Geospatial Technology in Urban Forest suitability: Analysis for Ranchi, Jharkhand, India

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Abstract. Changes in the landscape patterns have limited the range of greenery in the urban vicinity. Although urban forestry is widely recognized and practiced in developed countries, it is less known in developing countries. It is an integral part that cannot be overlooked because it enhances the quality of life and the environment for urban inhabitants and ensures the sustainable urban development.

Geospatial technology has the potential to analyse and delineate suitable sites for urban forestry. For the present study we have selected one of the Indian cities, Ranchi, where rapid urbanization has altered the climate of the city by increasing the summer heat, air and noise pollution. In addition, the development of infrastructure has left very little space for the development of greenery. The study utilized Landsat OLI satellite data (30 m resolution; 2015) and analysed it for suitable locations in open spaces after digital processing. A radius of 30 km from the city centre, Firayalal chowk was analysed. Ancillary data, like an ASTER DEM (resolution 30 m) wetness map, slope, soil carbon, a drainage and urban buffer were incorporated in the GIS domain for Multi Criteria Analysis (MCA). The land surface temperature was also computed using thermal bands of Landsat 8 OLI. A suitability map which identified potential area (27% as highly suitable, 38% as moderately suitable and 35% as least suitable sites within the existing open spaces). Highly potential sites are located along the Kanke reservoir, the Harmu River, near Khelgaon and the airport.

High temperatures (low vegetation and high settlement concentration) were noted within the 0-10 km buffer zone close to the city centre. Whereas low temperatures (high vegetation and low settlement concentration) were noted within the 20-30 km buffer zone, far from the city centre.

Therefore, integrating satellite remote sensing data in the GIS domain helps in analysing, identifying and locating suitable sites for urban forest development and management. The high temperature observed in the vicinity of the city centre should be the focal point for an urban forestry implementation programme.

Key words: Urban forestry, Geospatial, Ranchi, Landsat, Suitability, Multi Criteria Analysis.

1. Introduction

At present, the governments of various countries worldwide are attempting to address the issue of climate change. However, there are some major knowledge gaps which need to be looked at. The role played by urban forestry is one of the major factors. It is observed that urban green spaces help in mitigating the impacts of climate change by absorbing the various pollutants including greenhouse emissions and thus playing a vital role as a carbon sink to achieve a low carbon society (Forbes & Dakin, 2003). Urban forest and greenery around cities have seen to have many tangible and intangible benefits. Its development is one of the ways to lessen the gap between people and nature. The carbon cycle is altered because of the process of urbanization, as large parts of land are covered by urban built up. Though it is evident that trees play a vital role is such dry environments, urban planners and architects have neglected their role and least paid attention to it (Ugle et al., 2010). The trees are the main constituent in an urban forest ecosystem. They provide us with a variety of ecosystem services. A diagrammatic representation shows us the various benefits of urban forestry in combatting climate change (Fig. 1). The green spaces within the city act as islands of carbon sinks and later help in maintaining a low carbon society (Forbes & Dakin, 2003). Urban forests thus contribute to sustainable urban development by improving the quality of life and environment within the cities (Konijnendijk et al., 2006).

Many people have described or defined urban forestry, Helms (1998) has defined it as the art, science, and technology of trees and forest resource management in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic importance that the trees provide to the society. Another definition which describes urban forestry more appropriately is by Ismail and Jusoff (2004), which says that "Urban forestry is a practice of developing and managing scientifically suitable types of woody plants which thrive in the populated environment of the cities and are influenced by urban population and urban development, which provide a sustainable environment along with other physical, ecological, recreational and economic benefit".

India is a country having a large population in 29 states and 7 union territories. There has been considerable change in the process of its urbanization. The number of urban centers has increased by 2,774 since last census (2001) to 7,935 in 2011 as reported by Census of India, 2011. The urbanization status has been reported to have shown an increase from 27.81% in 2001 Census to 31.16% in 2011. The spatial growth of cities has been approximately three times faster than the growth of population as observed in the past 25 years (Jat et al., 2008).

The protection of trees is a priority. Time immemorial, India has followed the tradition of tree planting during the rule of various Kings and Emperors, who emphasized the need for greenery around their cities (Goparaju, 2012). In recent years urbanization has dominated the scenario and loss of green cover can be seen everywhere. In 2015, the government of India came up with an initiative of developing and renewing the urban cities, under the scheme of Smart cities. Some 100 cities have been chosen initially to develop and set an example for the others. In this context it is necessary that urban forests too find a place simultaneous with the urban built up.

Studies have shown that in the developed countries, green space/urban forest/woodland per inhabitant in Europe was 104 m^2/inhabitant (Konijnendijk, 2001, 2003). In France, it was 80 m^2/inhabitant (Moigneu, 2001; Konijnendijk, 2003), in Netherlands it was 228 m^2/inhabitant (CBS, 1998; Konijnendijk, 2003) and in Australia it was 80 m^2/inhabitant (Brack, 2002).

In India, studies have observed that green space/ urban forest/woodland in Delhi was 21.43 m^2/inhabitant (FSI, 2009). In Chandigarh, it was 56 m^2/inhabitant (Action Plan, 2009-2010). In Bangalore it was 16.8 m^2/inhabitant (Behra et al., 1985) and in Gandhi Nagar was 164 m^2/inhabitant (FDG, 2008). World Health Organization (WHO), suggested an international minimum standard which was later adopted by United Nations Food and Agriculture Organization (FAO; World Urbanization Prospects, 2014; WUP, 2014), which is that a minimum of 9 m^2 green open space per city dweller is needed (Kuchelmeister, 1998).

In India, satellite remote sensing data has been used for studying the planet's surface, natural resources and natural calamities. The availability of satellite data in various spectral bands and spatial resolutions makes it possible to study land features at multiple scales. Besides, repetitive coverage of the Earth's surface at regular intervals provides feasibility to monitor various dynamics in different time periods. Urban land use patterns are prone to change at short intervals because of various economic, social and environmental factors. Thus, in order to manage urban forests it is necessary that accurate, more reliable, less time consuming data is acquired (Bergen et al., 2000; Dwyer & Nowak, 2000). The focus on urban forest studies has yet to be established. In order to delineate suitable areas for developing urban forestry a thorough knowledge of land use/land cover, urban and other physical features of the city is necessary. A holistic view of the area can be studied using satellite remote sensing data and such huge data can be managed and analyzed only in Geographic Information System (GIS) domain.

In India, urban forests have not gained importance except for a few cities. Some of them are Bangalore (Nagendra & Gopal, 2010), it was the fastest developing city. Chandigarh is known as one of the best planned and greenest city of India (Chaudhry & Tewari, 2010; FSI, 2009). Delhi is the capital city (FSI, 2009), Bhopal a city developing fast for educational opportunities (Dwivedi et al., 2009). The commercial capital of India, Mumbai (Zearh, 2007) and Pune cities are known to maintain striking balance between urbanization and ecology (Patwardhan et al., 2001). Delhi has been reported to have 20.20% and Chandigarh 35.70% urban forest area (FSI, 2009; Action Plan 2009-2010).

There are several methods which can be adopted to arrive at a proper suitability map. M'Ikiugu et al. (2012) adopted a methodology where he used the Analytical Hierarchy Process (AHP) and the pair-wise comparison for identifying potential expansion areas for urban green space using GIS in Nairobi city of Kenya. Ibrahim and Roshli (2012) utilized the multicriteria analysis (MCA) by weighted means for identifying suitable location for urban forest development in south Johar (Malaysia) using remote sensing and GIS. Ismail and Jusoff (2004) used Landsat TM data of 1996 to delineate potential sites for urban forest development in the neighbourhood of the Kualalampur International airport. In India, in Chennai, urban green cover was assessed and quantified using geospatial tech-

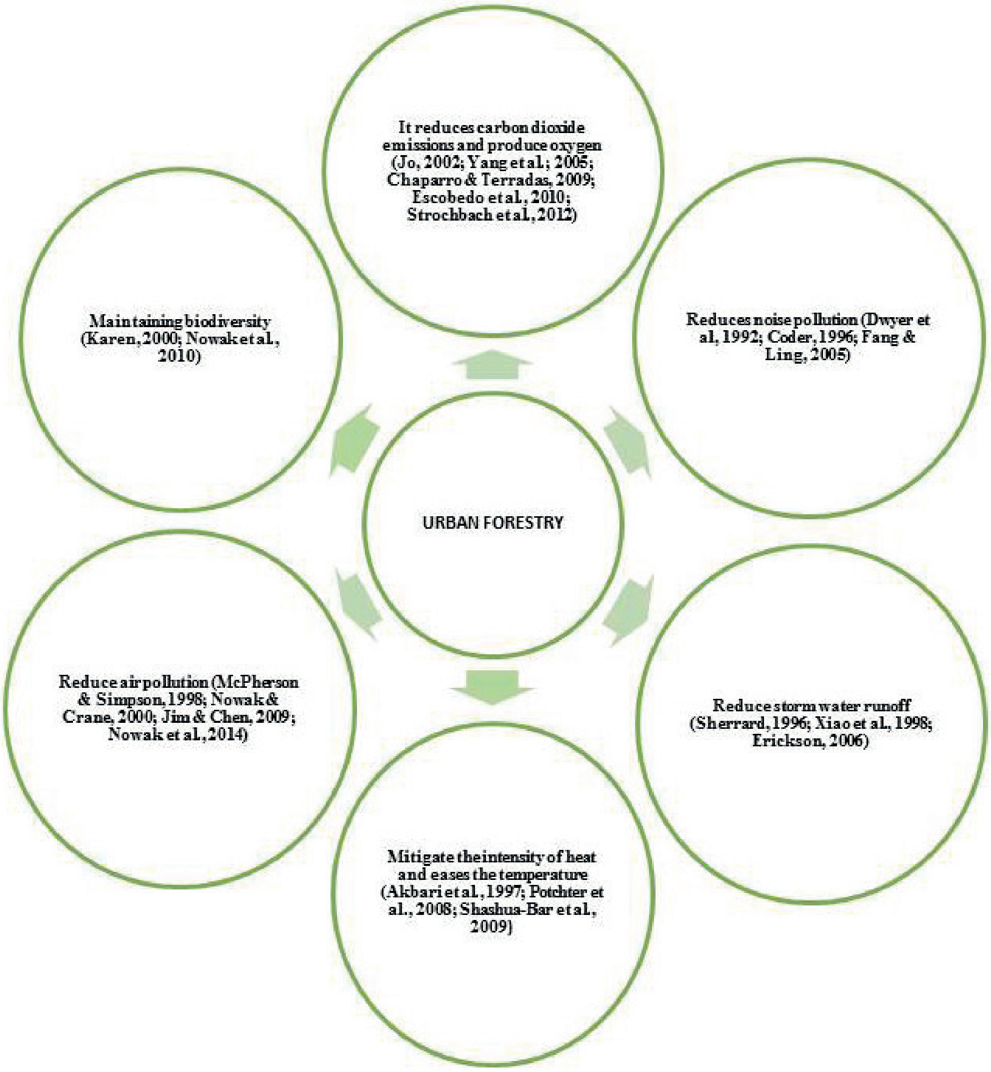

Figure 1. Diagrammatic representation of benefits of urban forestry

nology (Gandhi et al., 2015). Utilizing THEOS satellite images green spaces in Colombo city were studied and in GIS based analysis further areas were identified for further development (Senanayake et al., 2013). The Images of World view-II (acquired on 15 June 2010) was digitally processed and mapped the urban green space within the city of Ranchi (Kumar & Pandey, 2013).

The present study focuses the issue of developing urban forestry in the city of Ranchi. Ranchi is the state capital of Jharkhand. It is surrounded on all sides by forest which are of tropical and subtropical in nature. It is known as a hill station and was once upon a time a summer capital. Till few decades ago, cool climate in summers and afternoon showers were very frequent in this area.

After gaining importance as an independent state, it has witnessed rapid urbanization, infrastructure development and increase in population. All these factors have in turn affected the loss in green cover, depleting water resources and water table, degrading air quality and increasing urban heat. Presently, due to less rains, drought and drought like conditions prevail in the entire state. In another decade or so, it will witness more urban heating and environmental degradation. To mitigate such effects, it is necessary that urban areas emphasize on greening their surroundings.

The outcome of such initiative not only integrates geospatial technologies in climate change studies but will bridge the existing information gap and enable in deriving the results about existing carbon sequestration in urban areas for India specific conditions. Furthermore, the results will contribute to a knowledge base, which can be used for planning by city officials and decision makers to build low carbon society as well as by climate change experts (Amiri et al., 2009; Lim et al., 2009; Kumar & Pandey, 2013).

The objectives of our study were as follows:

1. to assess the feasibility of geospatial technology in urban forest site suitability,

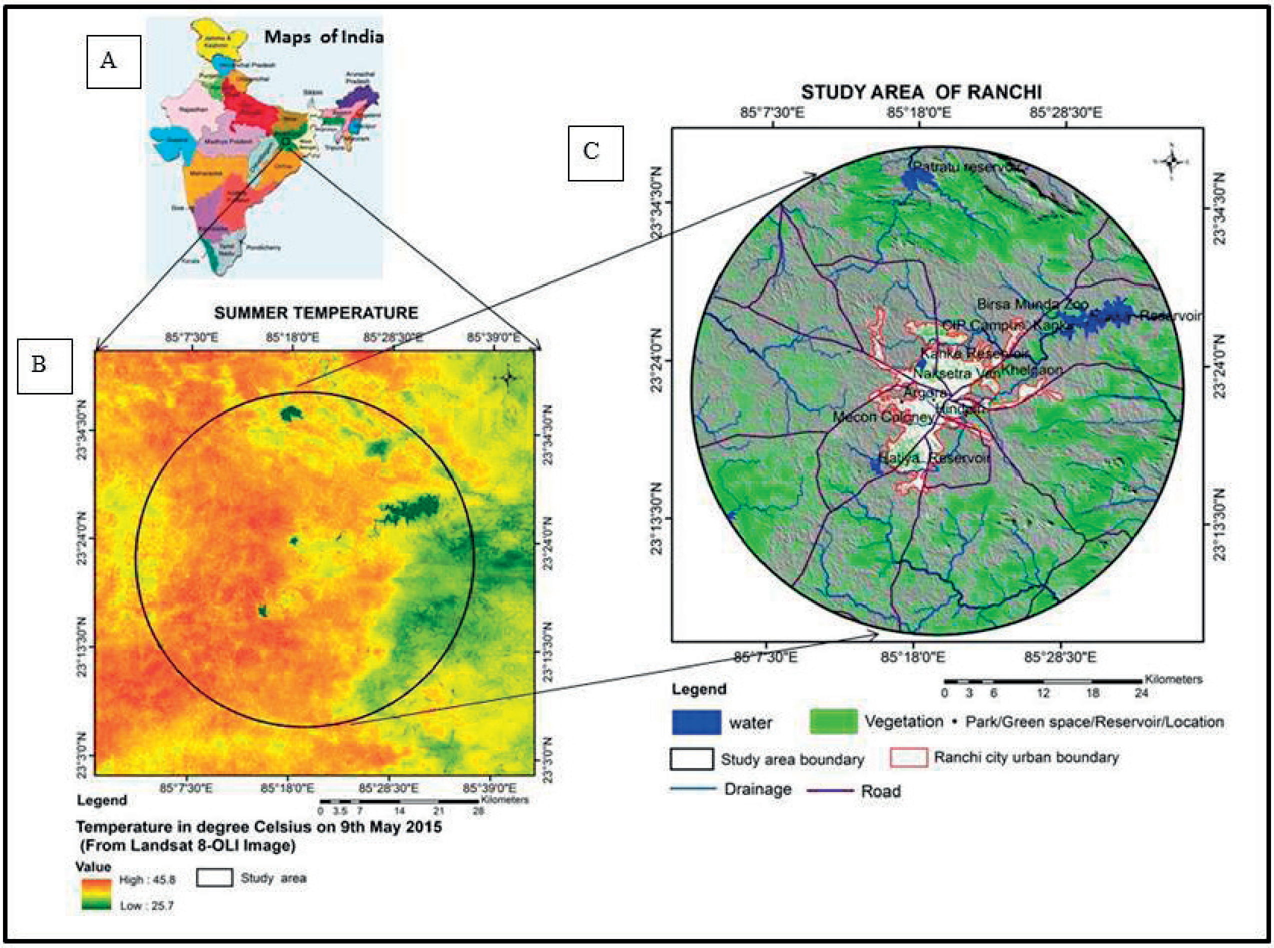

Figure 2. The location of the study area A) Country - India B) Land Surface Temperature (LST) map for the city Ranchi and surroundings C) Study area city Ranchi and surroundings

2. to identify suitable locations in open area as potential sites for developing urban forestry,
3. to analyse the urban temperature effect in three different buffer zones (at 10 km interval from the city center up to 30 km radius).

2. Study area

The study area for the analysis is the city of Ranchi, capital of Jharkhand state, India. It is located on the southern part of the Chota Nagpur plateau. It lies between latitudes 23º 06' 28'' N to 23º 38' 01''N and longitudes 85º 01' 41'' E to 85º 37' 25'' E covering an area of 280152 hectares. The average elevation from sea level is 652 m. The temperatures in summer range from 20°C to 37°C. The temperatures during winters are noted as 30°C to 22°C. The monsoonal rainfall covers the starts from mid-June and ends till mid-October with an average annual rainfall of 1530 mm (Kumari et al., 2014). The forests surrounding the city are of dense tropical dry deciduous type (Champion & Seth, 1968). The terrain is hilly. Also, the city is adorned with numerous waterfalls, making its climate more pleasant than other districts of the state. The Subarnarekha River and its tributaries is the lifeline to this area.

The chosen area for analysis is (circular) is 30 km radius from the city center, which is Firayalal chowk (Fig. 2). Three multi rings were generated at 10 km interval from the city center. The area covered between 0-10 km is 31170 ha, between 10–20 km is 93208 ha and between 20–30 km it is 155774 ha.

3. Materials and methods

3.1. Data preprocessing and analysis

The Landsat OLI data with (Path/row = 140/44) (dated 19-12-2015) having a spatial resolution of 30 m was chosen for analysis. The satellite data was downloaded from the portal of United States Geological Survey (USGS). The data was geometrically and radiometrically corrected dur-

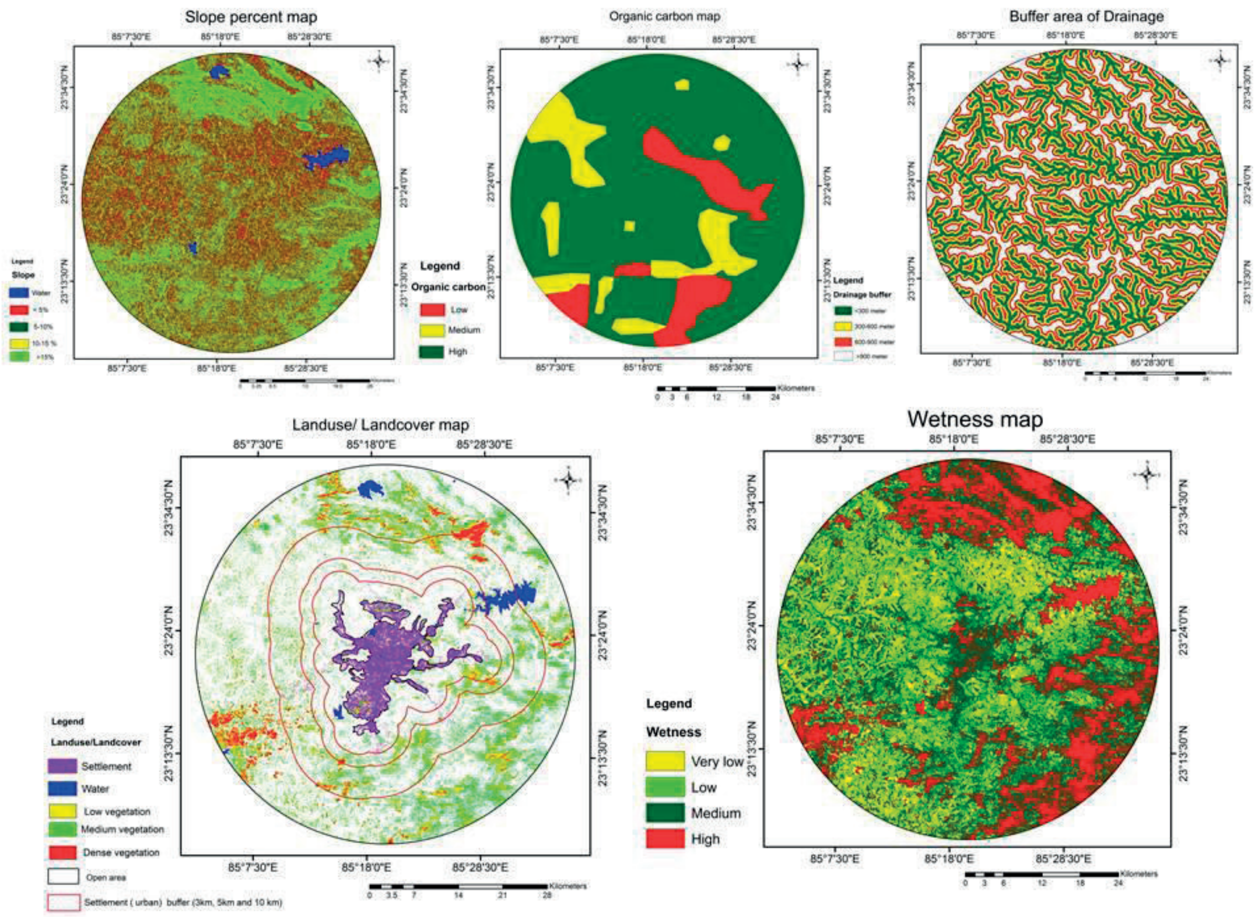

Figure 3. Various thematic maps used for the analysis

ing the preprocessing stage and was obtained in eleven bands. Various individual bands were layer stacked (TIFF format) to obtain a composite image, which was further converted into IMG format. The vector layer of the study area was used to extract the study area from the false colour composite. The false colour composite image was used to generate wetness map and land use/land cover map.

The Digital Elevation Data (DEM) was downloaded from the USGS portal (ASTER DEM with a resolution of 30 m). A subset image was obtained from the image using the vector layer of the study area. Thematic maps like slope map, drainage map were generated using spatial analyst tools of Arc GIS Software (Fig. 3).

The organic carbon map of the study was produced based on the map generated by Agarwal et al. (2013). The wetness map was generated based on coefficient derived by Baig et al 2014. The details of the methodology are explained in the flow chart (Fig. 4). The software's used in the analysis are ERDAS imaging (version 9.1) and ARC GIS spatial analyst (version 10.1).

The thermal bands in Landsat 8 OLI record the variation in land surface temperatures and store it in the form of DN values (Digital number). This can be further extracted and converted into degrees Kelvin. The Land surface temperature map was generated using the thermal band. Further, in each circular ring, some 20 points were generated randomly and average temperature was calculated.

3.2. Urban forestry analysis

The procedure for the study involved various steps as described in the flow chart. Digital processing of satellite data was done to delineate various thematic layers. The different parameters such as slope, wetness index, soil organic carbon, drainage buffer and urban buffer of urban forestry have been analyzed. All the thematic layers were given weightage and incorporated in Multi criteria analysis (MCA) to obtain the final suitability map. The weightage has been assigned to these themes as seen in Table 1.

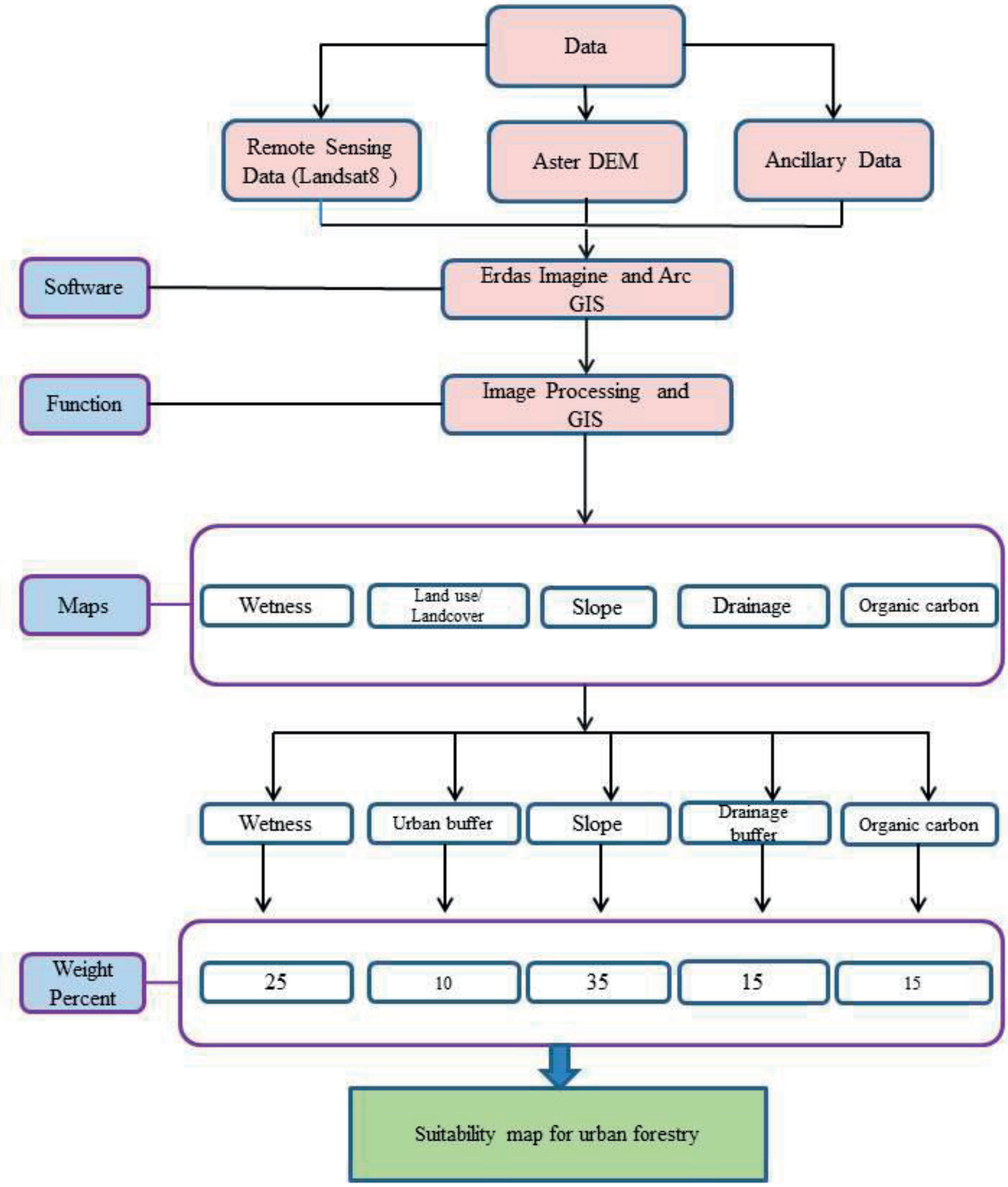

Figure 4. Flow chart showing the methodology for the analysis

3.3. Urban forestry suitability parameter

Urban forestry is strongly influenced by environmental and physical parameters, which control the plant growth. The weights and the ranks assigned for urban forestry are given in Table 1.

3.4. Land use/ Land cover for urban buffer map

The visual interpretation technique as described by (Lillisand & Keifer, 2004) was used to delineate the boundary of urban area from the false colour composite (FCC). Normalize Difference Vegetation Index (NDVI) was executed to delineate vegetated areas. Vegetation was stratified into

Table 1. Weight age for urban forestry suitability ranking for different maps

Thematic maps	Weight	Value/Description	Ranking	Intensity
Wetness (Baig et al., 2014)	25	Regrouped into 4 category	1 2 3 4	Low Medium High Very high
Organic Carbon (Agarwal et al., 2013)	15	Org carb (> 75%) Org carb (75-50%) Org carb (< 50%)	3 2 1	High Medium Low
Slope	35	<5% 5-10% 10-15% ≥ 15%	4 3 2 1	High Medium Low Very low
Drainage buffer	15	<300 meter 300-600 meter 600-900 meter ≥ 900 meter	5 4 3 2	Very high High Medium Low
Urban buffer	10	<3 km 3-5 km 5-10 km ≥ 10 km	5 4 3 2	Very high High Medium Low

dense, medium and low based on the NDVI values. Unsupervised classification was executed in order to extract other classes such as urban and water. Finally vegetation, urban, water and open area were integrated in one layer using the ERDAS Imagine model maker. Accuracy assessment of the classified data was computed using error matrix. Further 256 points were chosen in random sampling methodology and confirmed with the ground truth data.

4. Results and discussion

4.1. Land use and Land cover

The overall accuracy of the land use/ land cover classification data was 92% and kappa accuracy was 0.87. The final land use/land cover classes derived are the following dense vegetation, medium vegetation, low vegetation, water, open and urban (settlement).

4.2. Suitability analysis

The results obtained (after multi criteria analysis MCA) have identified the suitable locations for urban forestry in open spaces in the city of Ranchi. It was noted that 27%, 38%, 35% of the existing open spaces were subjected to high, medium and low suitability for the urban forestry suitability (Table 3).

Table 2. Suitability rating and area statistics for the urban forest development of the existing open spaces in the study area

Suitability rating for urban forestry	Area in hectares	Percentage
High	54530	27
Medium	75192	38
Low	71042	35
Total open space	200764	100

Further, locations were identified for suitability of urban forestry with settlement, water and existing low, medium and dense vegetation in city buffer (0-10 km, 10-20 km, 20-30 km) from the city center (Fig. 5). Within the city buffer of 0-10 km, 10-20 km and 20-30 km, the vegetation (overall) was found to be (approx.) 10%, 18% and 28% respectively.

Further, from the graph (Fig. 6) among the 3 city buffers (0–10 km, 10–20 km, 20-30 km) the buffer range of (0–10 km) needs high attention because the settlement percentage was very high 34% and vegetation percentage was relatively low 10%. We identified suitable locations in the buffer (0–10 km) and found 36% of the area of this buffer is highly suitable for urban forest development and landscaping.

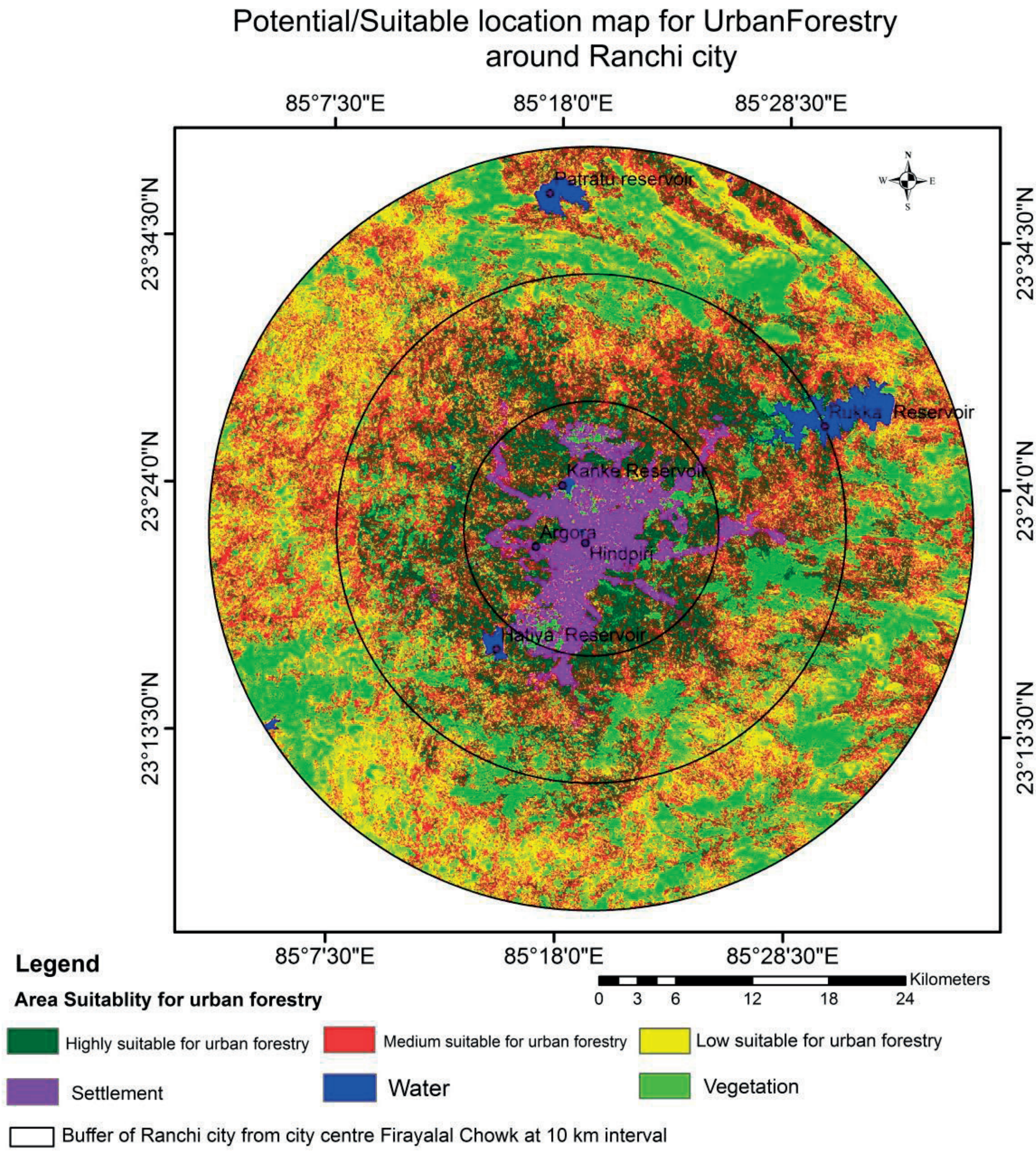

Figure 5. Suitability map of the study area

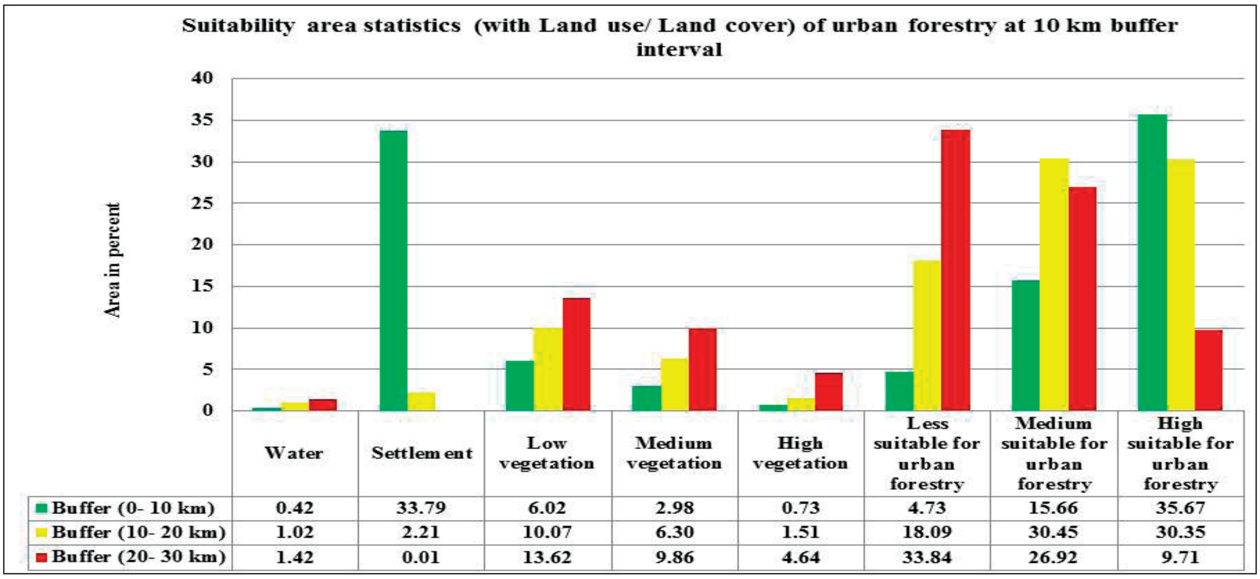

Figure 6. Suitablity area statistics (with landuse / landcover) of urban forestry at 10 km buffer interval

4.3. Description of the suitable areas for urban forestry development and landscaping

The city of Ranchi which lies amidst forests all around has parks and greenery inside the city too. Some of the known parks are Sidhu Kano Park, Machali Ghar, Nakshatra Van, Rock Garden, Gardens of the Governor house, BIT Mesra campus, MECON campus etc. The study conducted by Kumar and Pandey (2013) reveals that though the city has good green cover, still places in central, northern, western and south eastern parts of the city are devoid of greenery. Infrastructure and communication development within the city center has hindered development of urban green cover.

There are open spaces inside the city which can be developed for urban forestry such that its benefits can be tapped more. We identified highly suitable areas for urban forestry within the 30 km radius from city center because these open areas are close to the settlement and have mostly gentle slope, high wetness, high organic carbon and are in the vicinity of drainage system of the city.

4.4. Highly suitable areas in the vicinity of 0-10 km

1. North West of Kanke reservoir along the River Jumar: the area falls in Kanke block. The vicinity in few villages like Sundil and Jaipur can be developed.
2. South of Manitola to Namkum along the drainage (East of Airport).
3. South East of Khelgaon (East of Habatoli and Chirutoli) along the River Swarnrekha.
4. Along the Harmu river, from south of Lalit Narayan Mishra Colony and North of Dipatoli up to Harmu Colony can be developed.

4.5. Highly suitable area in the vicinity of 10-20 km

1. Along South West River of Swarnrekka, from Lowadih, Jamuari village to south of Khelgaon upto BIT Mesra Campus can be developed.
2. North West of Rukka reservoir and south of Kamta village buffer.
3. Along the River Jumar, North and North West of Sukrutuhu village.
4. North West of Dhurwa reservoir (in and around Piska village to Balalong village).

4.6. Urban heating effect: Land surface temperature in each buffer zone

The process of urbanization has led to an increase in the urban heat. The summer temperatures have been noticed to soar high in the recent years. The following Figure 7 shows 30 years month wise average high temperature noted for Ranchi from 1981 to 2010. Land surface temperature has been used to observe the temperature variations between the urban and rural landscapes in Indian scenario (Weng, 2003).

The average minimum and maximum temperature for each buffer zone was computed. It can be observed in the following Table 3.

Land surface temperature or urban heat forms one of the vital parameters influencing the global climate change

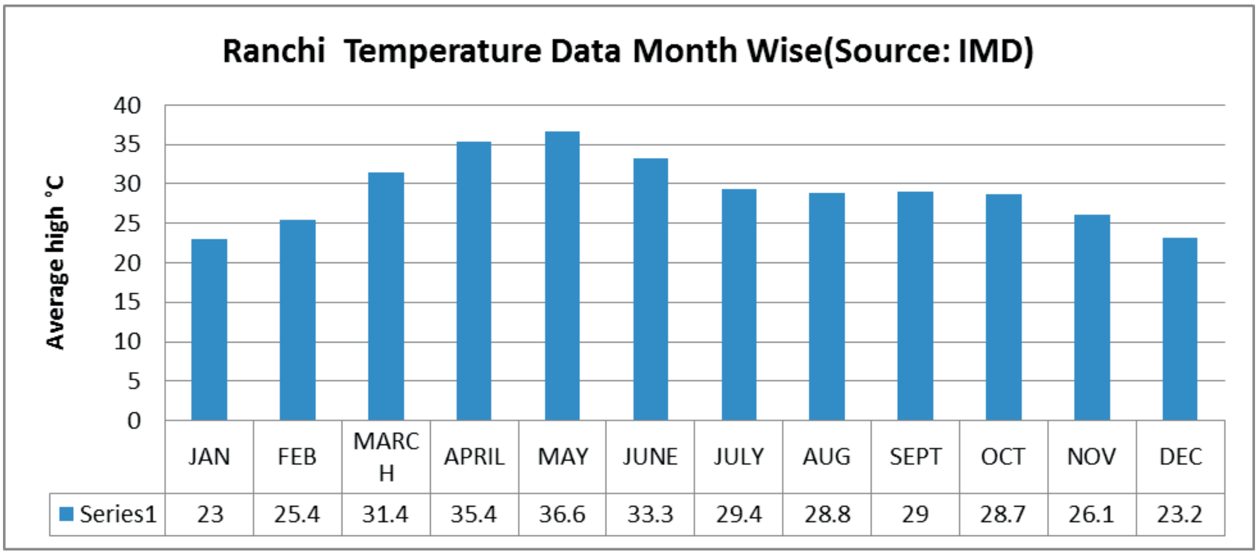

Figure 7. Ranchi average high temperature data

and is a major factor which determines the energy balance at the surface and physical dynamics of land surface processes (James & Mundia, 2014). We evaluated the temperature variation among the city buffer rings at 10 km interval from city centre (Table 3).

The mean temperature was 39.4°C, 37.65°C and 34.25°C at the buffer (0-10 km), (10-20 km) and (20-30 km) respectively. Further vegetation % shows increasing trend as well as settlement % and temperature shows decreasing trend as we move away from city centre to its periphery. Some similar studies were done by Amiri et al. (2009), Lim et al. (2009), and Kumar and Pandey (2013).

4.7. Urban Forestry: ecological implications

4.7.1. Role of trees in urban forestry

Table 4. Temperature, vegetation and Settlement data in various buffer rings

20 points	Buffer (0-10 km)	Buffer (10-20 km)	Buffer (20-30 km)
Mean Temp °C	39.42	37.65	34.25
Minimum °C	35.24	33.42	28.73
Maximum °C	42.38	41.03	39.63
Standard Deviation (S.D.)	1.73	2.08	3
Vegetation (%)	10	18	28
Settlement (%)	33.79	2.21	0.01

Trees are the basic unit of urban forestry. It brings about changes in the vicinity of urban environment in the following ways. First is evapotranspiration where the loss of water from the plant as vapor into the atmosphere occurs by absorbing the energy from solar radiation. This cools the leaf surface as well as air surrounding it (Taha et al., 1988; Grimmond & Oke, 1991).

Secondly, trees provide shade and intercept the solar heat from reaching the ground and heating up (Oke, 1989). This local cooling effect is important in open spaces within the urban built up areas. The movement of air current and heat exchange is affected by the presence of vegetation (Bonan, 1997). Thirdly, in winters, they alter the wind speeds and reduce the heat loss from the urban structures (Nowak & Dwyer, 2007). The significant benefits offered by urban shade trees are in reducing air conditioning demand and improving urban air quality by reducing smog. Such open green spaces help in creating a stress free environment which is a boon to people who wish to spend more time outdoors (Grahn & Stigsdotter, 2003). Thus to make urban forestry more effective, trees can be planted along the streets and crossroads and creation of parks should be encouraged (Givoni, 1991).

4.7.2. Mitigation of air and noise pollution

Trees help in absorbing the air pollutants and help in controlling the air pollution. In Ranchi city according to the study of Kumar and Pandey (2013), city centre had high aerosol concentrations because vegetation cover was less. High noise pollution levels critical (>75 dB(A)) and high (65–75 dB(A)) levels of ambient noise pollution showed areas with less vegetation, mostly in focusing around city centre. In the south of the Ranchi city, where HEC colony exists, lot of greenery is present which indicated moderate levels of (50–55 dB(A)) to moderately high (55–65 dB(A)) levels of ambient noise pollution. Thus planting trees within the city built up areas is a must to control both air and noise pollution.

4.7.3. Maintaining the carbon cycle

Trees contribute in balancing the carbon cycle by acting as carbon sink. They absorb the carbon dioxide from the atmosphere. The process of urbanization leads to concrete jungles which fail to absorb the greenhouse gases and thus alter the carbon cycle and warm up the atmosphere too. In this aspect the trees in urban area provide act as an island to absorb the heat as well as carbon dioxide from the surrounding atmosphere.

The trees will also provide a habitat to few floral and faunal species as well. Large areas can also act as areas for biodiversity conservation. Larger the area more is the biodiversity (Khera et al., 2009). Heterogeneity should be maintained while planting trees, big trees, herbs and shrubs would form a three tier system. Monoculture plantation has less benefits hence should be discouraged.

5. Conclusion

The above study has shown the strength of geospatial technology in delineating areas suitable for urban forest development in open spaces in and around the city. Remotely sensed satellite data is a cost effective, affordable (as Landsat data has a huge archive) and temporal coverage of data is one of the viable methods to analyse city's vegetation resources (Carreiro & Zipperer, 2008). Integration of satellite remote sensing data in GIS domain is a prerequisite in generating a base map. Coarse resolution satellite data like Landsat can be utilized to achieve this target, which provides good delineation of land use/land cover with considerable accuracy. Further, Geospatial technology would also help in monitoring urban forest environment at regular intervals and help in filling the critical knowledge gap due to unavailability of suitable data. Such data will help and enable the urban planners and decision makers to incorporate it in urban planning and development programmes which will translate the research into ground action. As Chiesura (2004) has rightly stated that a sustainable city cannot be designed without urban green spaces.

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