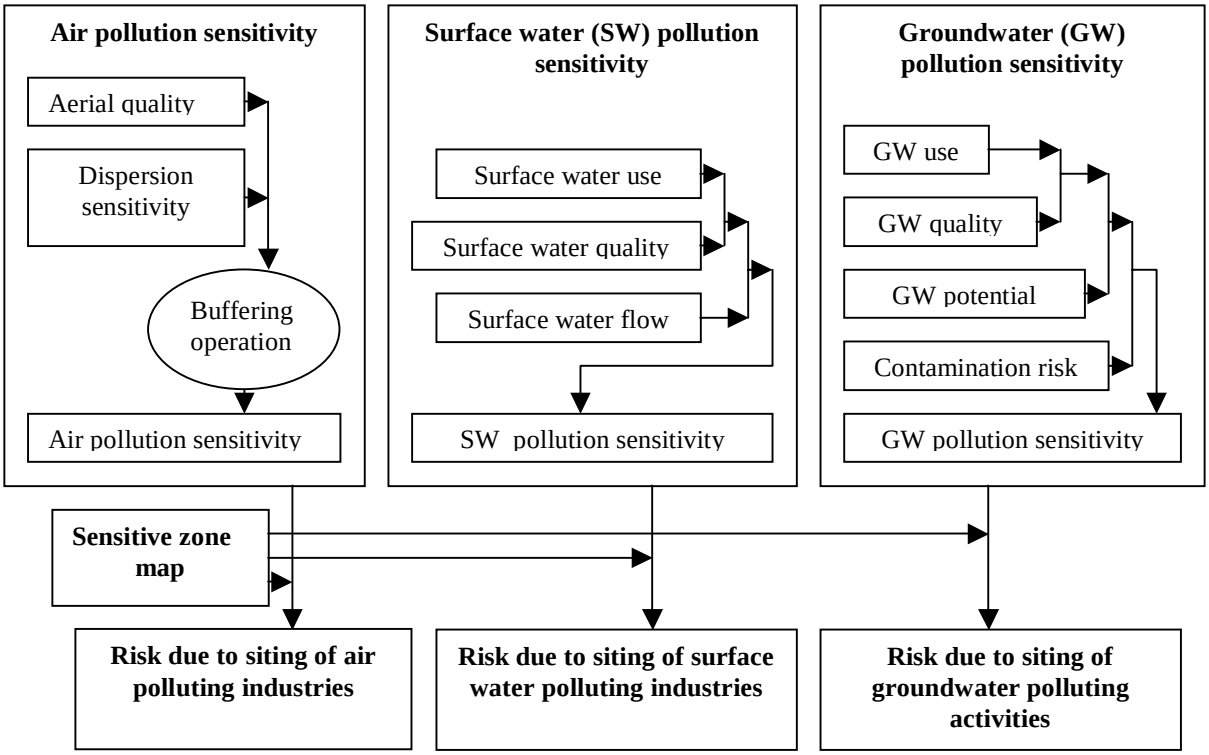

Figure 1. Generation of risk maps

describes the ability of the area to disperse and dilute air pollutants owing to its ventilating capacity, micro as well as macro level climate, vegetative cover and nature of earth surface. The plain areas have very good circulation of air and hence dispersion is normal. Areas with frequent inversion conditions and having extreme climatic conditions are critical as far as dispersion of pollutants is concerned.

In Kanpur city, the terrain is plain with no hills and no large-scale undulation. Also, frequent inversion of climate is not there. Hence, the dispersion activity for the entire district is normal. Since the dispersion is normal, dispersion sensitivity has no role to play in the generation of air pollution sensitivity map.

4.1.3 Air Pollution Sensitivity Map: Applying buffering operations at the boundaries of high, medium and low air quality regions should generate the air pollution sensitivity map. The buffer range is decided in the following manner:

- The high sensitive regions should extend 2 km from areas having low air quality. Also, it should extend 25 km to sensitive zones such as national parks, sanctuaries, areas with endangered species, etc. and monument areas of special significance. But such sensitive zones do not exist in present study area.
- The medium sensitive zones should extend 2-5 km from low air quality areas and 2 km to medium air quality areas.
- The low sensitive areas should be those that are beyond a distance of 5 km from the low air quality areas and 2 km from medium air quality areas.

The resulting map after buffering operation is the air pollution sensitivity map. It is found that central areas of Kanpur lie in the high sensitive zones. This includes Motijheel, Indra Nagar, Usmanpur, Kidwai Nagar, Fazalganj, Lalbangla, Jajmau, Industrial Estates, Panki and Armapur Estate. Medium sensitive areas are Dehli Sujanpur, Naubasta, Southern part of COD and Shekhpur in the South; Indian Institute of Technology and National Sugar Institute in the North. Low sensitive areas are minimal in the Kanpur city. It includes southern side of Chakeri, Tikra and Chhitmara villages.

4.1.4 Risks due to Siting of Air Polluting Industries: In air pollution sensitivity map, the zoning has been done without considering sensitive zones that are unsuitable for industrial siting (legal restrictions, physical constraints, etc.). The risks on locating air-polluting industries are determined by superimposing sensitive zone map on air pollution sensitivity map.

4.2 Surface Water Pollution Sensitivity: Sensitivity of an area to surface water pollution depends upon surface water use; quality of surface water and surface water flow. The corresponding georeferenced thematic maps are studied, categorized and overlay operations are performed to measure the overall surface water pollution sensitivity of the area in terms of three classes high, medium and low.

4.2.1 Surface Water Use Map: The surface water use in the district is categorized as high/low. The high use areas are those areas that are known to be dependent on the surface water sources for domestic supply. Low use areas are those watersheds that do not have significant use/ dependency. The heart of the city depends mainly on the surface water derived from the Ganga river for drinking purpose. These areas are Kidwai Nagar, Kakadeo, few areas of Fazalganj, Colonel Ganj and Phool Bagh. Therefore, dependency on surface water is high in these areas. Rest of the areas of Kanpur city depends on ground water and hence dependency on surface water is low.

4.2.2 Surface Water Quality Map: The water quality in the areas where surface water is used for drinking purpose is high because it is supplied to the areas after disinfection and no conventional treatment is done. In rest of the areas in Kanpur city, the surface water quality is poor because they are along the polluted stretch of river Ganga and river Pandu. Therefore, they have been categorized as low.

4.2.3 Surface Water Flow Map: Drainage basin of the river should be considered as high if 90% of the year has its flow rate greater than 100 cum/sec, medium if 90% of the year has its flow rate between 1-100 cum/sec and low if its flow rate is less than 1 cum/sec over the year. River Ganga's drainage basin is classified as high on the basis of observed facts. Drainage basin of Pandu river is classified as low.

4.2.4 Surface Water Pollution Sensitivity Map: The surface water pollution sensitivity map is generated in two steps. In the first step surface water use map is overlaid over surface water quality map and the resultant map is termed as overlay1. The resultant themes in overlay1 map are calculated depending upon the themes in overlaying maps according to the overlay matrix given in **Table-1**.

Table-1 : Overlay1 from surface water use and quality

Surface Water Quality	Surface water use		
	High	**Medium**	**Low**
High	High	Medium	Medium
Medium	High	Medium	Medium
Low	High	High	High

In the second step, the overlay1 map is overlaid over surface water flow map and map thus formed is surface water pollution sensitivity map. Themes of this resultant map depend upon the themes of overlaying maps according to the relation shown in the matrix in **Table-2**. From this, it is concluded that whole Kanpur city comes in the high sensitive zone in terms of surface water pollution.

Table-2 : Generation of surface water pollution sensitivity

Surface Water Flow	Overlay1		
	High	**Medium**	**Low**
High	High	Low	Low
Medium	High	Medium	Low
Low	High	High	Medium

4.2.5 Risks due to Siting of Surface Water Polluting Industries: In surface water pollution sensitivity map, zoning has been done without considering sensitive zones that are unsuitable for industrial siting. The risks on locating surface water polluting industries and the actual sites/zones available for locating surface water polluting industries are determined by superimposing sensitive zone map on surface water pollution sensitivity map.

4.3 Groundwater Pollution Sensitivity: Sensitivity of an area to groundwater pollution depends upon quality of ground water, groundwater use, groundwater potential, and groundwater table and infiltration rate through soil. The corresponding georeferenced thematic maps are studied, categorized and overlaid to find the sensitivity of an area due to groundwater pollution in terms of three classes high, medium and low.

4.3.1 Groundwater Quality Map: The groundwater quality map represents the quality of groundwater in the district with respect to drinking and irrigation purposes. The quality of groundwater should be indicated as high in those areas where water is potable and low in those areas where it is not even fit for irrigation purposes. Medium quality areas are those areas where water is fit for irrigation purposes but does not fit for drinking purposes.

4.3.2 Groundwater Use: According to CPCB (1995) groundwater use should be considered as high if it is used for drinking purposes and low if used otherwise. The entire population depends mainly on the ground water and its dependency is high throughout the district. Even in the heart of the city, ground water is used along with the surface water. Therefore, there is only high zone for groundwater use through out the district.

4.3.3 Groundwater Potential Map: The groundwater potential map indicates the availability of the groundwater in the district. It shows where the groundwater is in abundance and where it is insufficient. Guidelines from CPCB, suggest categorization should be based on the criterion shown in the **Table-3.** On the basis of groundwater potential there are only medium and low potential zones in the district.

4.3.4 Groundwater Table Map: As per the guidelines suggested in (CPCB, 1995), Kanpur has no high zones based on the groundwater table height. Table 3 suggests this procedure of categorization.

Table-3 : Classification as per groundwater yield and groundwater table (CPCB 1995)

Groundwater yield (gpd/ft)	Groundwater table	Designation
< 25000	More than 20 m	Low
25000-100,000	6-20 m	Medium
> 100,000	Below 6 m	High

4.3.5 Groundwater Pollution Sensitivity Map: Groundwater pollution sensitivity map is prepared in three steps. In the first step, groundwater quality map is overlaid over groundwater use map. As groundwater use is high throughout the district, overlaying is done based on this fact and no separate groundwater use map is prepared.

The resultant map is named as overlay1 map and categorization is done based on **Table-4**.

In the second step overlay1 map is overlaid over groundwater potential map using the following decision matrix given in Table 4 and the resultant map is termed, as groundwater protection need map or overlay2 map.

Table-4 : Generation of overlay1 and overlay 2

Groundwater Quality / Groundwater potential	Groundwater use	Overlay 1
	High	**High**
High	High	High
Medium	High	High
Low	High	Medium

In the third step, overlay2 map or groundwater protection need map is overlaid over contamination risk map. The map thus formed is groundwater sensitivity map. Contamination risk map is a resultant map of overlaying of groundwater table map and infiltration rate map. Infiltration rate map was not available and groundwater table map is assumed to be the sole governing factor in the determination of contamination risk map. Overlaying according to the decision matrix given in Table 5, leads to groundwater sensitivity map.

Ground water pollution sensitivity is either high or medium throughout the district. Also medium sensitive zones are few in the district. They are near Panki, small areas around Phool Bagh and near airport. Rest of the areas are in high risk zones.

Table-5 : Generation of groundwater sensitivity

Contamination risk	Overlay2		
	Low	**Medium**	**High**
Low	Low	Medium	High
Medium	Low	Medium	High
High	Medium	Medium	High

4.3.6 Risks due to Siting of Groundwater Polluting Activities: In the groundwater pollution sensitivity map, zoning has been done without considering sensitive zones that are unsuitable for industrial siting. The risks on establishing the groundwater polluting activities and the actual sites/zones available for locating groundwater polluting activities are determined by superimposing sensitive zone map on groundwater pollution sensitivity map.

5. Zoning for Industrial Siting

The zoning of district has been done based on the sensitivity to air pollution, surface water pollution and groundwater pollution and sensitivity maps prepared. To determine the industries that fit into a particular zone, the pollution generation potential of the industries is to be determined. Classification of industries is done based on the air, surface water and groundwater pollution they cause. Based on this, type of industries is recommended in the classified zones of risk maps. Many industries cause air pollution as well as surface water pollution together. Their combined suitability is determined in industrial suitability map by combining air pollution sensitivity map, surface water pollution sensitivity map and sensitive zone map. The following classification has done based on guidelines from CPCB (1995).

5.1 Air Polluting Industries: Air polluting industries are those, which emit any solid, liquid or gaseous substances into the atmosphere in such concentrations, which may be or tend to be injurious to human beings or other living creatures or plants or environment. These are further classified as below:

- **A1 category**: Industries with emissions from combustion of fuels using coal [3] 125 t/hr or equivalent fuel or industries having process emissions emitted through organized let out system or having fugitive emissions or odor nuisance or industries generating noise levels > 90 dBA.
- **A2 category**: Industries with combustion emissions from usage of coal < 125 t/hr or equivalent or generating noise levels between 70-

90 dBA or having diesel generator sets of capacity > 50 KVA

- **A3 category**: Industries having emissions only from boilers of steam generation capacity less than 2 t/hr but using coal or noise of < 70 dBA or using diesel generator sets of capacity up to 50 KVA

5.2 Surface Water Polluting Industries: Water polluting industries are those which contaminate or likely to contaminate or alter the physical, chemical or biological properties of water or discharge any sewage or trade effluent or any other liquid, gaseous or solid substance into water (directly or indirectly) as may, or is likely to create nuisance or render such water harmful or injurious to public health or safety, or to domestic, commercial, industrial, agricultural or other legitimate uses, or to the life and health of animals or plants or of aquatic organisms.

- **W1 category:** Industries generating wastewater of inorganic nature or organic waste of not easily bio-degradable or toxic nature or combination of all.
- **W2 category**: Industries generating wastewater, which is easily bio-degradable and non-toxic, industries generating slurries and high temperature effluent.
- **W3 category**: Industries with wastewater from domestic use/cooling or boiler blow down (having no temperature variation and metals or other contaminants) or generating no wastewater or industries with complete recycling system/ reutilization with zero discharge.

5.3 Solid Waste Generating Industries: Industries that generate solid waste and hazardous waste are classified as solid waste generating industries, which cause groundwater pollution at the dumpsites. They are further classified as below:

- **S1 category:** Industries generating hazardous waste and as defined under rule 3(i), 3(n) and 4 of Hazardous Waste Management and Handling Rules, 1989.
- **S2 category:** Industries generating inorganic and organic compostable waste and all wastes with leachate potential.
- **S3 category**: Industries generating solid waste of inert nature or no waste or with recycling arrangements.

An industry may be a combination of A1, W1 and S1 or A1, W2, S3 and so on. For example, an industry may be relevant only from water pollution and may not be relevant from air pollution and solid waste generation. Based on the nature of air pollution and water pollution potential and solid waste generation, 27 combinations of industries are possible.

5.4 Individual Industrial Zoning: Based on the above classification, recommendations on risks involved in locating industries in various zones are given below. The criterion is adopted from CPCB (1997).

- According to risks due to siting of air polluting industries, high risk areas are very sensitive to air pollution and hence air polluting industries (A3 category) may be considered in these areas. Medium risk areas are unsuitable for highly (air) polluting industries (A1 category), but in these zones siting of medium and low polluting industries (A2/A3 category whose impact is not likely to exceed 2 km) may be considered. The low risk areas may be considered for all types of air polluting industries (A1/A2/A3 category). However, the industries with very high pollution potential and whose impact is likely to exceed 5 km are to be reviewed individually in the low risk zones.
- According to risks due to siting of surface water polluting industries, the district Kanpur has only high risk zone. The high risk areas are very sensitive to water pollution and hence no water polluting industry should be allowed in these areas. However based on the micro-level studies only very low water polluting industries (W3 category) may be considered.
- According to the risks due to siting of groundwater polluting map, the high risk areas are very sensitive to groundwater pollution and hence, disposal of effluents or solid/hazardous waste on land should not be allowed. The medium risk areas may be considered for controlled and limited discharges of only easily bio-degradable and non-toxic effluents.

Since the district has no low risk areas, the discharge of toxic or not easily bio-degradable effluents and disposal of hazardous waste on land must not be allowed in the district. Hazardous waste should either be incinerated or disposed off in suitable areas outside the district. Organic compostable waste disposal may be allowed in medium risk zones. Inert solid waste may be disposed even in high risk areas.

5.5 Combined Industrial Zoning: Many industries are both air polluting as well as surface water polluting. Therefore, a combined map termed as industrial suitability map is prepared by overlaying of air pollution sensitivity map, surface water pollution sensitivity map and sensitive zone map.

Three types of zones are identified which may be considered for siting mixed category of polluting industries. These zones are scattered in different parts of the district and divided into three groups as shown in the **Figure-2**. They are explained as under:

- **Zone-1 (A_hW_h):** Siting of any type of air and/or water polluting industries should not be allowed in these zones. Based on micro-level studies these zones may be considered for siting of industries with low air pollution potential and/or

low water pollution potential (A3 and/or W3 category)

- **Zone-2 (A_mW_h):** Industries having medium air pollution potential whose impact is not likely to exceed 2 km (A2 category) or industries having very low air pollution potential (A3 category) but not having any type of water pollution (W3) category may be considered (based on local conditions) for siting in these zones. Industries with high air pollution potential (A1 category) or high or medium water pollution potential (W2/W1 category) should not be allowed in these zones.
- **Zone-3 (A_lW_h):** Industries with any type of air pollution (A1/A2/A3 category) and also not having any water pollution potential may be considered for siting in this zone. However, based on micro-level studies, siting of industries with very low potential (W3) categories may also be considered.

Where in symbol A_i W_j, i and *j* indicate air (*A*) and water (*W*) pollution sensitivity respectively as high (*h*), medium (*m*) and low (*l*).

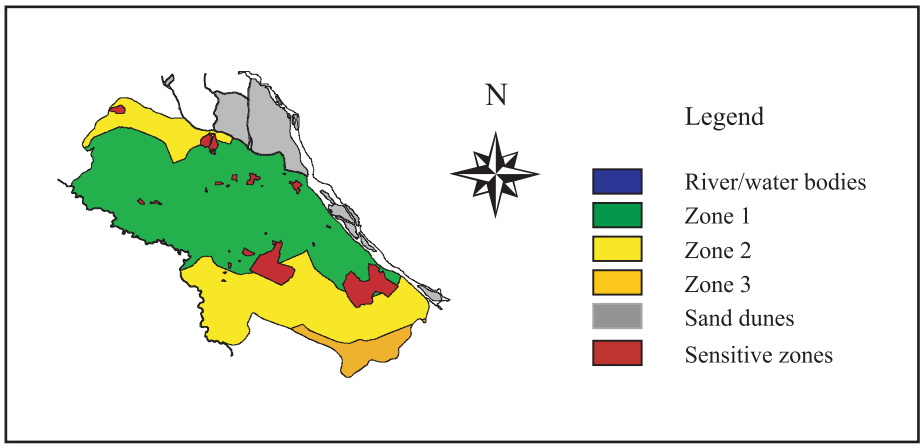

Figure-2 : Industrial suitability map

6 Limitations of Zoning Atlas

The zoning atlas, besides its several advantages suffers from the following limitations:

1. The zoning atlas considers only the environmental aspects. It is beyond the scope of the present work to look into economic aspects such as availability of raw material, market, labour etc.
2. The atlas is prepared mostly on the basis of available information as it is very expensive and time consuming to gather primary data.
3. This atlas provides only the macro-level aspects. For micro-level planning, detailed studies have to be carried out. The information provided by the set of maps should primarily be used for reconnaissance of the planning area.
4. The atlas and recommendations have been developed based on the current scenario of the district. The atlas needs modification/updating as and when the scenario of land use or the environmental quality or any theme (data/ information) relating to air/water pollution sensitivity changes.

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