Site Suitability Analysis For A Greenfield Airport in Kolkata Using GIS and Remote Sensing

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Objective

This paper attempts to find the most suitable and feasible sites for the construction of a greenfield airport in Kolkata using Site Suitability Analysis in ‘GIS and Remote Sensing’.

Table of Contents

Abstract

Geographic Information Systems (GIS) and Remote Sensing are widely recognized as a valuable tool for capturing, storing, manipulating, analyzing, managing and displaying all types of geographical data. Due to the complex nature of airport planning modalities, the potential of GIS applications in resolving several issues on airports is increasingly acknowledged by many.

In this paper, we have discussed some of the potential benefits of ArcGIS applications in airport site selection. Using site suitability analysis an attempt has been made by the authors to find the most suitable and feasible sites for the construction of a greenfield airport in Kolkata, West Bengal, India.

Here, the study takes into consideration the most import and likely factors such as slope, drive-time buffer, land use/land cover information, restricted zones and the prevailing meteorological conditions. Accordingly, different candidate sites for the new airport have been analyzed.

The study also highlights the role of such a multi-criteria approach performed within the step by step decision-making process concerning the site selection for recommending five different sites for the plausible development of a new airport at Kolkata.

Introduction

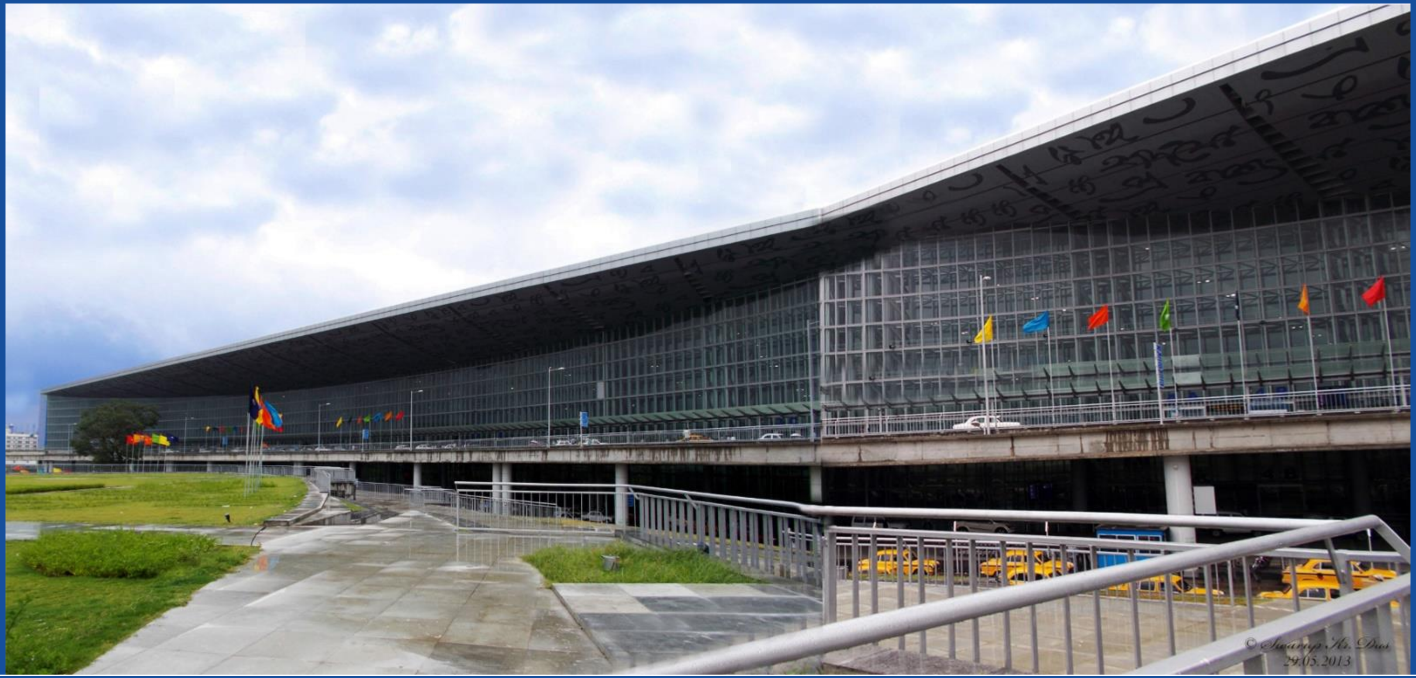
As the passenger traffic has been increasing at an alarming rate which is expected to reach 370 million by 2020, this would undoubtedly make India as the world's 3rd largest aviation market. The total passenger traffic of India (both domestic as well as international) has increased by almost four times from 73.35 million in the financial year (April to March) 2006 to 280.24 million in 2018.

Which are the busiest airports in India?

The busiest airports of India have been Indira Gandhi International Airport (Delhi) followed by Chhatrapati Shivaji International Airport (Mumbai), Kempegowda International Airport (Bengaluru), Chennai International Airport (Chennai) and Netaji Subhas Chandra Bose International Airport (Kolkata) respectively.

About NSCB Airport

Kolkata airport is located in the Dum Dum region which is about 17 km from the central city area and around 5 km from the industrial IT hub area. It is one of the largest in eastern India and since it is the only international airport of the state, it has become an aviation hub that handles more than 9 million passengers per year.



Let us have a look at the NSCB Airport

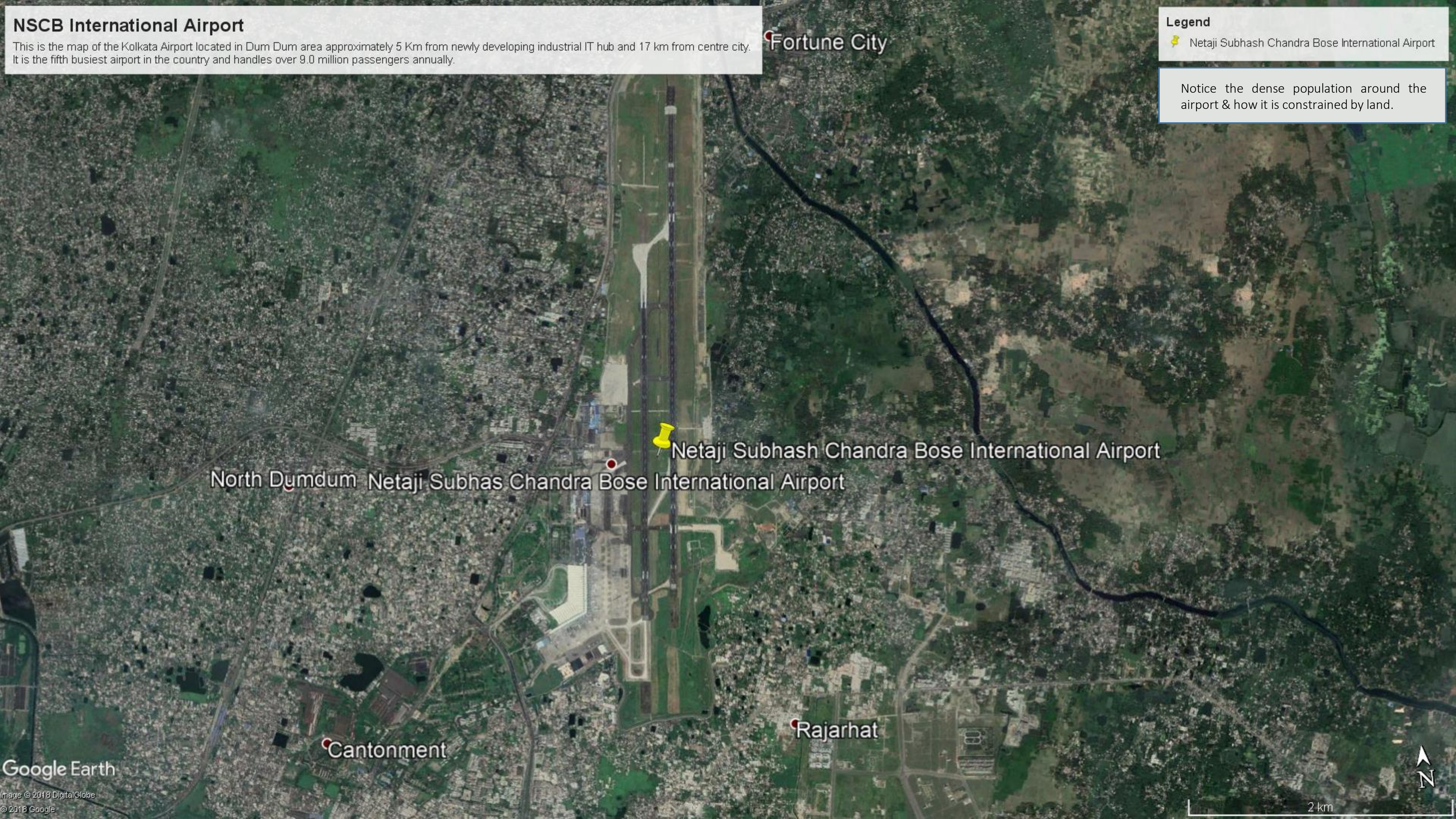
NSCB International Airport

This is the map of the Kolkata Airport located in Dum Dum area approximately 5 Km from newly developing industrial IT hub and 17 km from centre city. It is the fifth busiest airport in the country and handles over 9.0 million passengers annually.

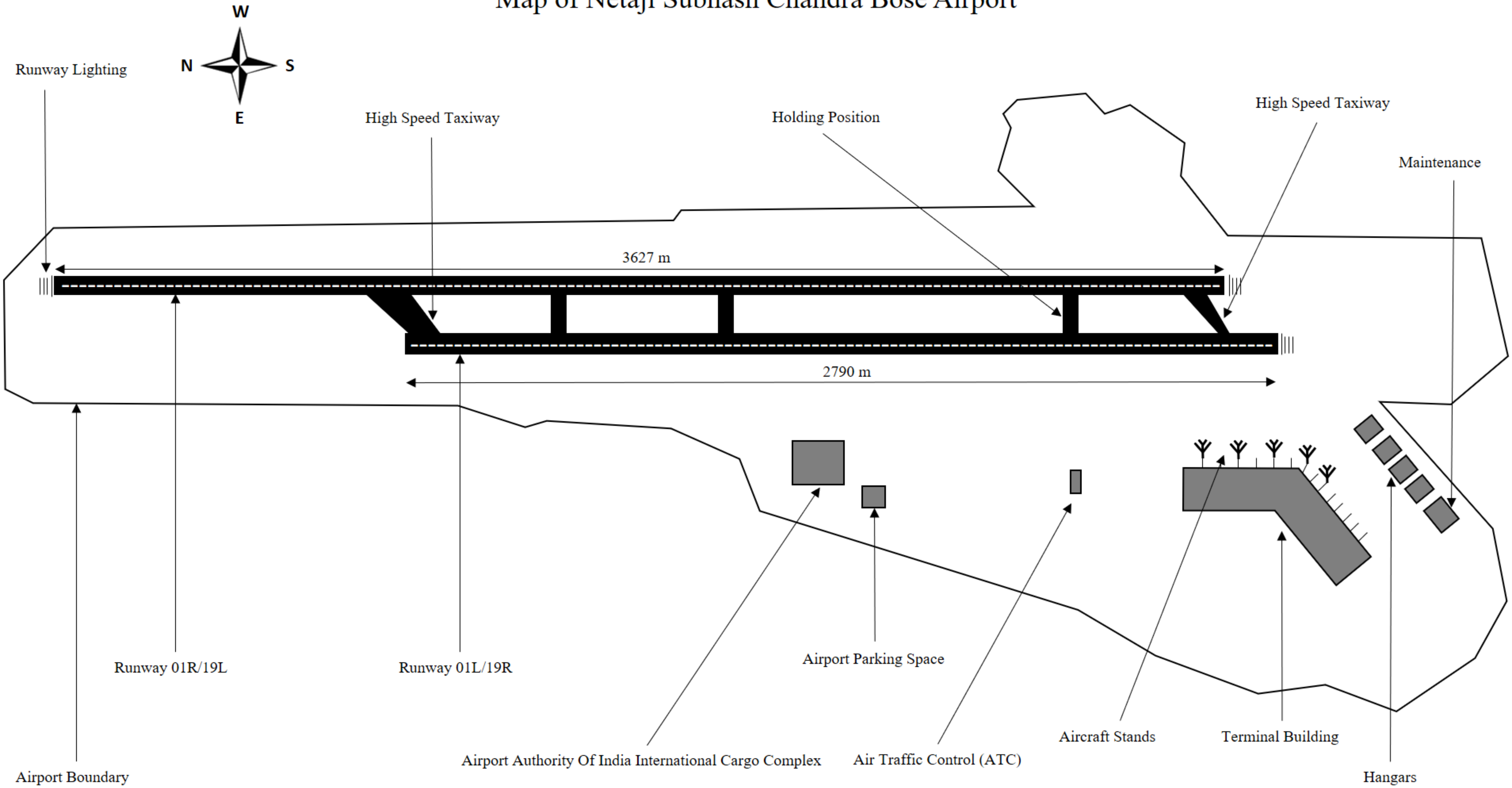
Legend

Netaji Subhash Chandra Bose International Airport

Notice the dense population around the airport & how it is constrained by land.



Map of Netaji Subhash Chandra Bose Airport



Problems faced by NSCB Airport

- Due to the growth of airlines such as Spice Jet, Indigo, Go Air, and Jet, the number of passengers at the airport gradually rose resulting in overcrowding of the two terminals of the airport. To curb this, an exhaustive modernization plan was developed for the airport which included expansion of parking bays, rapid-exit taxiways, main runways, existing terminals, cafes, ticketing counters, check-in kiosks, etc. which led to a plan for a full-fledged new integrated terminal for both international as well as domestic passengers. The new environment-friendly terminal increased the overall capacity of the airport to over 20 million passengers per year.

- Land at the Kolkata airport is highly constrained to create such a separation as the boundary wall is located to the east and the terminal building to the west.

- Due to these limitations, the second runway at the airport is only used in exceptional cases when the primary runway is shut down due to emergency or maintenance purposes.

Problems faced by NSCB Airport

- Exacerbating this problem is the issue of a limited number of parking bays in the airport.
- Although more bays have been planned, it will only be a matter of a few years before they too will get saturated.
- Moreover, acquiring more land in the vicinity of the airport is an impossible task due to the dense population around.

Suggestions given by the Kolkata Government

- As a solution to the above problems, the Kolkata Government suggested the Kazi Nazrul Islam Airport at Andal near Durgapur. The distance between both airports is nearly 190 km which means that if you fly from one airport to the other it would take around 20-25 minutes. According to aviation experts, a city airport should be ideally located within a two-hour drive from the city but the travel time from NSCB airport to Kazi Nazrul Islam airport is over 3 hours. Thus, due to this large separation between the two, the second airport has to be closer to the city and Durgapur cannot serve this purpose.

- Another alternative was the Behala Airport which is the second of the two airports that exist in the Kolkata Metropolitan Area and both the Airports Authority of India (AAI) and the Ministry of Civil Aviation, India has plans to develop it into a fully functioning commercial airport by expanding the existing runway to 1380 meters. Most modern day commercial aircraft, for example the Airbus A320 ideally requires between 3000-7000 feet of runway for landing and taking off. That means that, even if the runway is extended to 4500 feet it would be insufficient for most aircraft to carry out safe operations in this area. Therefore, this also rules out the possibility of Behala Airport being used as a second airport for Kolkata.

Methodology

The selection of a suitable site for an airport is usually a complex task and it depends on several factors such as: regional plan, airport use, proximity to other airports, ground accessibility, topography, obstructions, visibility, wind conditions, noise nuisance, grading, soil as well as drainage characteristics, future development opportunities and economic considerations. In this study, the site suitability analysis is carried out based on the following parameters: slope, drive-time buffer, land use/land cover information, restricted zones and meteorological conditions as explained below.

Methodology

a. Drive-time buffer :

According to most airport officials, an airport ideally needs to be located within a drive-time of around one and a half hours or at most two hours away from the centre of the city.

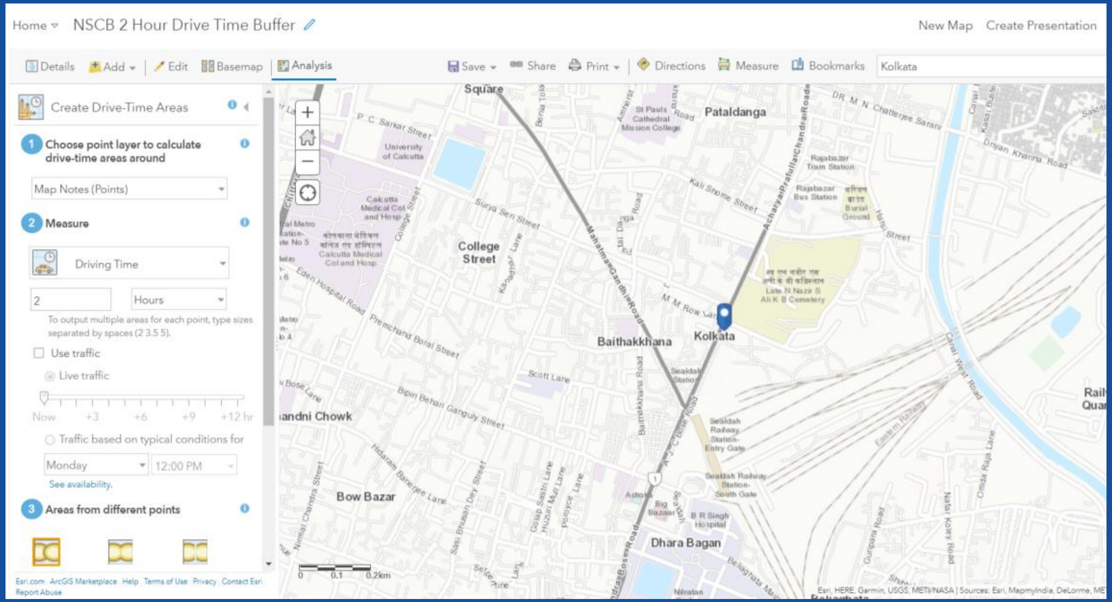
Here, we used the 'Create Drive-Time Areas tool' in ArcGIS Online to create a two-hour drive time-buffer around the city of Kolkata using the Esri service areas to calculate the areas that can be reached in a travel time or distance specified by a street network based on travel mode.

This tool configures the transit of vehicles such as cars and finds alternatives to optimize travel time. The driving speed taken into consideration was based on historical data and live traffic information that depicts actual conditions in reality.

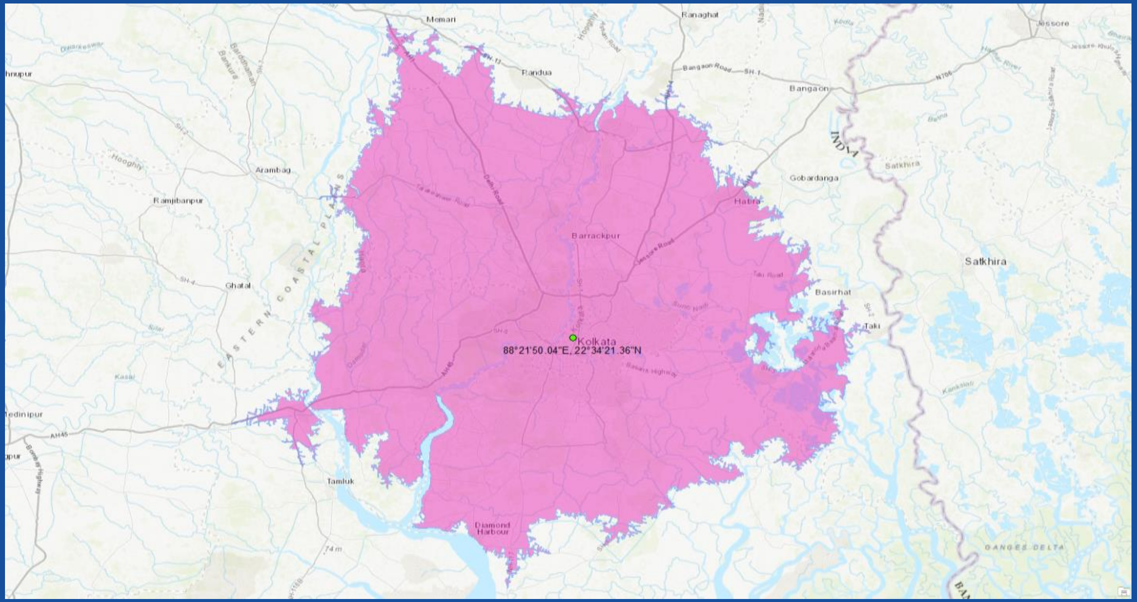
This layer was then exported to ArcMap and it was saved in shapefile format.

Methodology

a. Drive-time buffer :



Creating the 2 Hour Drive Time Buffer Map in ArcGIS Online



The generated 2 Hour Drive Time Buffer Map in ArcMap (Shapefile Format)

Methodology

b. Slope :

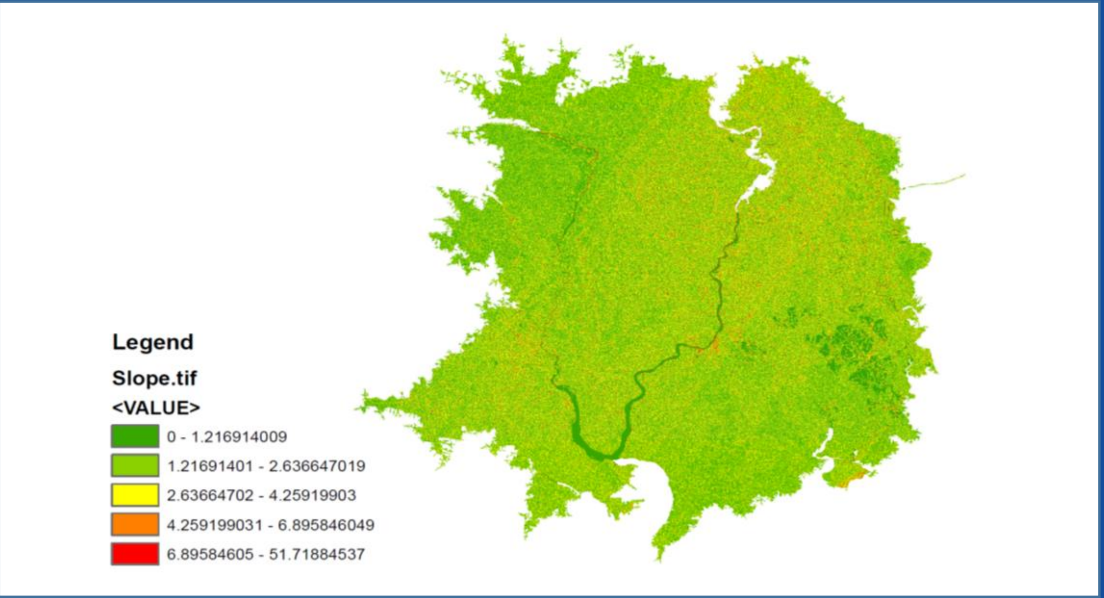
The runway of the airport ideally needs to be as flat as possible so that excessive engine thrust can be avoided. The International Civil Aviation Organization (ICAO) specifies that the maximum limit of slope for airports that serve large aircraft should be between 1.25% and 1.5%. Elevation data was downloaded from the 30m SRTM Tile downloader website and a mosaic dataset was created using the 'Mosaic to New Raster Tool' in ArcMap.

Then the 'Define Projection Tool' was used to convert the raster from Geographic Coordinate System (GCS) to Projected Coordinate System (PCS), i.e. 'WGS_1984_UTM_Zone_45 N' in which the units are measured in meters. The slope was then calculated in degrees using the 'Slope tool' which can be found in the 'Surface toolset' which is part of the 'Spatial Analyst toolbox' in ArcMap.

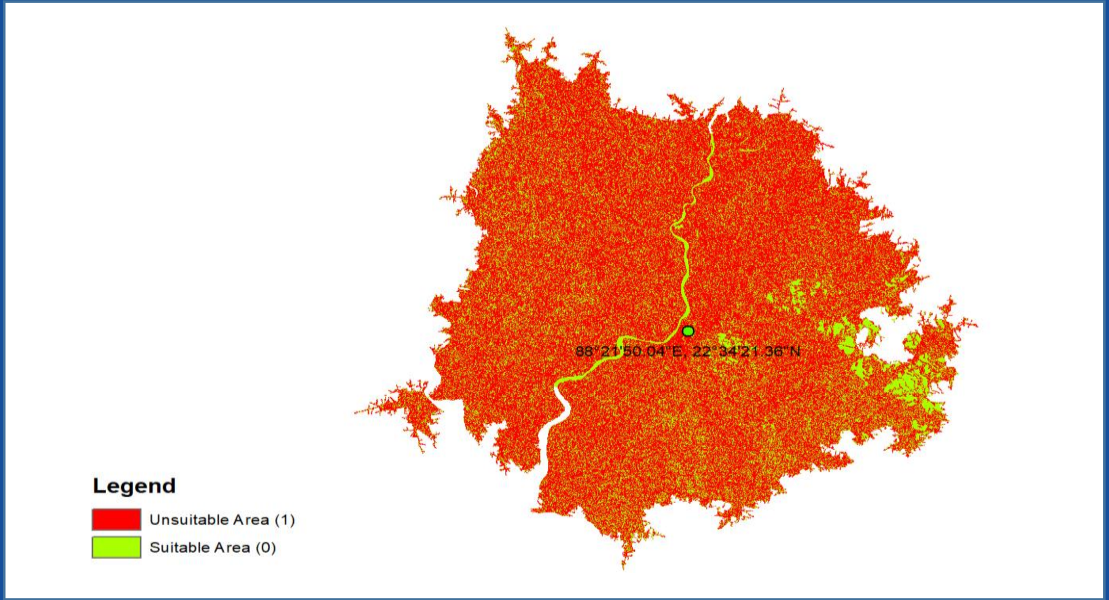
Finally the 'Reclassify tool' which is part of the 'Spatial Analyst Extension' was used to assign a value of '1' to areas with suitable slope for the construction of the airport (i.e. with values of slope less than 1.25 degrees) and '0' to the rest of the areas which were unsuitable for construction.

Methodology

b. Slope :



Slope generated using the 'Slope Tool' in ArcMap



Reclassified Slope which was used as an input to the 'Weighted Overlay' tool

Methodology

c. Land Use/Land Cover :

We downloaded the LULC map (1:250000 scale) of West Bengal from Bhuvan's website which is managed by the National Remote Sensing Centre (NRSC).

The downloaded TIFF file was masked to the two-hour drive time buffer shapefile and appropriate symbology was assigned to various classes present in the raster.

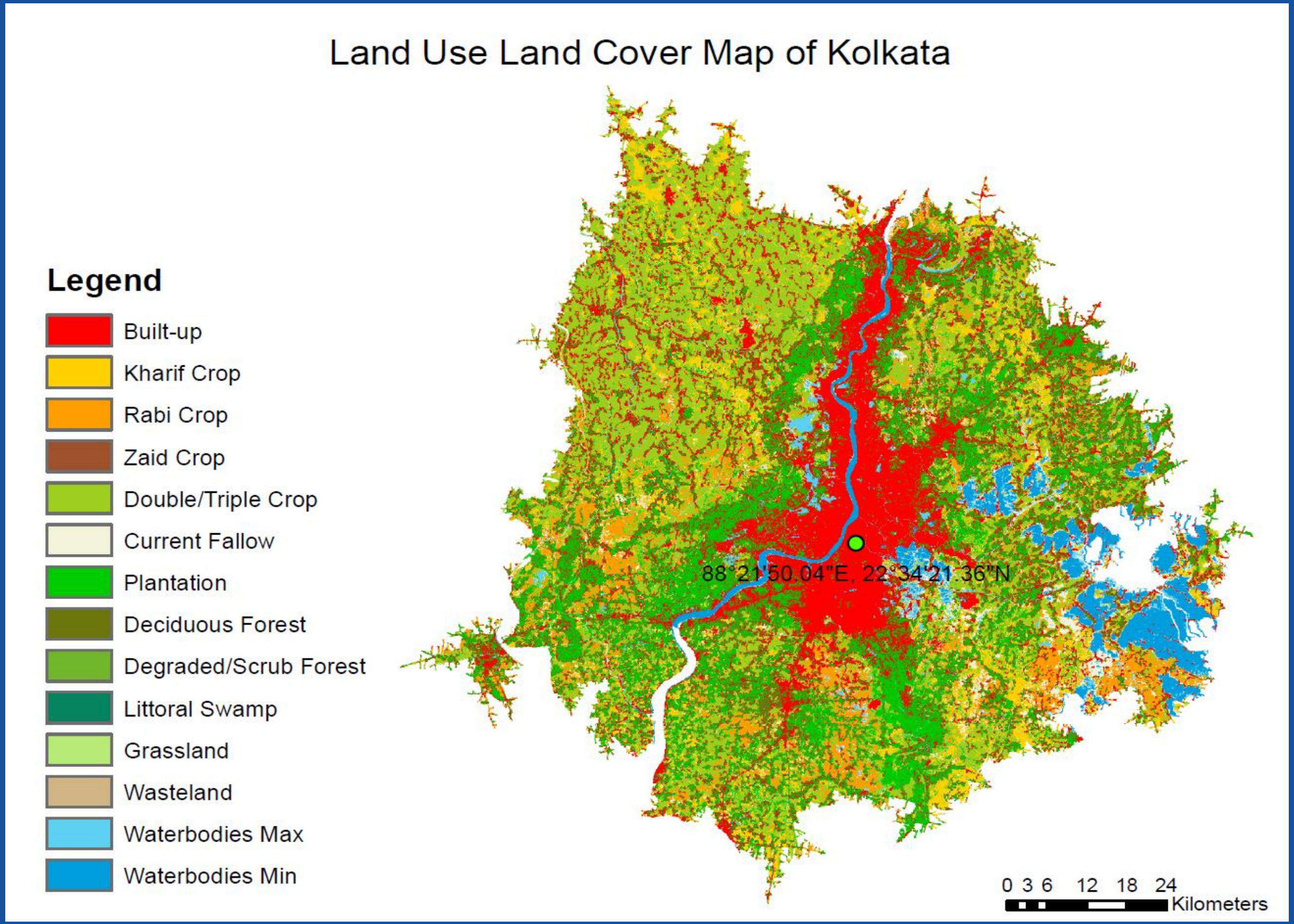
On the basis of suitability, the 'Reclassify tool' was used to assign proper weightage to the different classes.

Class	Weightage
Current Fallow	9
Kharif Crop	9
Rabi Crop	9
Zaid Crop	9
Double/Triple Crop	7
Plantation	7
Deciduous Forest	5
Degraded/Scrub Forest	5
Littoral Swamp	3
Grassland	3
Wasteland	3
Waterbodies Max	0
Waterbodies Min	0
Built-up	0

Weightage assigned to different classes of the LULC Raster

Methodology

c. Land Use/Land Cover :



Methodology

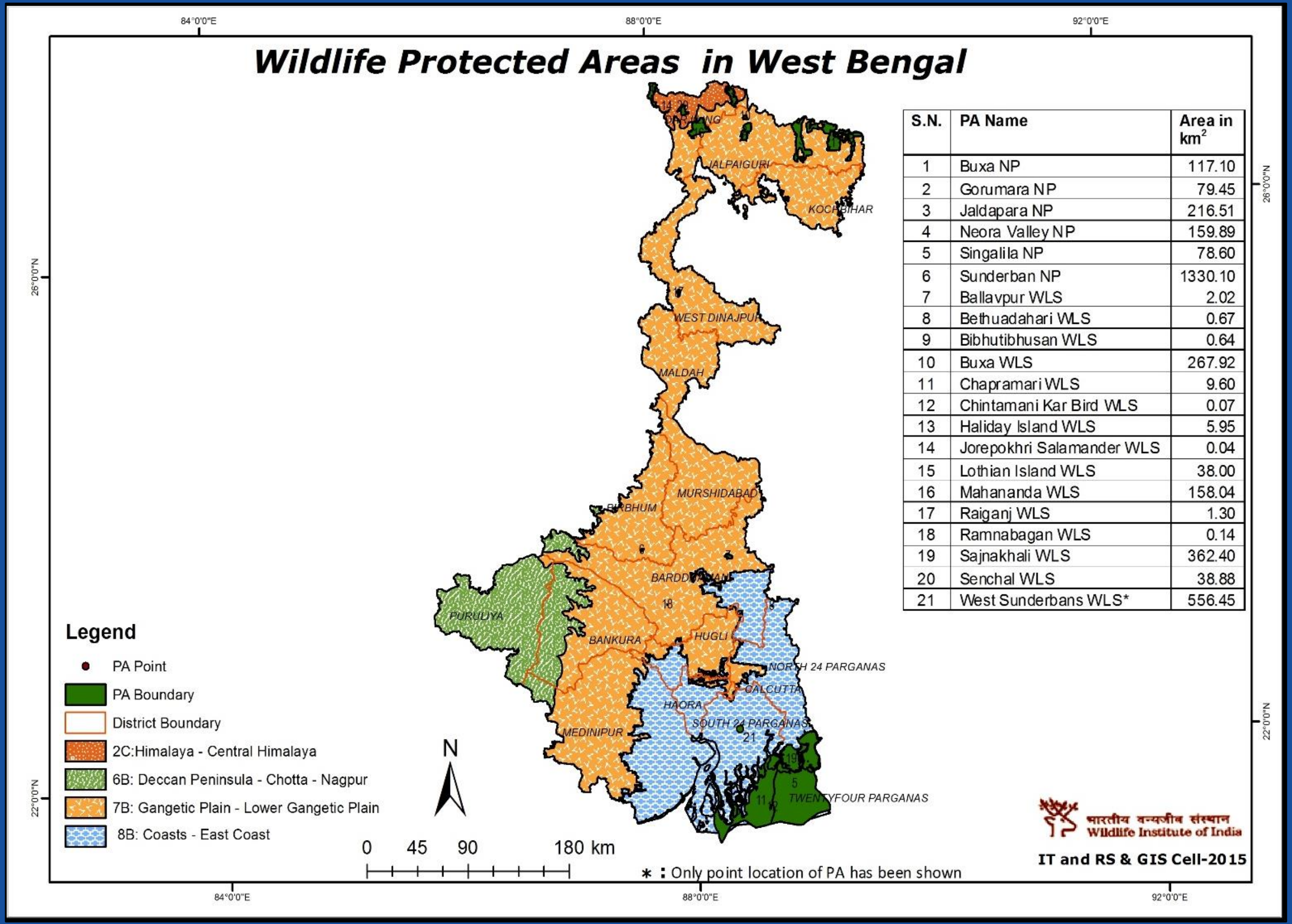
d. Restricted Areas :

Many areas in the study area are restricted zones/protected areas such as biosphere reserves and national parks. National parks and Wildlife Sanctuaries are areas of significant ecological, floral, faunal or of natural significance. They are notified by the State Governments and protected by the Forest Departments under the provisions of the Wildlife (Protection) Act, 1972 & its amendments, Indian Forest Act of 1927, Forest (Protection) Act of 1980, Biological Diversity Act, 2002 and the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006. Hunting of wild animals, encroachment and/or destruction of habitat, construction of tourist lodges and other such activities are prohibited in protected areas.

The restricted areas were digitized and removed from our study area. Construction cannot be done in the path of rivers or perennial streams. So a buffer of one kilometer was generated using the 'Buffer tool' (Analysis) on either side of rivers and it was classified as restricted since construction is not feasible here.

Methodology

d. Restricted Areas :



S.N.	PA Name	Area in km^2
1	Buxa NP	117.10
2	Gorumara NP	79.45
3	Jaldapara NP	216.51
4	Neora Valley NP	159.89
5	Singalila NP	78.60
6	Sunderban NP	1330.10
7	Ballavpur WLS	2.02
8	Bethuadahari WLS	0.67
9	Bibhutibhusan WLS	0.64
10	Buxa WLS	267.92
11	Chapramari WLS	9.60
12	Chintamani Kar Bird WLS	0.07
13	Haliday Island WLS	5.95
14	Jorepokhri Salamander WLS	0.04
15	Lothian Island WLS	38.00
16	Mahananda WLS	158.04
17	Raiganj WLS	1.30
18	Ramnabagan WLS	0.14
19	Sajnakhali WLS	362.40
20	Senchal WLS	38.88
21	West Sunderbans WLS*	556.45

Methodology

Using Weighted Overlay :

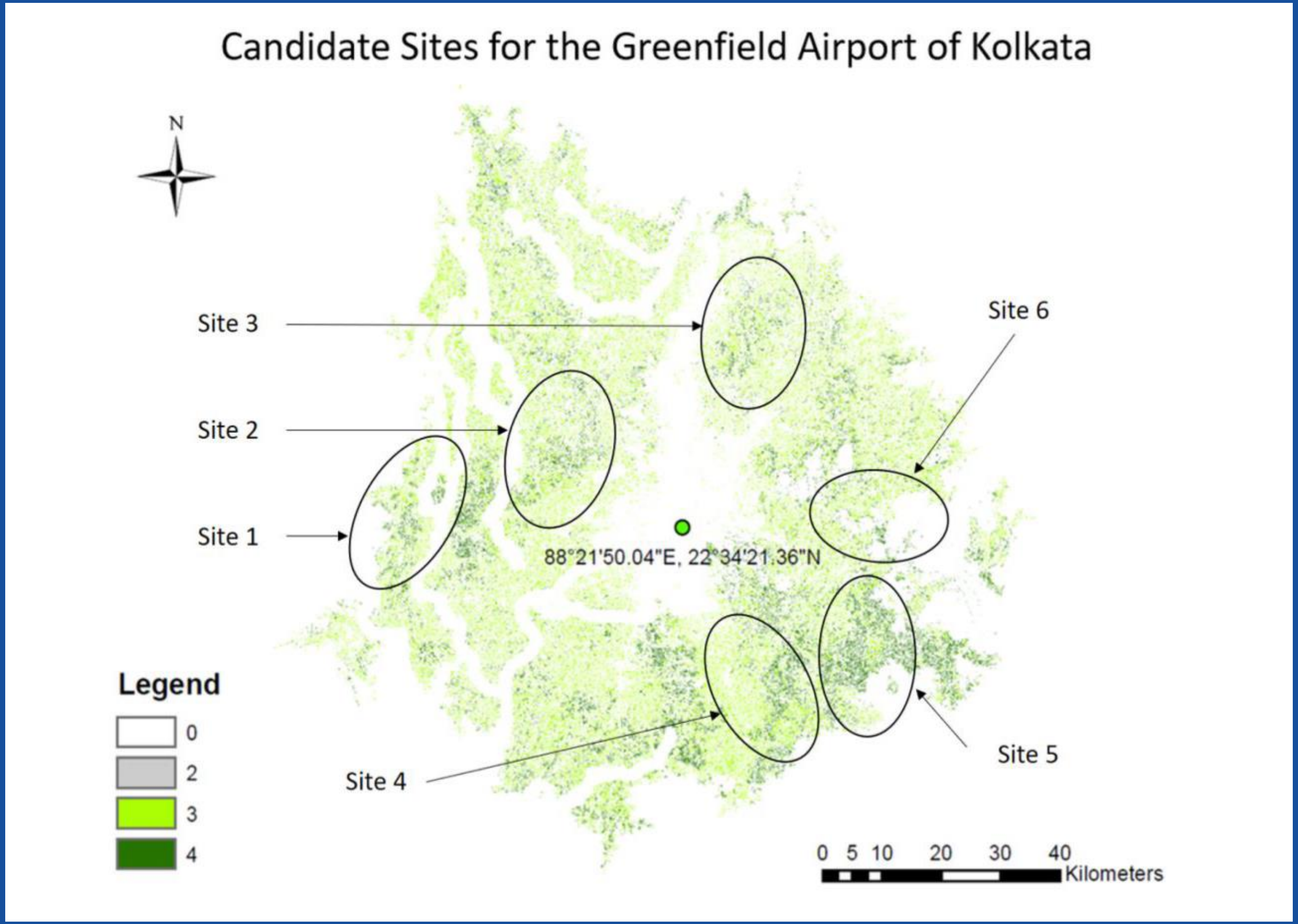
The generated files were given as input to the 'Weighted Overlay tool' in ArcMap to create the site suitability map for Kolkata. The importance given to the slope was 60% and land use/cover was given 40% weightage.

Weighted Overlay tool allows the calculation of a multiple-criteria analysis between several rasters. It was achieved through the following steps: reclassifies values in the rasters taken as input and combines them into an evaluation scale of suitability or preference risk, multiplies the cell values of each input by the rasters weight of importance and adds the resulting cell values together to produce the final suitability raster where value '0' represents not suitable and value '4' corresponds to most suitable.

Based on the visual interpretation of the suitability raster, six different candidate sites having dimensions of about 6x4 km were identified for the construction of the new airport, in order to accommodate at least 4 runways making it futureproof and also keeping in mind the scope for future expansion of the airport.

Methodology

Using Weighted Overlay :



Methodology

e. Meteorological Conditions :

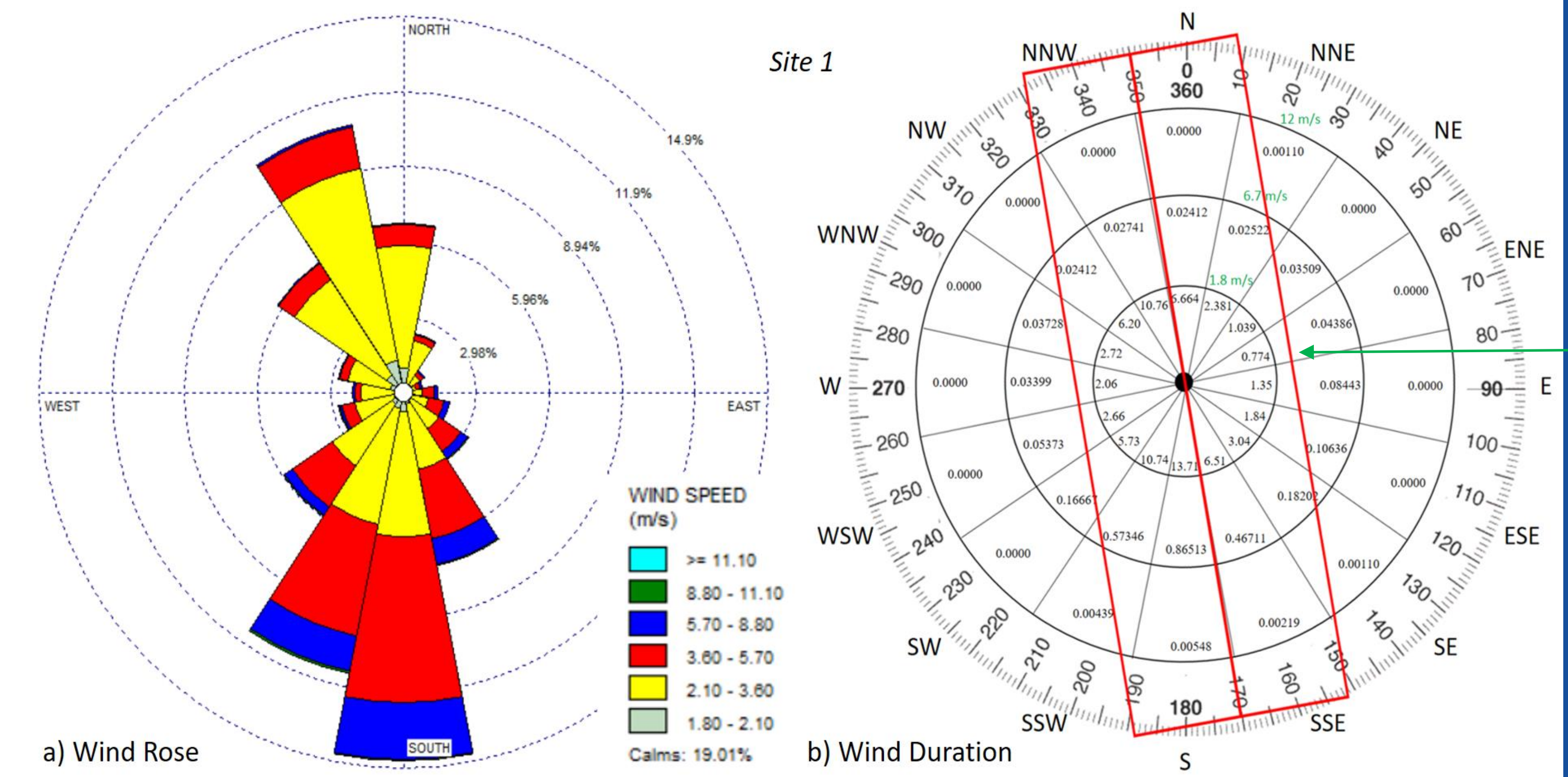
It is important to understand the direction, intensity and duration of winds in a specific site/region. If the wind intensity is too high, a resistance or uplift condition might be created to standby aircraft and this can pose to be a safety hazard condition, restricting movement or operation of aircraft.

We downloaded wind data for the past ten years (from 01-01-2008 00:00 hours to 31-05-2018 23:00 hours) from the Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2). The meteorological dataset had a temporal resolution of one hour and it was regridded using bilinear interpolation into the 'geos 0.25' grid format.

We used R programming language to read and extract data from these files. The output was saved to an excel sheet and the wind rose diagram was plotted using WRPLOT View which is a free software that provides visual wind rose plots, frequency analysis and plots for several meteorological data formats. The wind rose diagram generated was used to determine the best possible runway direction for the respective candidate sites.

Methodology

e. Meteorological Conditions :

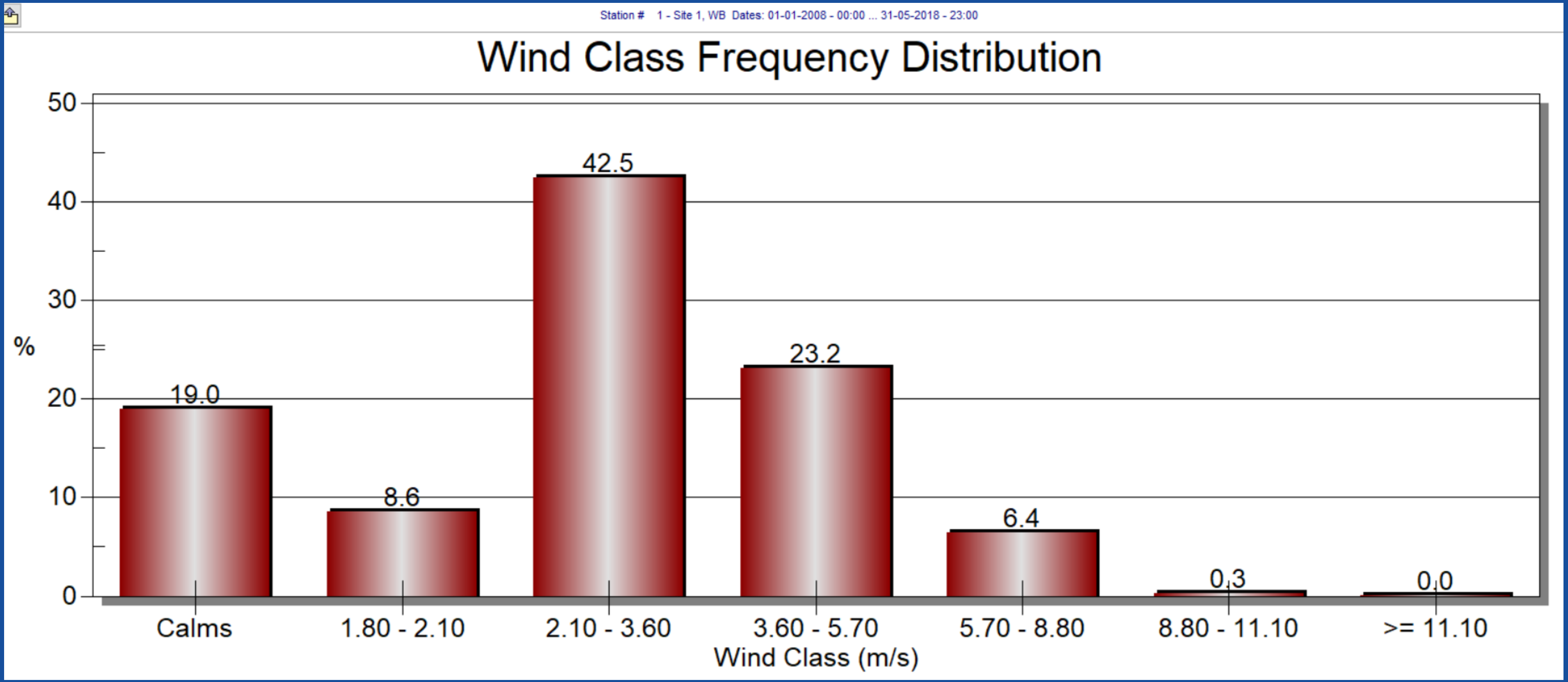


Best Possible Runway Direction

Wind Rose and Wind Duration Diagram for Candidate Site 1

Methodology

e. Meteorological Conditions :



Wind Class Frequency Distribution Diagram for Candidate Site 1

Results and Discussions

Considering the above factors, it is also important to understand the regional plan, airport use, proximity distance, ground accessibility, obstructions, noise nuisance, grading, drainage and soil characteristics, future development, availability of utilities, and the economic consideration of the candidate sites for an airport construction.

The candidate site should also form an integral part of the national network of airports in the country. The approach zone of Site 3 coincided with that of the NSCB airport and since the physical separation between the two was only about 12 km (making it dangerous for simultaneous flight operations to take place) it was eliminated from our consideration in the study.

Due consideration was taken to select a site where the landing and takeoff paths of the aircraft pass over land which is free from industrial or residential areas due to noise pollution and safety concerns. Grading, drainage and soil characteristics are also crucial for the construction and maintenance of airports. Candidate sites with high water tables need to be avoided due to the possibility of the requirement of costly subsoil drainage. It was also necessary to think of future development due to increasing air traffic. This is the reason why we selected candidate sites having enough area to accommodate at least 4 runways within the airport.

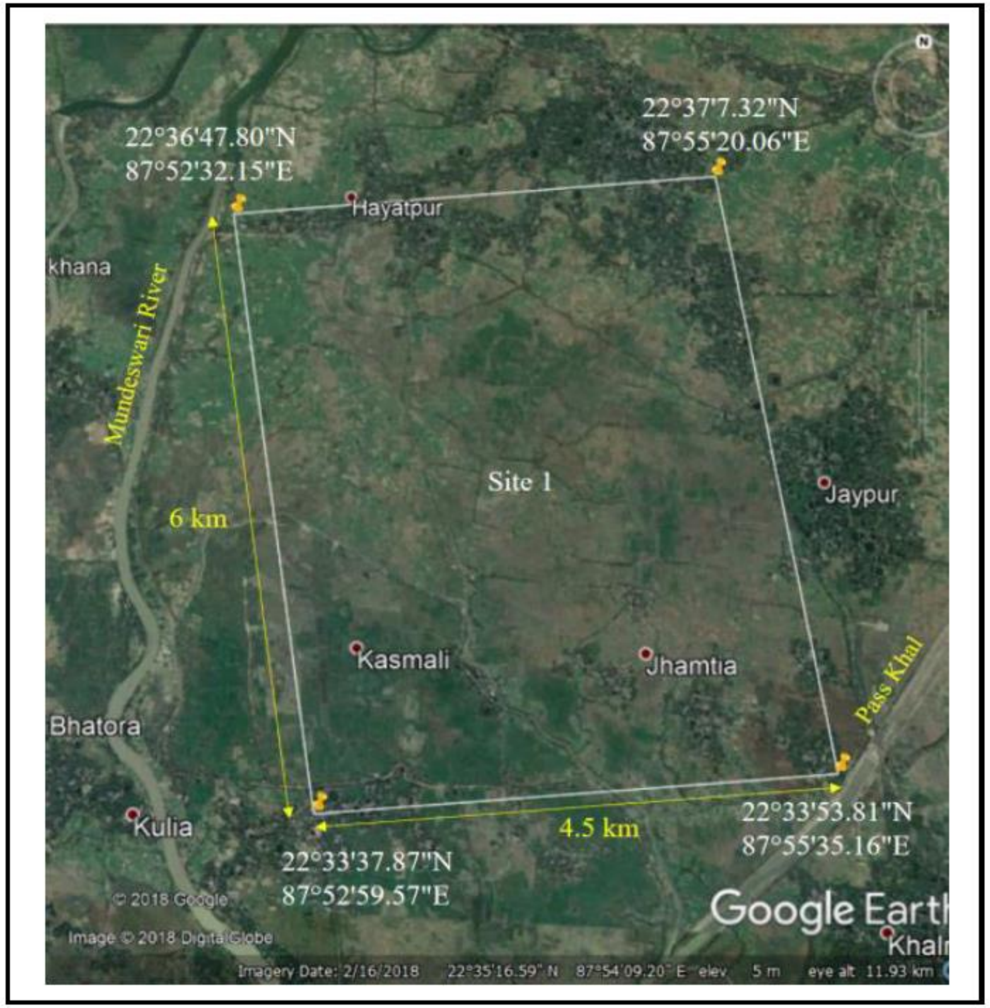
Results and Discussions

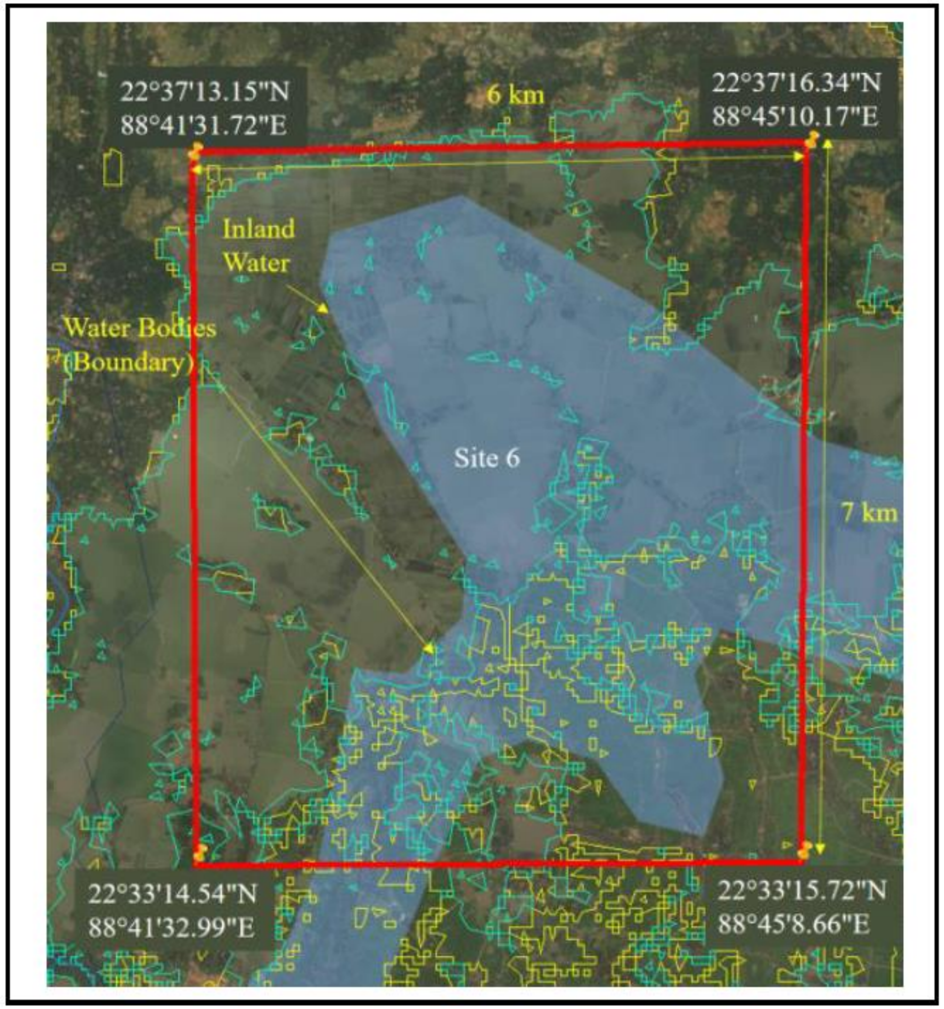
	Paramter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
1	Locations						
	Latitude	22°34'56.68"N	22°39'32.40"N	22°48'51.81"N	22°23'37.10"N	22°26'34.88"N	22°35'20.61"N
	Longitude	87°54'28.42"E	88°10'17.71"E	88°26'9.64"E	88°32'16.98"E	88°39'50.10"E	88°43'33.59"E
	Elevation (m)	6m	3m	6m	2m	4m	0m
2	Area	2760 ha (6820 acre)	3120 ha (7709 acre)	3690 ha (9118 acre)	3460 ha (8550 acre)	3370 ha (8327 acre)	4580 ha (11317 acre)
3	Forest Area	Nil	Nil	Nil	Nil	Nil	Nil
4	Aerial Distance from NSCB Airport	55.81 km with initial bearing as 081° 55′ 25″ and final bearing as 082° 07′ 50″	28.2 km with initial bearing as 091° 31′ 22″ and final bearing as 091° 37′ 43″	18.09 km with initial bearing as 176° 38′ 39″ and final bearing as 176° 38′ 53″	30.24 km with initial bearing as 341° 51′ 47″ and final bearing as 341° 49′ 40″	32.24 km with initial bearing as 316° 04′ 57″ and final bearing as 316° 04′ 57″	29.55 km with initial bearing as 283° 45′ 40″ and final bearing as 283° 39′ 13″
5	Predominant Wind Direction	NbW-SbE (350º-170º)	N-S (357º-177º)	N-S (4º-184º)	NbE-SbW (12º-192º)	NbW-SbE (350º-170º)	N-S (0º-180º)
6	Land Use	Agriculture	Agriculture/ Commercial	Agriculture	Agriculture	Agriculture	Agriculture
7	Surrounding Area of proposed Airport	Villages with agricultural land	Villages with agricultural land/Commercial	Villages with agricultural land	Villages with agricultural land	Villages with agricultural land	Villages with agricultural land
8	Fully affected Villages	10Villages-Khajur Daha, Jhamtia, Kasmali, Kamar Khola, Madhya Jaypur, Paschim Jaypur, Kalasdihi, Chak Janardan, Kakrol and Shibgachhia	6 Villages-Baigachhi, Dakshin Santoshpur, Chak Mahishjol, Mahishgote, Uttar Santoshpur, and Kanaidanga	11 Villages- Chakbelu, Ratanpur, Baichhigachhi, Bargachhia, Baliaghata, Basudebpur, Tapanpur, Kushdanga, Guma, Keutia P and Tentulia	13 Villages- Kamar Hati, Kasinagar, Bausahar, Kashinathpur, Jalalabad, Satbaria, Mathurapur, Garanbaria, Sangur, Dakshin Kasipur, Nabhasan, Makrampur, and Raypur	9 Villages-Jibantala, Miagheri, Paina, Sastakhali, Haora Mari, Hadiya, Bhabananda, Ghikhali, and Mallik Kati	10 Villages- Roykhan, Jhanjha, Dihigachhi, Sonarhula, Bantosha, Ramjoy Gheri, Sarabaria, Muchikhola, Munsi Gheri, Ramchakir Gheri, Gobaria Abad, and Dhantala
	Affected Households	5014	3714	5578	7837	4988	5656
	Affected Population	23075	18781	24833	36888	25629	25208
9	Partially Affected Villages	Chingrajola, Hayatpur, Solbaga, Nignan, Khari Geria, Jaypur, Amragari, Rautara, Ghardubra, and Chak Hayatpur	Khas Mara, Dakshinbari, Hantal, Sadatpur, Rajapur, Mansinhapur, Bhadua, Ban Panchbere, Kamalapur, Mamudpur, Dudhkomra, and Mahishnala	Sahapur, Tababeria, Beraberia, Atghara, Belu, Dangatanga Tangi, Shrirampur, Komarduni, Rautara, Mukundapur, Abhirampur, Shyamnagar Hansia, Gurdaha, Mathurapur, and Teleni Para	Solgohalia, Sri Krishnapur, Banamalipur, Mathurapur, Dakshin Rajapur, Situri, Jhungri, Bazarati, Karunarhati, Dari Madhabpur, Kashia Danga, Mahes Pukuria, Kustia, Dharmatala , and Kharidoga	Saranger Abad, Ganga Cheri, Hatiamari, Kayam Khan, Jay Khali, Chung Hata, Khar Gachi, Pita Simulia, Gokulpur, Netra, and Chandibari	Kachurhula, Mallick Gheri, Nebutala Abada, Dirghadaria, Adampur, Khas Balander, and Ranigachhi

Results and Discussions

	Parameter	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
10	Impact on Water Bodies	Small ponds & a stream was identified (seasonal)	Small ponds & a perennial stream and canal was identified	A seasonal stream & the Noai canal was identified	Small ponds were identified	Presence of water bodies & inland water within the site	Presence of water bodies & land subject to inundation (wetlands) within the site
11	Historical and Archaeological Sites	Nil	Nil	Nil	Nil	Nil	Nil
12	National Parks and Wildlife Sanctuaries within 10km radius	Nil	Nil	Nil	Nil	Nil	Nil
13	Critically Polluted Area	No major industrial areas in the vicinity. Presence of small scale factories and industries within 10 km.	Several small industries and factories within and around a 10 km radius of the site.	Presence of small scale factories and industries within a 10 km radius towards the western and southern end of the site	Presence of small scale factories and industries within a 10 km radius towards the northern and western end of the site	Several small factories andindustries around a 10 km radius of the site.	Barely a few factories within a 10 km radius of the site.
14	Noise Sensitive Villages in the funnel (Villages in the Funnel area up to a distance of 3km from runway end depending on the position of the runways): Approach funnel of non-instrument approach for runway code 3 and 4.	Northern End: Chak Hayatpur, Mansuka, Par Kalahar, Narendrapur, Bhairabpur, Palashpai, Chanpanagari, Jhikhira & Ghardubra Southern End: Nignan, Khari Geria, Ajangachhi, Fatik Beria, Dhanyaghari, Hio & Khalna	Northern End: Dudhkomra, Chak Bangla, Ichhapasar, Bade Sola, Haripur, Baghati, Singjor, Bhagabatipur, Nawabpur, Radhaballabh-pur, Alipur & Anantarampur Southern End: Jamdanda, Oadipur, Keshabpur Pal Para, Khasjalalsi & Boharia	Northern End: Bhatpara (City), Rautara, Mukundapur, Abhirampur, Rambati, Chankia, Bahirpur & Sashipur Southern End: Teleni Para, Atghara, Madhabpur Dogra Bari, Chharuhat, Narayanpur, Bijoypur, Nilganj & Sebarhat	Northern End: Jhungri, Shaksahar, Balipur, Bazarati, Chak Bhika, Dara, Bangoda, Amreswar, Karunarhati, Kashia Danga, Taldighi, Madhabpur, Hogaldara & Dara Southern End: Solgohalia, Kalaria, Gaur Daha, Sri Krishnapur, Karkhanar Chak, Makhal Tala & Banamalipur	Northern End: Par Kalugachhi, Kalugachhi, Padmapukuria, Garabad, Gar, Santra, Pipuldaha & Rajendrapur Southern End: Saranger Abad, Ganga Cheri, Kaluakhali, Khagra & Kaora Khali	Northern End: Khordachand-pur, Goalpukur, Kalikapur, Sadarpurbeha-la, Madar Tala, Trimohini, Komabad, Harpukuria, Sakendarnagar, Jamalpur, Chak Kalikapur, Kripalpur, Aziznagar, Chatkabaria & Ajban Nagar Southern End: Behari P, Samla, Atpukur, Kachurhula, Uchildaha & Mallick Gheri

Results and Discussions





Maps of Site 1 (Left Side) and Site 6 (Right Side)

Conclusion

Considering the above factors, it is also important to understand the regional plan, airport use, proximity distance, ground accessibility, obstructions, noise nuisance, grading, drainage and soil characteristics, future development, availability of utilities, and the economic consideration of the candidate sites for an airport construction.

The candidate site should also form an integral part of the national network of airports in the country. The approach zone of Site 3 coincided with that of the NSCB airport and since the physical separation between the two was only about 12 km (making it dangerous for simultaneous flight operations to take place) it was eliminated from our consideration in the study.

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Thank You