Policy report on

Proposed Mitigation Strategies for the Angul - Talcher Industrial Area in the State of Odisha

submitted by

Prof. Manju Mohan
(Consultant-Incharge)

Centre for Atmospheric Sciences,
Indian Institute of Technology Delhi
Hauz Khas New Delhi-110016

in association with

Visiontek Consultancy Services Pvt .Ltd
(An Enviro Engineering Consulting Cell)
Bhubaneswar

Sponsored by

State Pollution Control Board, Odisha

March, 2018

EXECUTIVE SUMMARY

Most of the Asian cities are growing at a rapid pace because of large populations, migration, high urban standard of living and industrialization. As a result, cities and industrial surroundings around the world are heating up. Quantification and mitigation of such effects is challenging for the scientific community. Urban Heat Island (UHI) intensity defined as air or land temperature differences between urban and rural areas can be helpful to gauge the urban effects on atmospheric conditions. This is a phenomenon in which a predominance of dark, impermeable surfaces and concentrated human activity cause urban surface and atmospheric temperatures to be several degrees hotter than those in the suburban or rural surroundings. Urban heat islands have significant and wide-ranging effects on public health, air quality, energy consumption, climate adaptation, quality of life, storm water management, and environmental conditions. Given this range of impacts, city programs to reduce excess heat are often spread across a number of agencies, each with its own strategy and priorities. Although less known and studied, the human activities in and around major industrial projects can significantly contribute to heat island generation and consequently result into adverse impacts on human health and welfare and may contribute to overall warming at various scales in the atmosphere. Thus, mitigating heat island effect due to large agglomerations of industries can benefit buildings, neighborhoods, cities, suburban areas, and eventually the global climate.

This report is based on the detailed modelling and measurement studies carried out to determine Industrial Heat Island (IHI) intensities, assessing contributing factors and developing mitigation scenarios for impact assessment for the Angul- Talcher Industrial region proposed by the Odisha State Pollution Control Board as a part of Climate Change Action Plan of the State of Odisha and executed by the Indian Institute of Technology Delhi. Angul-Talcher Industrial Area (ATIA) is one of the oldest industrial areas of the country and was declared as 7th among all Critically Polluted Area (CPA) in India due to open cast mines, an industrial set of Aluminum smelting, thermal power generation, steel making etc. It is expected that various planning and regulatory bodies will find it useful to suitably implement mitigation practices presented here.

Volume I of the report entitled "Heat Island Study in Angul-Talcher Area of Odisha" dated March 2018 pertains to the scientific and technical details of the study covering landuse - landcover classification of the study area, field programme, industrial heat island intensity assessment from modelling and measurements, mitigation scenarios, impact on atmospheric warming due to aerosols and impact on meteorology with the help of climate modeling.

Volume II of the report covers various data collected and compiled for the study such as general information on industries and mines in study region, meteorological data, traffic movement, fuel consumption in industrial and domestic sector and building details of various industrial and mining units and houses in villages and town and block level population etc.

This policy document is based on mitigation scenarios developed and simulated for the identified hotspots and landuse-landcover of the study area based on numerical modelling and examining the current-state-of-the Art control strategies. Further, certain areas closer to the hotspots and landcovers are specifically identified as potential spaces within the study area in Angul-Talcher industrial region for implementation.

Hence, this report should be helpful for policy makers or other concerned agencies to weigh in various options for formulating and executing mitigation strategies presented here. It is envisaged that this document will help to evolve a policy framework for consideration of concerned regulatory bodies/implementing agencies in the state of Odisha.

ACKNOWLEDGEMENTS

At the outset, we gratefully appreciate the initiative undertaken by the Odisha State Pollution Control Board (OSPCB) to get a study conducted on heat island of one of the highly industrialized zone, namely the Angul Talcher as a part of Climate Change Action Plan of State of Odisha. We sincerely acknowledge the vision and initiative undertaken by the officials of OSPCB, Shri R. Balakrishnan (Chairman), Shri Debidutta Biswal (Member Secretary), Shri Rajeev Kumar (Former Member Secretary) , Shri Nihar Ranjan Sahoo (Senior Environmental Engineer) and Shri Simanchala Dash (Senior Environmental Engineer) for getting this study on Industrial Heat Island conceptualised and operationalised in collaboration with Indian institute of Technology Delhi which is first of its kind in India and one amongst few across the world. Advice and time to time guidance in the study and facilitating data and industry support from the officials of State Pollution Control Board, Odisha namely Shri Nihar Ranjan Sahoo (Senior Environmental Engineer) and Shri Simanchala Dash (Senior Environmental Engineer) is gratefully acknowledged. We are also highly thankful to Ms Subhadasini Das, Deputy Environmental Engineer, Mr. Bijaya Kumar Bhoi, Asst. Environmental Engg. and Dr. B. B. Dash, R.O, SPCB, Angul, Odisha and other officials of OSPCB for assisting on-site logistics and data collection.

M/S Visiontek Consultancy Services Private Limited (VCSPL), Bhubaneswar was designated as Sub-Consultant in the study mainly with tasks associated with the collection of all background and secondary data and to provide all necessary logistical and manpower support for successful completion of the field programme as well as desired assistance in preparation of the reports. Continuous support and inputs in every possible manner of VCSPL officials namely Shri P. Kumar Ranjan, Managing Director; local experts Shri P.C. Mishra (Director, Environment, VCSPL) who has worked incessantly for the field programme and procuring the data and providing logistical support towards completion of this report is sincerely acknowledged.

We are especially thankful to all officials affiliated with various government sectors, coal mines, industries and city and village dwellers that have supported and helped with data and field campaign.

(Prof. Manju Mohan)

Consultant-Incharge: Heat Island Study in Angul-Talcher Area,

(on behalf of the Project Core Group)

Centre for Atmospheric Sciences,

Indian Institute of Technology Delhi

Hauz Khas, New Delhi-110016 INDIA

email:mmanju@cas.iitd.ac.in;

mmohan66@gmail.com

HISAT Project Team

1. **Indian Institute of Technology Delhi (IIT Delhi)**

   Core Group (Faculty):

- **Prof. Manju Mohan (Consultant -Incharge)**
- Dr. Sagnik Dey (Co- Consultant -Incharge)
- Dr. S.K. Mishra (Co- Consultant -Incharge)

Support Staff/Scholars:

1. Dr. Neelesh Kumar Lodhi (Project Staff)
2. Ms. Shweta Bhati (Project Staff)
3. Ms. Preeti Gunwani (Research Scholar)
4. Ms. Medhavi Gupta (Research Scholar)
5. Mr. Ankur Prabhat Sati (Research Scholar)
6. Mr. Sourangsu Chowdhary (Research Scholar)
7. Mr. Vivek Kumar Singh (Research Scholar)
8. Mr. Rahul Jain (M.Tech Student)

2. M/S Visiontek Consultancy Services Private Limited (VCSPL)

1. **Shri P. Kumar Ranjan (Managing Director)**
2. Shri P.C. Mishra (Director, Environment)
3. Mr. Ashish Sahu (Staff)
4. Mr. Prabhakar Mishra (Staff)
5. Mr. Bijay Sahu (Staff)
6. Mr. Tapas (Staff)

CONTENTS

1. BACKGROUND

Rapidly increasing urbanisation is associated with growth in industrial activities, built up infrastructure such as residential, commercial and official complexes, and vehicular population resulting into significant changes in land use/land cover (LULC) of a region and increase in anthropogenic heat emissions. All these changes affect local meteorology of an area and one of the consequences is the heat island phenomenon. Angul-Talcher area is one of the oldest industrial clusters of the country. It is situated in the central part of Odisha and is around 120 km away from the capital city of Bhubaneswar. Angul-Talcher is one of the fastest growing industrial hubs in the state of Odisha. Angul-Talcher is also categorized as Critically Polluted Industrial Cluster (CPIC) based on its environment quality and pollution load. The industrial area of Angul-Talcher in Odisha state has a complex urban-industrial fabric and significant industrial heat emissions. Thus, it becomes a potential region for development of heat island hotspots.

2. URBAN HEAT ISLAND

An urban heat island essentially means an urban area wherein air temperatures are higher than surrounding or peripheral under developed areas/rural areas leading to generation of an 'island' of hot temperatures. The classical concept of urban heat island considers the air temperature difference between a city centre and the surrounding area. It is defined as "closed isotherms indicating an area of the surface that is relatively warm; most commonly associated areas of human disturbance such as towns and cities". Primarily heat islands are formed due to storage and release of heat by built up structures in an urban center. There is greater absorption of solar radiation due to multiple reflections and radiation trapping by building walls and vertical surfaces in the city. This is followed by delayed release of heat by buildings and paved surfaces in the city. In addition, release of heat emissions in anthropogenic activities such as combustion of fuels for urban transport, industrial processing, and domestic space heating/ cooling also contribute to the heat island effect.

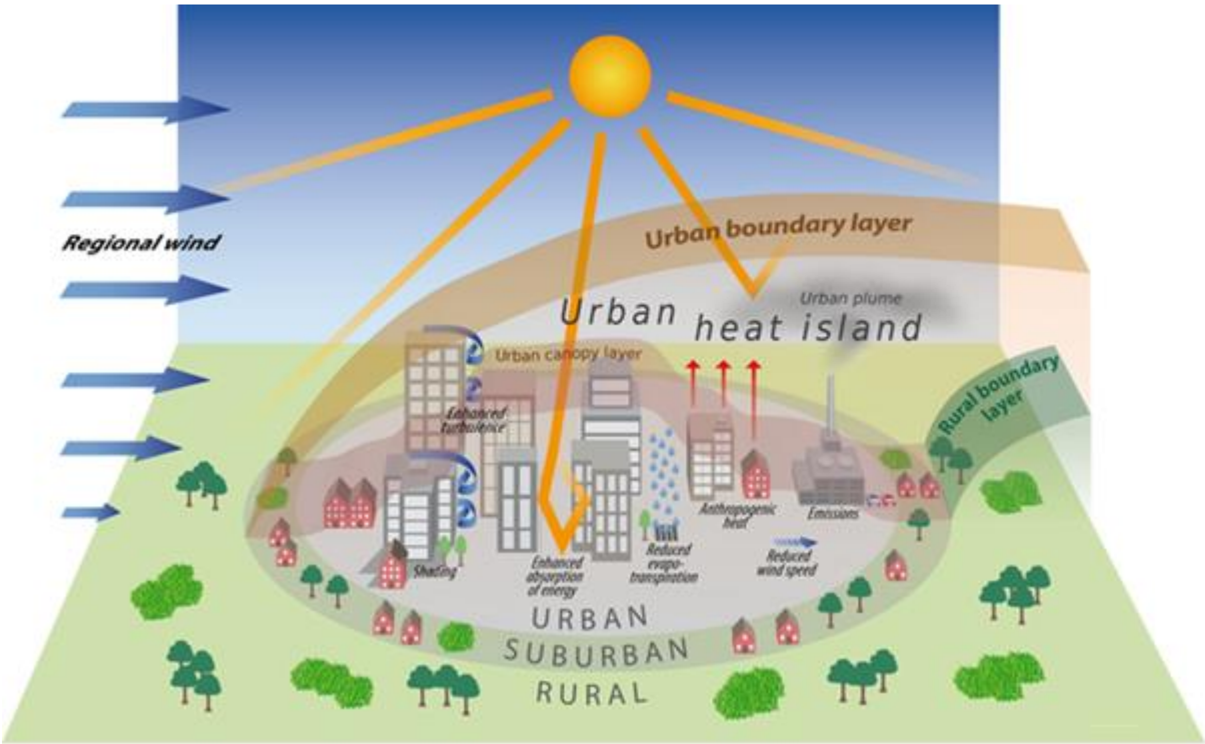

Figure 1: Conceptual diagram of Urban Heat Island (Source: [1])

3. MOTIVATION TO STUDY INDUSTRIAL HEAT ISLAND

Lack of Studies on Industrial Areas

- Most of the heat island studies have focused on urban cities. Climate change impacts are being witnessed by the global communities, due to increasing population and expansion of townships and settlements to industrial zones. Thus, it has become pertinent to focus on several heat emission sources from agglomerations of industries and factors contributing towards heat islands in the industrial regions.
- The concept of urban heat island phenomenon is applied here to the industrial zones and the study is classified as Industrial Heat Island (IHI). The study pertains to the IHI assessment and elaborating its contributing factors and proposed mitigation strategies. This is performed based on primary data collected from an intensive field programme in this region, detailed secondary data, LULC classification, atmospheric modelling towards contributing factors such as to propose mitigation strategies. This policy document is meant

to focus on the mitigation strategies specific to Angul-Talcher industrial based on the technical study covered in technical volumes and the current state-of-the-Art available for this purpose.

Salient features of the study area, methodology and results in brief are presented in next few sections and subsequently mitigation strategies are proposed.

4. SALIENT FEATURES OF STUDY AREA

- Angul Talcher Industrial Area (ATIA) is a highly industrialized area including open cast mining in major part of the area. This region is one of the hottest districts in Odisha where maximum summer temperature goes up to 44-46°C.
- ATIA is dominated with red categories of industries like coal mining, Aluminum smelting, thermal power generation, steel making etc. The industrial activities like steel and thermal power plants release substantial quantity of heat causing high ambient temperature.

- The study area has been selected taking into consideration entire administrative area of Angul Talcher Industrial area (ATIA) which is around 356 km^2 along with the neighboring regions which amounts to a total area of 3000 km^2 (50 km x 60 km). The extent of the study area has been delineated so as to include entire administrative area of Angul Talcher Industrial area (ATIA), the Critically Polluted Area (CPA) as defined by SPCB, Odisha, and neighboring regions. Geographically, the study area is bounded by latitudes 20° 41' 10" N to 21° 08' 37" N and longitudes 84° 55' 00" E to 85° 30' 00" E and lies in Angul and Dhenkanal districts of Odisha.

- 50 monitoring stations were selected based on representativeness of all LULCs in the study area, along with safety and security of the equipment. More stations have been chosen in regions with high industrial/mining activity in comparison to open and forest areas. Population for all 734 villages/towns in the 08 blocks of the study region within Angul-Talcher area is 10,10,516.

- Analysis of spatial variation of various LULCs of the study area enables in appropriately selecting sites for field monitoring. Landsat 8 satellite data product of USGS (United State Geological Survey) is considered for preparation of Land Use Land Cover (LULC) of the study area. Angul Talcher industrial area consists of several land use and land cover features. Total of 9 classes are defined in the LULC of ATIA which covers an area of 3073

km^2. These features are Forests, Industry, Cropland, Mining, Scrub Forest, Scrub Land, woodland Forest, rural and urban settlements regions and Water Bodies. The most dominating LULC of the region is the "cropland" which covers almost 57 % of the total study area.

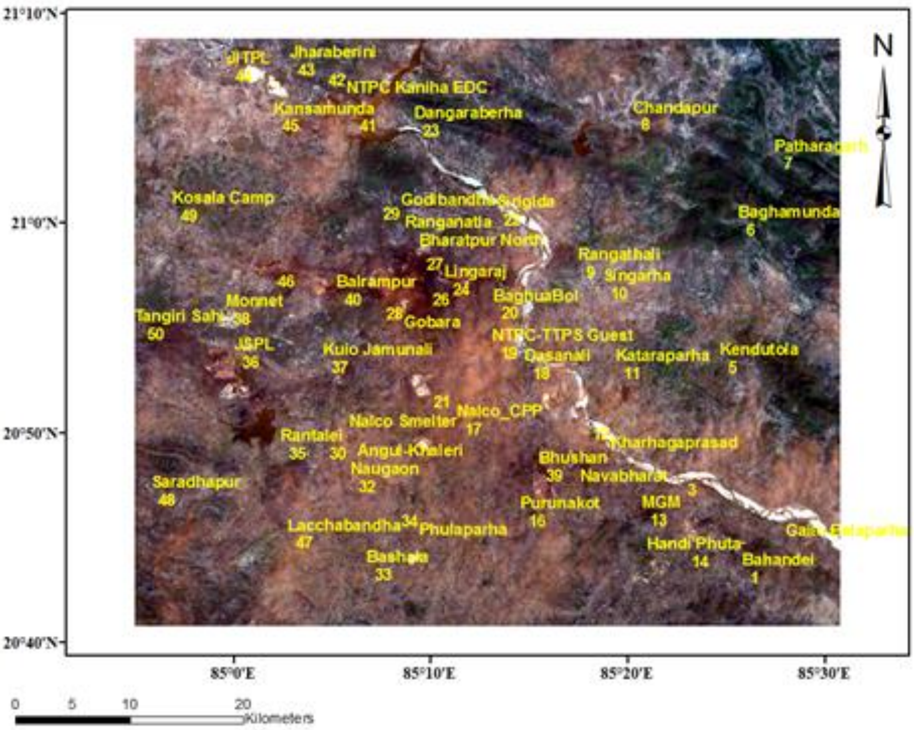

Figure 2: Study Area and Monitoring Sites

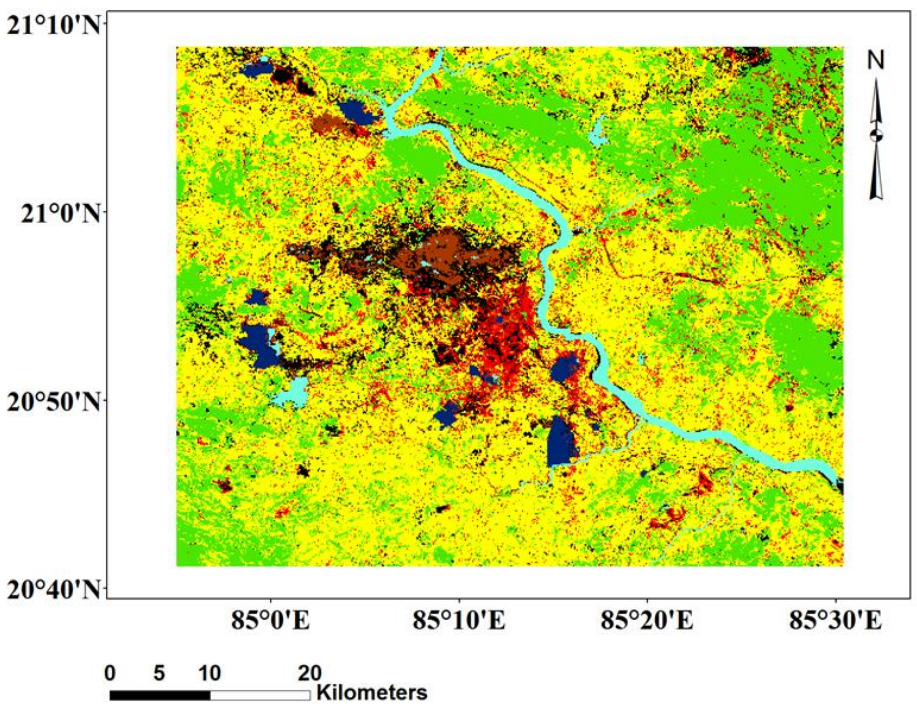

Figure 3: Land use land cover distribution in selected study area of Angul-Talcher

Water Body (3.7%) Mining(1.2%) Industry(1.1%) Forest(25.4%)
Urban and Rural Settlements (4.1%) Cropland(57.2%) Waste Land(7.2%)

6. METHODOLOGY

The scope of the present work can be broadly outlined as follows:

- **Assessment of heat island intensities based on observations:** Spatial patterns of various meteorological parameters such as air temperature, land surface temperature and relative humidity have been studied through measurements undertaken in field experiments. Heat island intensity was classified LULC wise (ie, Cropland, Water body, Industry and Mines) for better representation and understanding of maximum temperature and heat island intensity (both in canopy as well as in surface temperature) across all the classes. In addition, satellite derived land surface temperatures have also been utilized. These measurements helped in determining the intensity of surface heat island and canopy layer heat island.

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- **Modeling system for assessment of heat island intensities:** Empirical relations (based on statistics and regression) as well as mesoscale meteorological model (WRF) based simulations have been applied to assess heat island effect in the study region. WRF has been used for simulating surface and canopy layer heat island intensities. Observations of the field campaign were employed to examine the validity of empirical relations as well WRF meteorological model.

- **Analysis of impact of urban canopy (represented by building geometry) and industrial activity on local meteorology:** Inclusion of urban canopy model determined how building geometry and anthropogenic heat (released by industrial activity and other sources) impact heat island effect within the study region.

- **Identification of Mitigation Measures:** On the basis of monitored data in field campaigns as well as model results, suitable remedial measures have been suggested for abatement of heat island effect with respect to building material thermal properties and LULC within the study region. Impact of mitigation scenarios on ambient temperatures were assessed from computational model simulations.

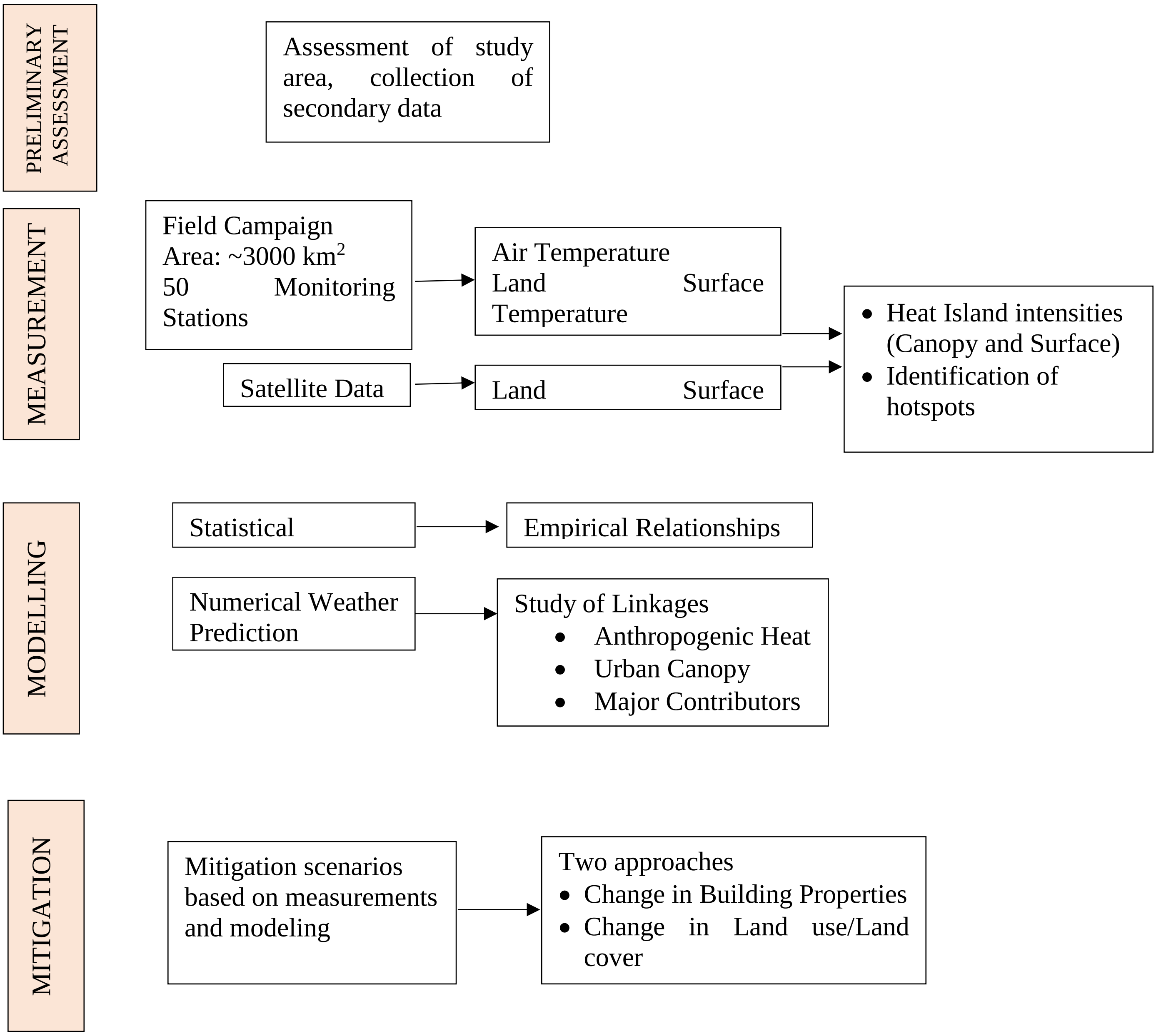


Figure 4: Framework of Methodology adopted for Heat Island Study in Angul-Talcher

7. MAJOR HEAT ISLAND HOTSPOTS FROM OBSERVATIONS

Nighttime

Mining sites (2.74°C) > Industry (2.52°C) > Settlements (2.13°C)> Croplands (2.06°C)

Frequent Nightime Hotspots:

Mining: Lingraj (4.04°C) and Bharatpur North (3.16°C)

Industry: JITPL (3.85°C), Bhushan (3.63°C), NTPC Kaniha EDC (3.16°C), JSPL (3.04°C) and Naba Bharat (2.97°C)

Croplands: Kansamunda (3.18°C), Singarha (2.88°C) and Jharaberini (2.86°C).

Daytime

Croplands (2.07°C)> Mining sites (1.70°C)> Settlements (1.68°C) >Industry (1.45°C).

- Frequent Daytime hotspots: croplands of Sirigida, Jharaberini, and Dangarbera

Table 1: Average Heat Island Intensities (°C) for three months of the field campaign (15 Apr – 14 Jul 2016) for different LULC

		Industry	Mining	Settlements	Croplands
Nighttime	15 Apr – 14 May	2.73	2.97	2.26	2.2
	15 May – 14 Jun	2.58	2.81	2.19	2.19
	15 Jun – 14 Jul	2.25	2.42	1.92	1.81
	Mean (15 Apr – 14 Jul)	**2.52**	**2.74**	**2.13**	**2.06**
Daytime	15 Apr – 14 May	1.27	1.5	1.77	2.44
	15 May – 14 Jun	1.3	1.69	1.48	1.93
	15 Jun – 14 Jul	1.77	1.91	1.78	1.83
	Mean (15 Apr – 14 Jul)	**1.45**	**1.7**	**1.68**	**2.07**

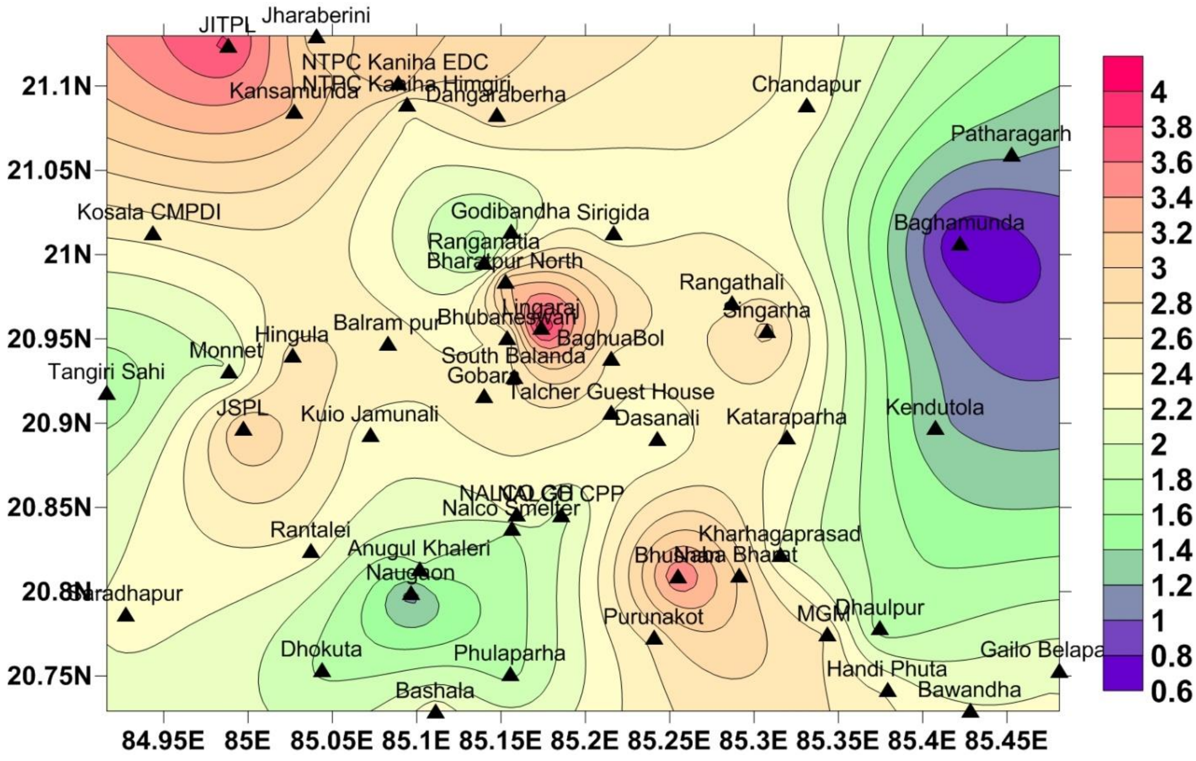


Figure 5: Spatial variation of nighttime heat island intensity during 15 Apr-14 May 2016

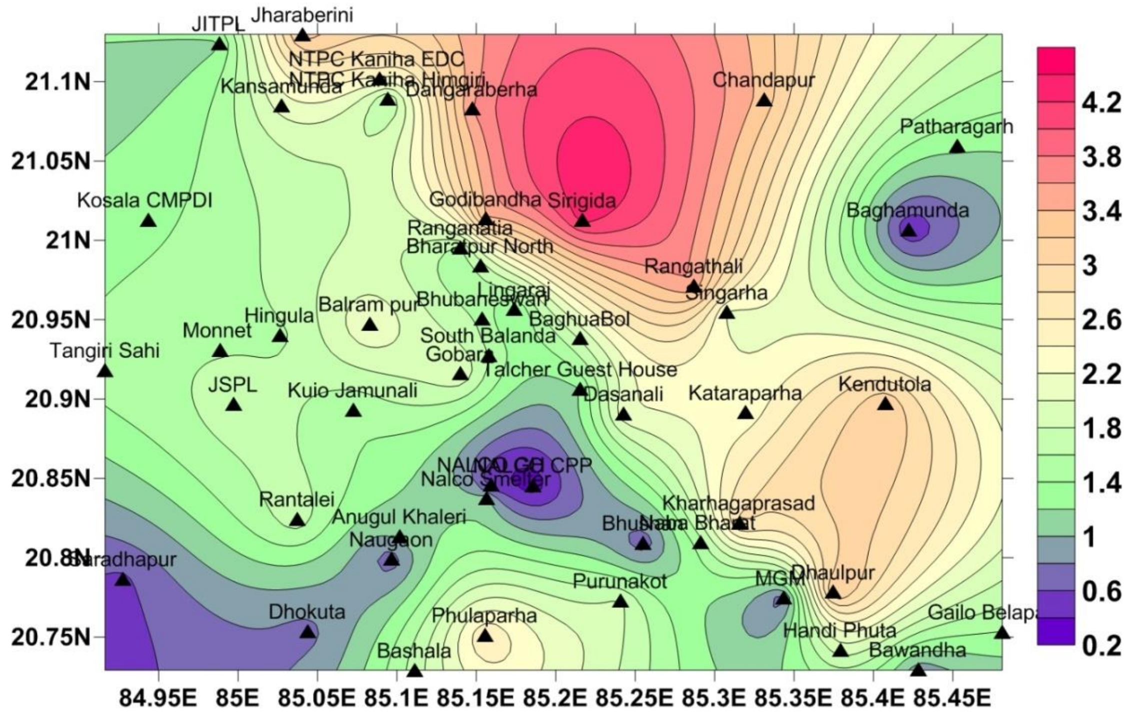


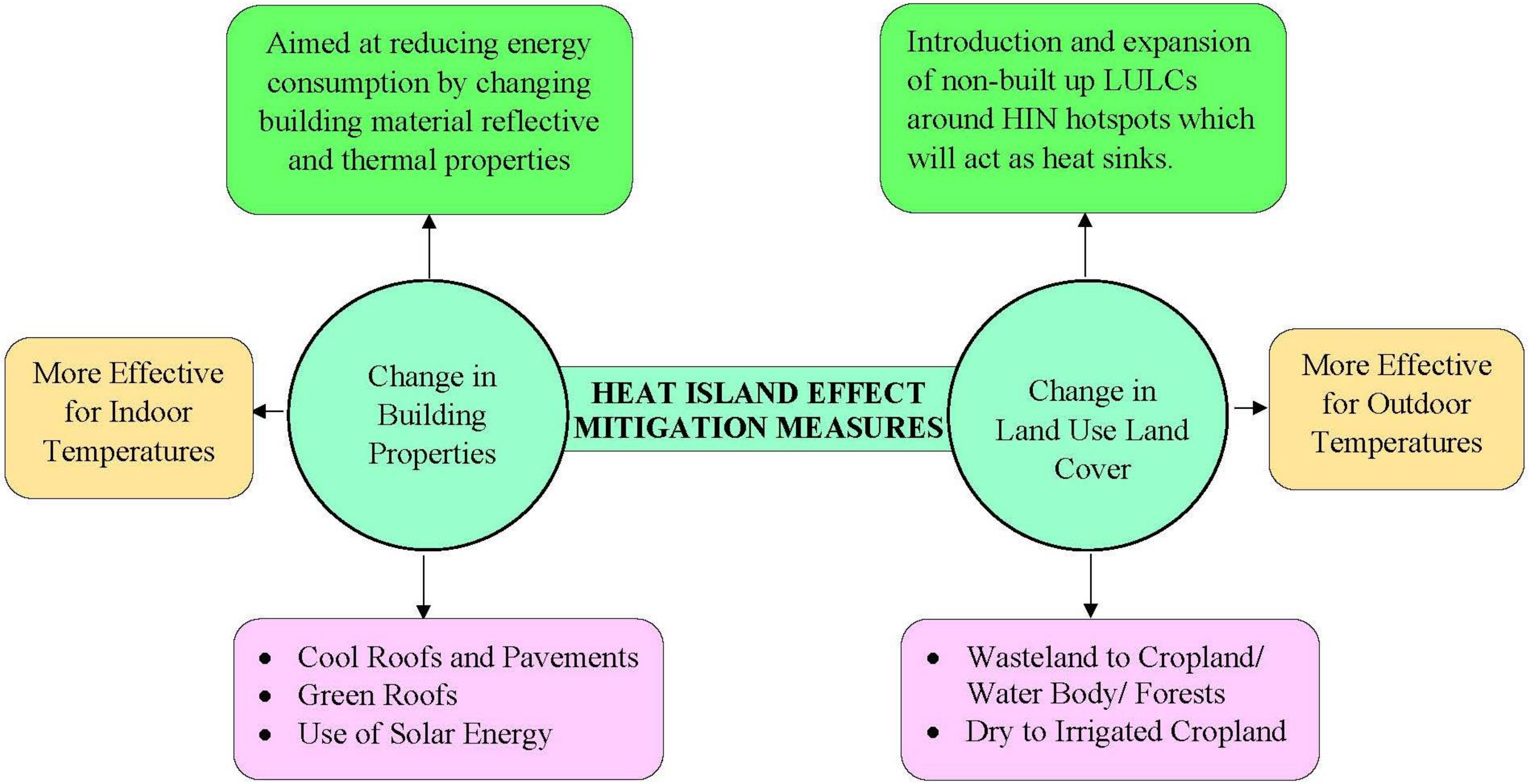
Figure 6: Spatial variation of daytime heat island intensity during 15 Apr-14 May 2016

Analysis based on Modelling

- Industry wise contribution towards ambient temperatures has been explored and it has been found that major industries like JSPL, NTPC-Kaniha, and Navbharat could contribute on hourly basis upto 2 – 5 °C in ambient temperature.

- Mitigation scenarios related to alteration of building material properties as well as change in LULC have been designed for Angul Talcher study area. Impacts of these mitigation measures on local temperature are analyzed with modelling with due consideration of impacts of Urban canopies and anthropogenic heat emissions from each of the major industrial units in the study area in addition to all other emission sources in settlement areas, vehicular traffic, small industries, townships etc.

8. MITIGATION MEASURES



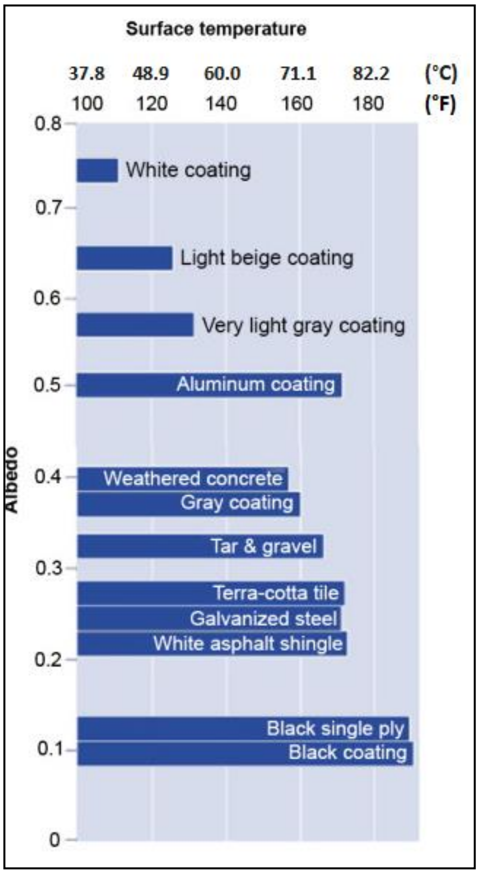
(I) Mitigation measures aimed at altering building properties

1. Reflective Roofs

- Reflective roofs transfer less heat to the building below, so the building stays cooler and uses less energy for air conditioning.

↑Temperature difference between dark and reflective roof can be about 54°F (~30°C) [2]

↑White coating for reflective roof [3]

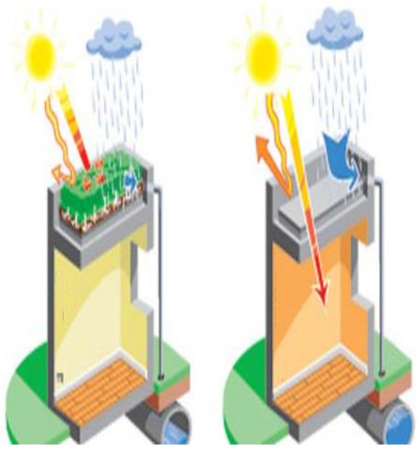


Surface temperature of different roof materials [4] →

2. Green Roofs

- A green roof system is an extension of the existing roof which involves cultivation of selected plants in a medium over roof surface.
- Roof temperature is reduced through daily dew and evaporation cycle.

↑Green Roof vs Traditional Roof [5]



↑Green Roofs on CII-Sohrabji Godrej Business Centre, Hyderabad [6]

3. Solar Panel on Roofs

- Solar panels absorb renewable solar energy to produce energy usable in building.
- By shading the roof, solar panels reduce the cooling energy demand within a building

↑Solar Panels on roof in building of IIT Delhi;

Image Source: IIT Delhi

← Solar Panels on roof in building of Rajkot city, Gujarat;

Image Source: Times of India [7]

4. Inverted Earthen Pots for Cool Roof

- Inverted earthen pots are laid on the roof and the spaces formed in between are filled with plain cement concrete or lime concrete
- Air cavities in earthen pots on the roof surface act as insulation layer to obstruct heat transfer.
- Approximate Cost: Rs 160 ft^{-2} [8]

Case study demonstration of roof insulation by earthen pots in Surat, Gujarat [8]

5. Permeable Pavements

Permeable pavements allow stormwater to infiltrate into underlying soil thereby reducing surface temperature

↑Pavement tiles with vegetation

6. Cool Pavements

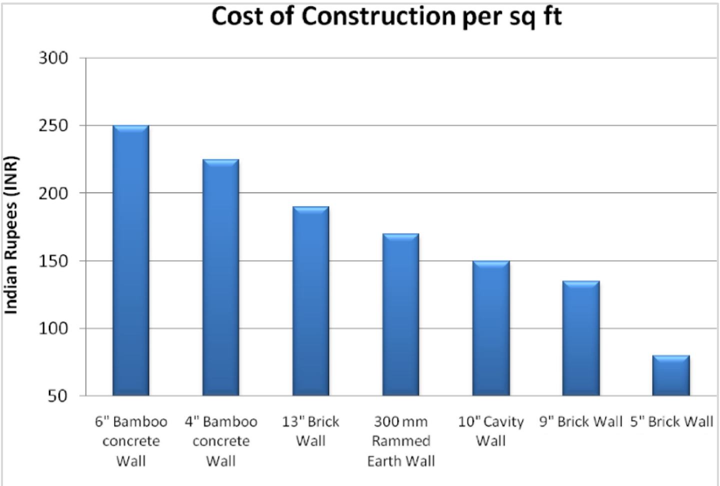
- Work on the same principle as cool roofs.
- Reflect heat resulting in lower surface temperatures.

←Reflective pavements reflect back *substantial radiation Image Source: Lawrence Berkeley Laboratory*

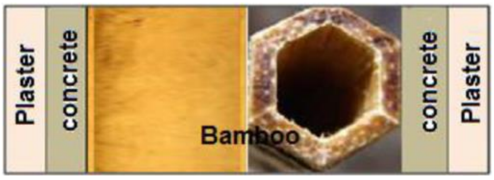
→Los Angeles pioneered a pilot scheme in May 2017 to cool the city by painting over many of the city's black roads with a reflective grey coating called CoolSeal which is anti-glare and is expected to keep the surface temperature cooler by 5-10°C.

7. Alternate Construction Material

- Natural and locally occurring materials like bamboo and rammed earth have high thermal resistivity as compared to energy intensive materials like bricks and cement thereby reducing cooling load.
- Cost of construction of 6" bamboo concrete wall: Rs 250 ft^{-2} ; rammed earth wall: Rs 170 ft^{-2}



← Construction cost (for wall) of different types of materials. Bamboo as construction material is expected to reduce annual cooling load by 7.3–7.5% **(Kandya and Mohan [9])**



↑A prototype of Bamboo–concrete composite wall, Double layer 2 inches (127 mm) full bamboo with 1-inch concrete and 1-inch (25.4 mm) plaster [9]

↑Bamboo corrugated sheet for roofing

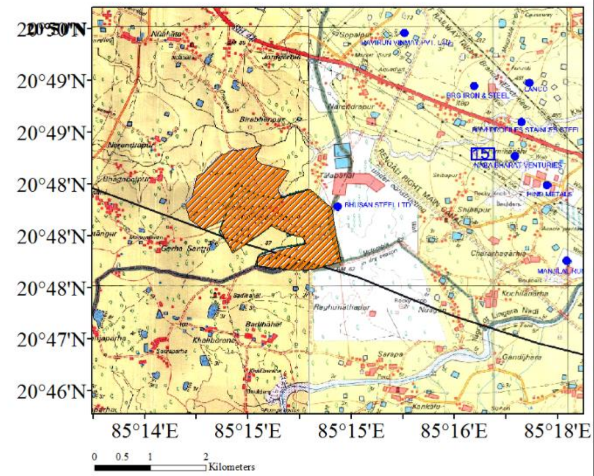
(II) Mitigation measures aimed at LULC changes

9. Conversion of wastelands into water bodies/mixed forests/croplands

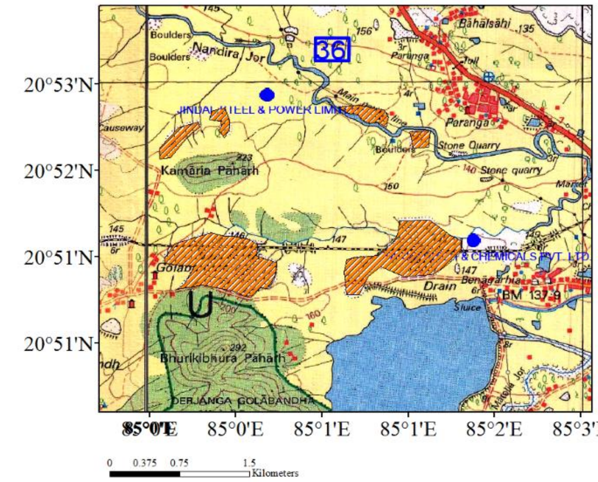
Various patches of wastelands in the study area can be converted into water body, cropland or forest area depending on the feasibility.

 An artificial water body (*Johad*) in Rajasthan [10]	**Construction of mini water bodies near HIN hotspots to increase soil moisture**: • *e.g.* Use of ***Johad*** or storage pits • Constructed in an area with naturally high elevation on three sides, a storage pit is made by excavating the area, and excavated soil is used to create a wall on the fourth side. • Also called madakas in Karnataka and pemghara in Odisha.
 Case Studies of Miyawaki method by Afforestt Top: Growth in 2 years in Arbor Rd Estate, Wargal, Telangana Bottom: Growth in 4 months in Bangalore Airport [11]	**Development of forests in wastelands** • Forests, like water, also serve as heat sinks. • Certain plantation techniques support growth of plants even in hostile soils • e.g. Miyawaki technique which is employed by Afforestt, a commercial service provider based in India. The technique involves planting a number of different types of trees close together in a small pit. This enriches the green cover and reinforces the richness of the land proven to work worldwide, irrespective of soil and climatic conditions. • The methodology guarantees growth of atleast 1 meter every year and a completely maintenance-free, wild and native forest after the first three years. • Basic cost of design, forest creation and walkway sitting is approximately Rs 5000 per m^2 with a minimum space of $100m^2$. Cost per m^2 decreases with increase in area to be converted

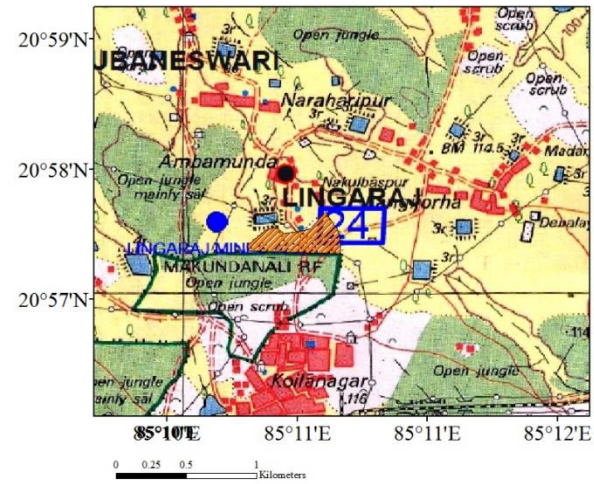
After having discussed the various types of mitigation strategies, potential wastelands near some HIN hotspots mainly close to the major industries are identified which can be considered for conversion with a suitably chosen mitigation strategy [Represented by shaded region]



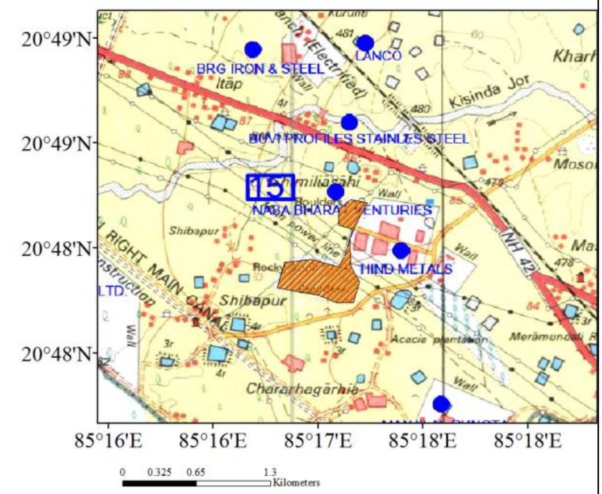
Bhushan



JSPL



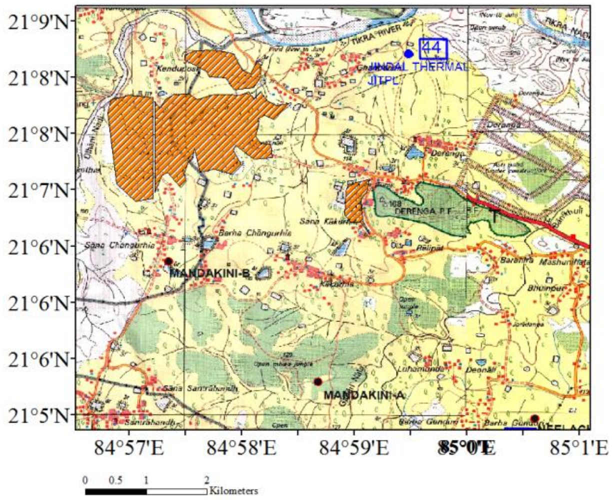
Lingraj



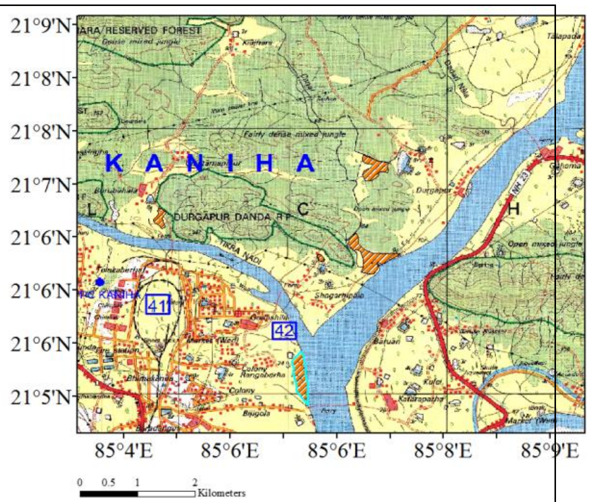
Navbharat

10. Conversion of dry cropland into irrigated croplands

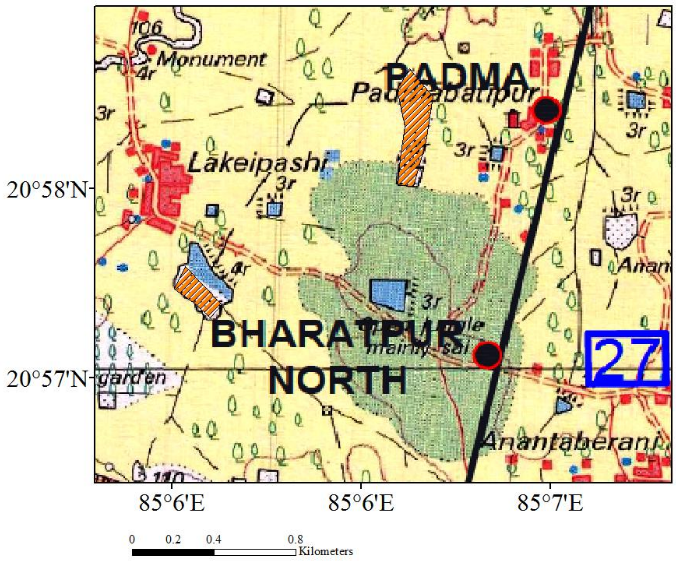
Numerous stretches of croplands were observed as dry lands during the field experiment period of April - May which was probably due to lack of irrigation facilities. Development of irrigation facilities will not only enhance soil moisture but also ensure more revenue opportunities for farmers. These drylands can also be considered to be converted into water bodies/forests as mentioned earlier in case of wastelands.



JITPL



NTPC Kaniha



Bharatpur North

Potential dry croplands near some HIN hotspots which can be considered for conversion

[Represented by shaded region]

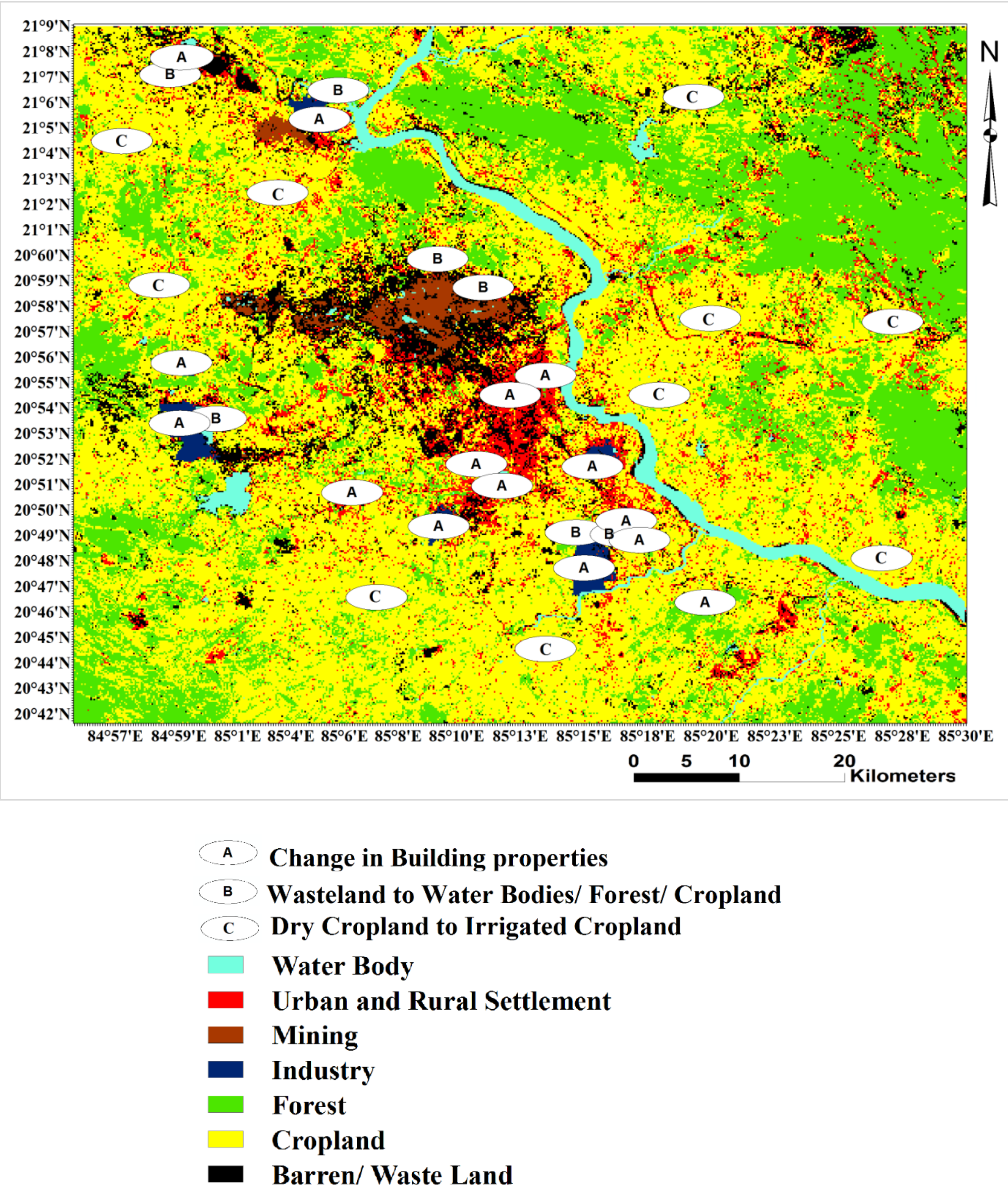


Figure 7: Applicable areas for different mitigation measures in Angul-Talcher Area

9. DUST MITIGATION IN MINING AREAS

- Dust control is one of the chief concerns in coal mines. Fine components of coal dust contribute towards heat absorption.
- Haul roads, material and flyash handling, material stock yard, crusher house are some areas of coalmines most prone to dust pollution.
- There are certain chemical options for suppression of dust in coal mines such as Dustron PC (Coal) [supplied by Syntron Industries Pvt Ltd, Ahmedabad], full name] which is a surface treatment material for dust consolidation and agglomeration with higher moisture content.
- Dustron PC (Coal) is applicable for open cast metal (mineral) mines haul road, over burden area, overburden haul road and roads of mineral stock yard / pile.
- Advantages
    - Dust free environment
    - Biodegradable, environment friendly and nontoxic
    - Air borne dust under permissible limit
    - Safe for human health and plant life
    - Dust and fungi resistant
    - Improved strength of roads and reduced maintenance cost of haul roads

Figure 9: Case of Dustron PC Application in unpaved haul roads of coal mines

Image Source: Syntron Industries [12]

KEY ASPECTS OF MITIGATION

- Change in landuse-landcover has more impact on heat island effect mitigation by impacting the ambient air temperature while alteration of the building material properties is more effective for indoor environment.
- Mitigation measures can be implemented conveniently at smaller spatial scale of few 100 m^2 to more over local scale (~ 1 km). However, larger areas will show greater impacts.
- In general, the maximum impact based on modelling studies is seen in case of introduction to water bodies or an increase in forest cover in the vicinity upto about 1 km of the tune of about 5 °C or so.
- These mitigation scenarios can be implemented in a reasonable time frame depending upon the location and the spatial extent of the application of the mitigation measure. These mitigation scenarios are expected to provide a reference for consideration of a suitable strategy taking into account socio- economic implications and policy measures.
- **Awareness**: Local institutions should take initiative to run awareness programs in industrial sector, educational institutes, community halls and different levels of local bodies meeting to generate a general awareness for the heat island effect/thermal stress. These awareness program should include various sources of HI and interaction of local bodies with common people. Guidelines from certain national level programs such as Prevention and Management of Heat-Wave Action plan of National Disaster Management Authority can also be incorporated for preparing communication program and issuing advisories.

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