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Heat Island Effect in an Industrial Cluster – Identification, Mitigation and Adaptation

CONTENTS

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Introduction

Urban Heat Island (UHI) is a situation with elevated air temperatures in urban areas in contrast to their non-urban rural vicinities. The phenomenon is present in all big and small cities around the world with varying intensity. The industrial agglomeration of Ib-valley in Jharsuguda faces the problem of heat island effect which may be attributed to changes in land cover, energy intensive industrial activities, mining, etc. The Ib-valley region of Jharsuguda is one of four identified UHIs (Jharsuguda, Titlagarh-Balangir, Angul-Talcher, Bhubaneswar) in the state of Odisha. It has been observed that there is a steady build-up of heat in the region, over the years, resulting in higher night time temperatures. Therefore, it is important to develop mitigation strategies to reduce the causes of UHI and adaptation strategies to cope with the heat stress. The key challenges to implement these strategies are primarily related to **proper execution of industrial and institutional framework as well as inadequate drive, capacity, and awareness among the institutions and the affected population**.

This briefing paper outlines the UHI mitigation and adaptation strategies based on the study conducted in this region. It provides a comprehensive strategy for mitigation and adaptation of the heat island effect. The sectoral contribution of different sources and sinks to heat islands has been analysed to determine where actions can be targeted. Sector specific measures to reduce the heat island effect over the Ib-valley region in Jharsuguda have been recommended on the basis of analysis of the contribution of each measure to the reduction in heat release. An indicative potential of the impact of each measure along with the cost of implementation were estimated, wherever sufficient data was available. However, the execution of these plans requires investment, commitment, and coordination from each sector, community group, and

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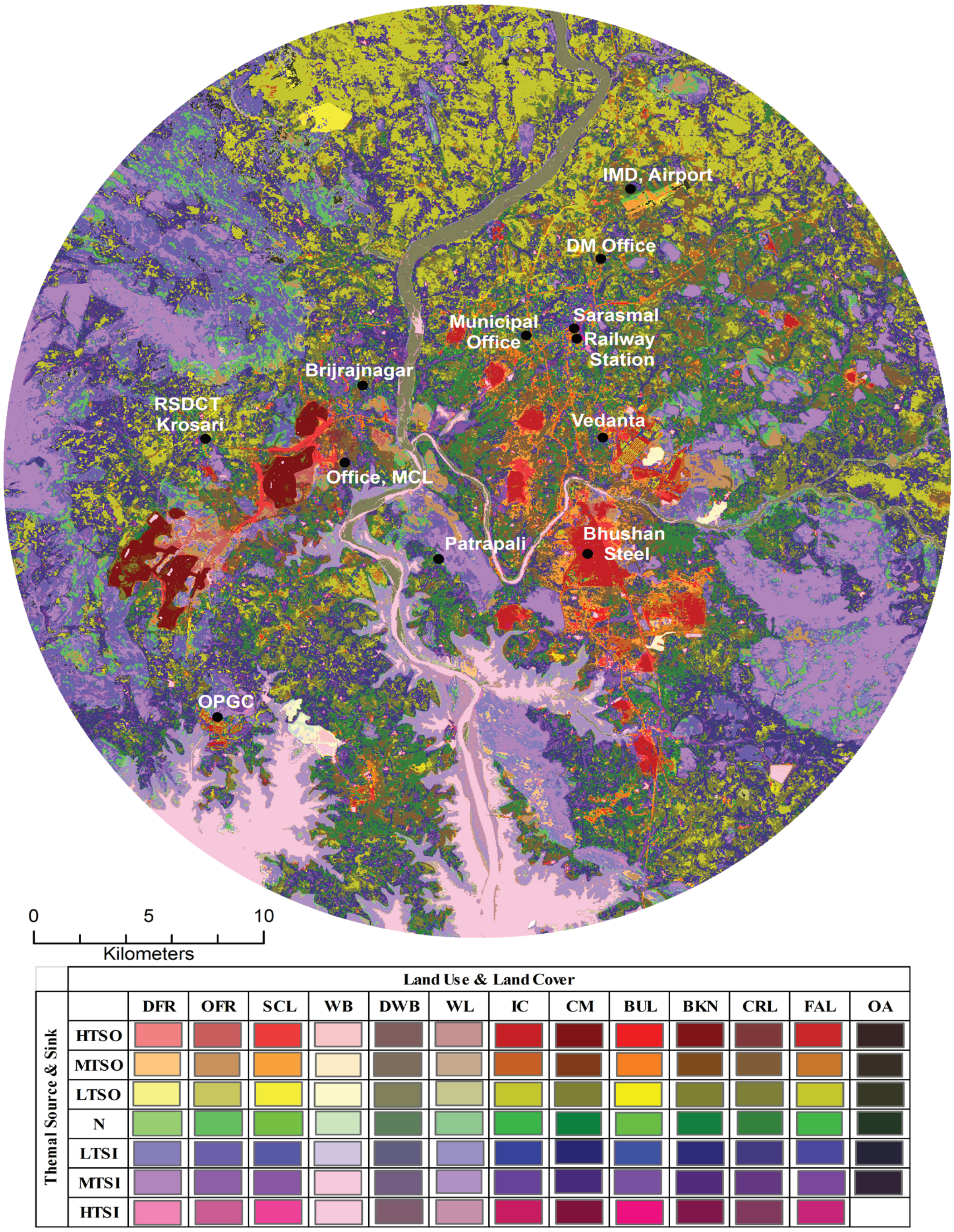
Thermal Source & Sink and Land Use / Land Cover Matrix



Dense forest (DFR); Open forest (OFR); Scrub Land (SCL); Water bodies (WB); Dry Water bodies (DWB); Wet Land (WL); Industrial Cluster (IC); Coal Mine (CM); Built up (BUL); Brick kiln (BKN); Crop Land (CRL); Fallow Land (FAL); Open Area (OA);

High Thermal Sources: HTSO (> 45 °C); Moderate Thermal Source: MTSO (40 -45 °C); Low Thermal Source: LTSO (35 -40 °C); Neutral: N (30 -35 °C); Low Thermal Sink: LTSI (25 -30 °C); Moderate Thermal Sink: MTSI (20 -25 °C); High Thermal Sink: HTSI (< 20 °C)

Figure 1: Thermal heat sources and sinks plotted in a spatial map along with their land use classes to suggest what and where heat mitigation plan should be implemented. Total geographical area is classified in terms of thermal zones (source and sinks)—high, moderate, neutral, and low based on land use practices and function. 40% area out of total geographical area is under thermal sources, 13% area is under neutral category (neither a source nor a sink), and rest 48% are thermal sinks.

local and state government agencies. To strengthen the institutional mechanism and coordination, the roles and responsibilities of each institution have been worked out and documented.

The key methodologies followed in the study were: a) identification of thermal hotspots using satellite remote-sensing, b) direct monitoring of ambient air temperature and humidity in 12 locations of the district and statistical analysis using thermal retentivity and heat index approaches, c) assessment of bio-physical parameters to identify the key thermal sources and sinks, and d) estimation of net heat release from coal mining and industrial activities using IR camera imaging.

It was found that there has been a steady built-up of heat in the study area over the years, resulting in higher night time temperature which can be attributed to increase in industrial activities, coal mining, urban growth, deforestation, and increase in open non-vegetated surface.

Methodology

The following key methodologies were adopted to establish the UHI phenomenon in Jharsuguda.

1. **Indirect satellite-based measurements:** Development of daily mean temperature contour map averaged over one month for the entire area using MODIS 7 Thermal Infrared (TIR) band data at 1 sq. km resolution to identify thermal hotspots based on land surface temperature (Figure 2).
2. **Direct monitoring at predetermined locations based on satellite data analysis:** Identification of the thermal hotspots in the area using thermal retentivity and heat index indicators[1] – calculated based on the real-time data recorded in the temperature-humidity data loggers installed at eleven locations [A. Brijraj Nagar, B. Patrapali, C. Bhushan Steel Area, D. Municipality Office, E. Market Road – Railway Station, F. Krosaki, G. Odisha Power Generation Corporation (OPGC)

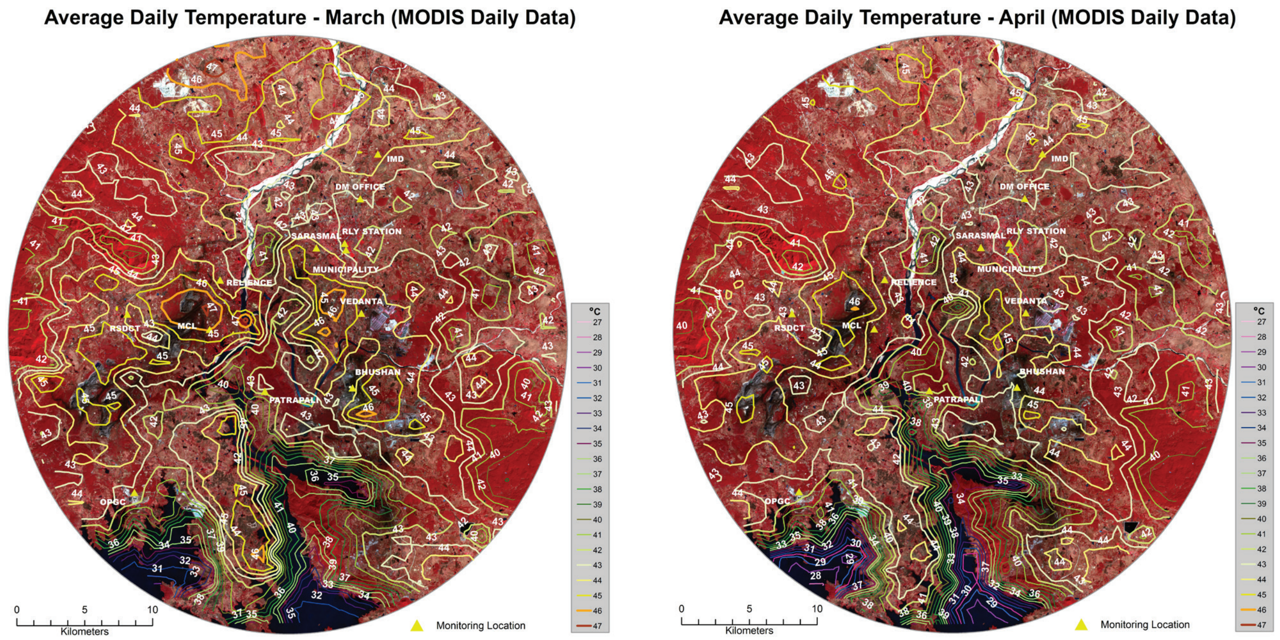


Figure 2: Daily average Land Surface Temperature (LST in 0C) in March and April 2016 using MODIS daily data. Yellow contours indicate hotspot regions. Ambient temperature trend-lines were plotted for the years 2005 to 2010 using IMD data. It was found that T_{max} increased by 0.36 °C, T_{min} increased by 0.55 °C, and the diurnal temperature difference T_{max} – Tmin decreased by 0.15°C, implying that minimum temperature has increased more than the maximum temperature during this period, at a confidence interval of 99%. This establishes a steady build-up of heat in the study area over time.

[1] **Thermal retentivity:** Refers to the extent of retention of heat in a given location during the course of a day, i.e. lower the difference between maximum and minimum ambient air temperature, higher the thermal retentivity.
Heat index: It is a composite index which takes into both account ambient air temperature and relative humidity of a given location; also called "feels like" temperature.

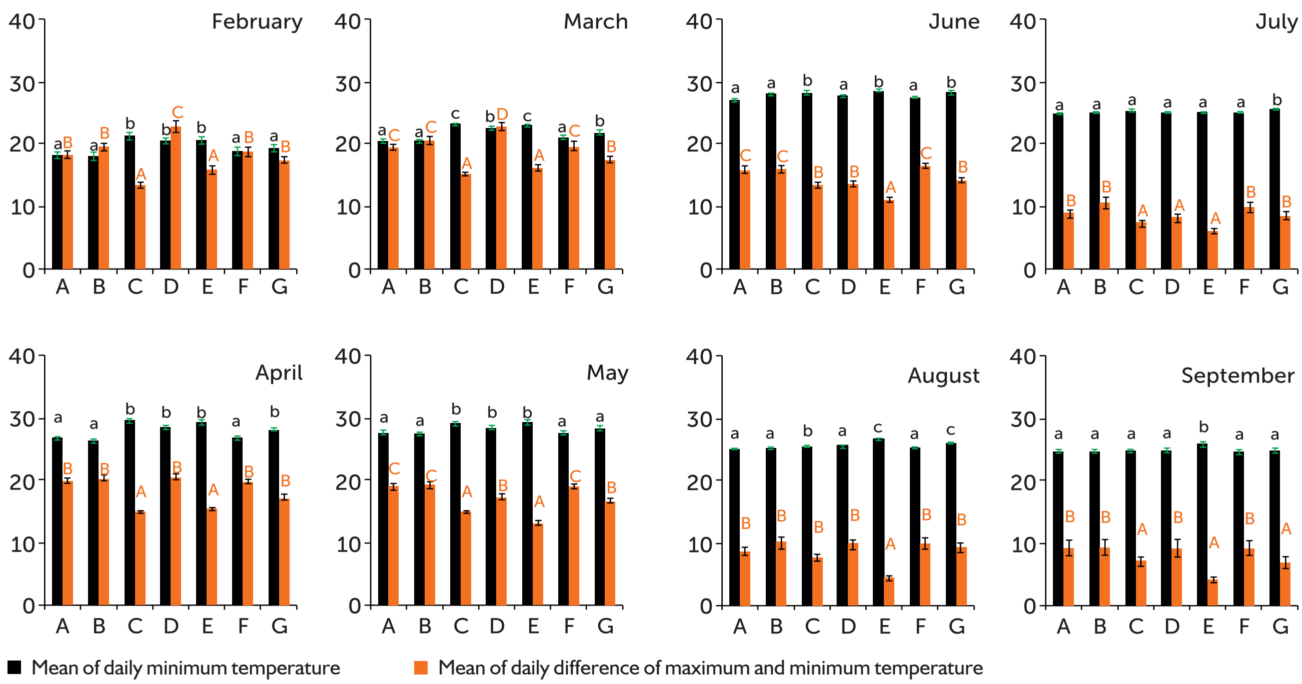


Figure 3: Monthly variation of T_{min} and (T_{max} – T_{min}) from February to September at different sampling locations A to G (X axis). Higher the T_{min} and lower the T_{max}-T_{min}, higher is the thermal retentivity of the region. Monthly averages of these parameters have been computed for each location and categorized based on Tukey's Honest Significant Difference (HSD) test. Lower case letters above the black bars indicates same statistical class for minimum temperature while upper case letters above the orange bars indicate same statistical class for diurnal temperature difference.

Area, H. Airport/IMD Station, I. DM office, J. Sarasmal Village, K. Mahanadi Coalfields Ltd. Office Area].

3. **Estimation of heat release from various anthropogenic activities**: Heat release from different industrial activities, such as open-cast coal mining (OCP), storage of coal in industry stockyard, etc., based on the surface area under different land use types (quarry area, barren land, de-coaled area, reclaimed area, backfilled area, etc.)[2] and surface temperature (obtained from IR camera) of each of the heat sources and sinks has been estimated as shown in Figure 4.
4. **Assessment of biophysical parameters of land uses to identify thermal sources and sinks:** In this model, the total geographical area is classified in terms of thermal zones (source and sinks)—high, moderate, neutral, and low based on land use practices and function. Nearly 40% area out of total

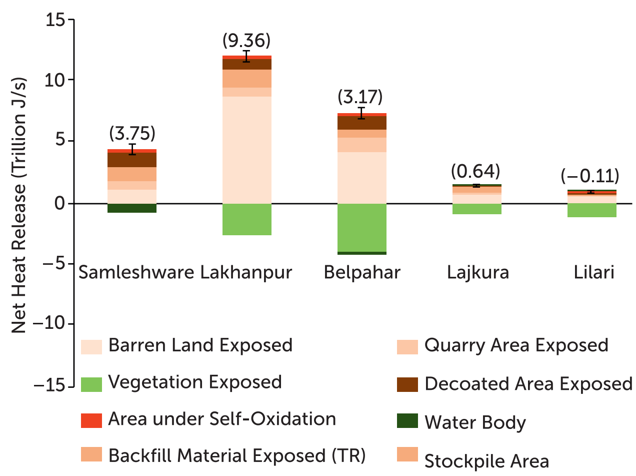


Figure 4: Heat release in 5 OCPs by land use type. Net Heat released is highest for Lakhanpur open-cast project (OCP) followed by Belpahar OCP due to large quarry area (area under excavation), and least for Lilari OCP due to the relatively small area within mine boundary. Area under vegetation is largest in case of Belpahar OCP, followed by Lakhanpur OCP.

2 **Water Body:** The area within the mine boundary (typically void spaces) filled with inflowing groundwater.
Stockpile Area: The storage area for mined coal typically just outside the quarry.
De-coaled Area Exposed: The area within the mine boundary from which extractable coal has already been removed.
Area under Self-Oxidation: The parts of the de-coaled area as well as fractures within the quarry area undergoing partial combustion in the limited presence of oxygen at high ambient temperatures.
Vegetation Exposed: The vegetated area within the mine boundary, typically reclaimed from de-coaled areas.
Backfill Material Exposed: The de-coaled area which has been technically reclaimed through sand, gravel, etc.
Quarry Area Exposed: The area within the mine boundary which is currently under excavation.
Barren Land Exposed: The area covered with exposed rocks or thin soils within mine boundary.

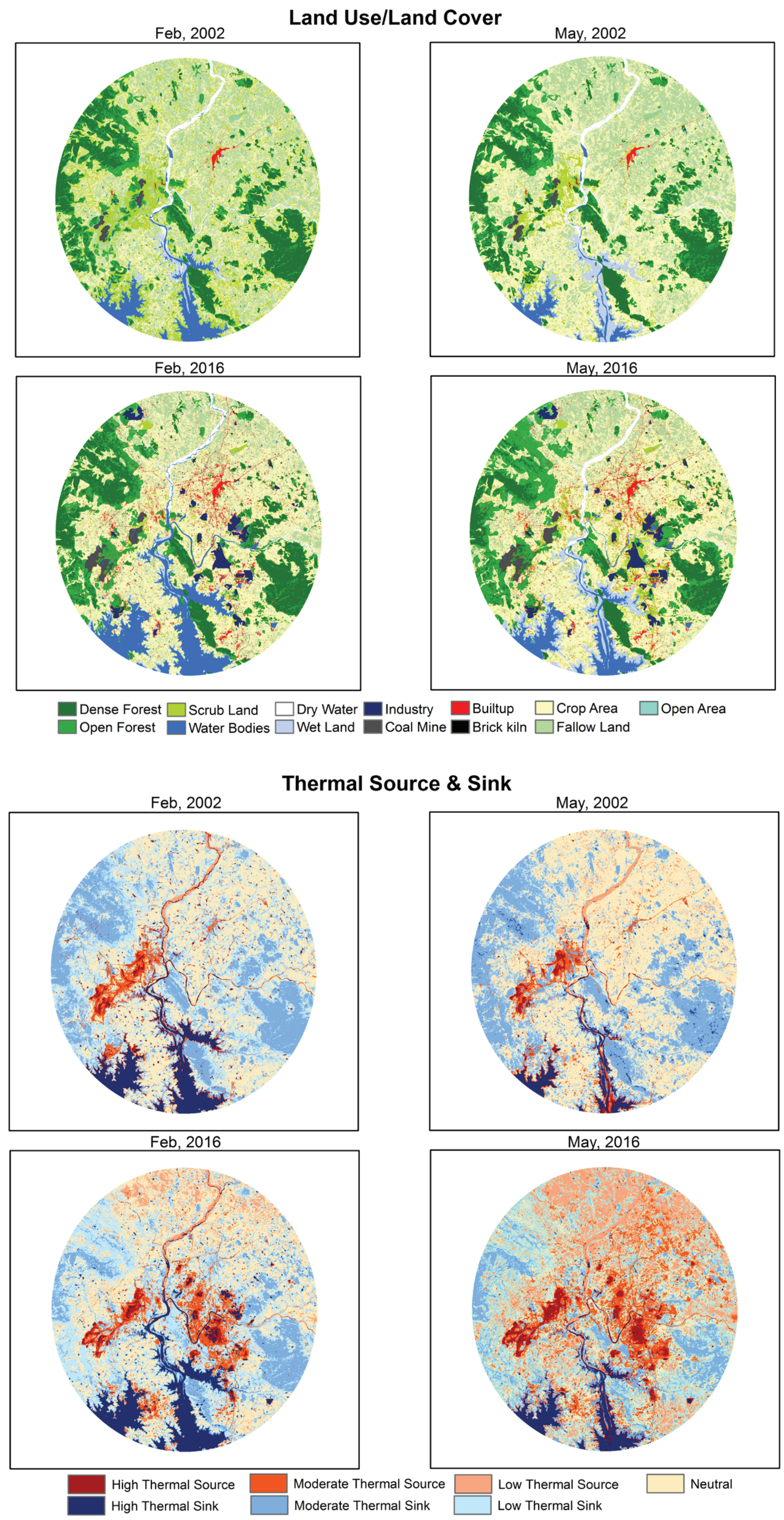


Figure 5: Temporal change in a) land use/land cover and b) thermal sources and sinks in Ib-valley from 2002–2016. Built-up area has increased from 0.30% to 4.14% of total geographical area, which is more than 12 times with respect to the baseline of 2002. Similarly, coal mine area has increased twice and industrial area has increased 10 times than the base year. It has been observed that dense forest cover has decreased and open forest has increased during this period. Seasonal effects were observed on water bodies and fallow land, while agriculture land shows an increase of 14%.

geographical area is under thermal sources, 13% area is under neutral category (neither a source nor a sink), and rest 47% are thermal sinks.

Key Findings

The key findings are summarized in the Table 1.

Table 1. Key findings in the study.

Model	Key Findings
Remote Sensing – Land Surface Temperature Model	There has been a steady build-up of heat in the region over the years resulting in higher night time temperatures. Coal mining, industries, urban settlements, and open non-vegetated surface have been identified as thermal hotspots
Ambient Air Temperature – Thermal Retentivity Model	'Bhushan Steel Area' and 'Market Road' are hotspot locations in summer; 'Market Road' is hotspot location in monsoon as well as combined period (summer and monsoon). This is likely because the high built-up are located on market road.
Ambient Air Temperature – Heat Index Model	'Bhushan Steel Area', 'Municipality', and 'Market Road' are hotspot locations in summer; 'OPGC', 'Market Road', 'Municipality' are hotspot locations in monsoon; 'Bhushan Steel Area', and 'Market Road', 'OPGC' are hotspot locations in the combined period. Higher heat sources, combined with higher built-up as well as more rotating population contributes to the higher heat index.
Remote Sensing – Biophysical Model	Coal mining, industries and urban settlements are high thermal sources; forests, vegetation and water bodies are high thermal sinks.
Heat Release Model	a) Coal Mining – Impact of bio-reclamation of de-coaled area (in terms of heat release per unit de-coaled area) highest for Lajkura and Lakhanpur and least for Lilari.

Mitigation Measures

The most suitable set of heat mitigation measures have been recommended based on modelling and prioritized based on analysis of information collected from stakeholders' consultation using Multi-Criteria Decision Analysis (MCDA) through Analytic Hierarchy Process (AHP) approach. The sectors covered include coal mining, industries, cropland, and urban planning. The recommended interventions along with their description, heat mitigation potential, priority ranking (based on impact to cost ratio), indicative costs, and the responsible implementing agencies are provided in the Table 2.

Table 2. Sectoral Intervention Options for Heat Mitigation

Sector	Description of Intervention	Impact of Intervention
Coal Mining	Improved management of de-coaled areas through increased bio-reclamation as well as creation of water bodies in mine void spaces.	Reduction in net heat release impact per unit de-coaled area highest in Lajkura, and Lakhanpur.
	Introduction of 4 new coal washeries.	Reducing self-oxidation by reducing ash content of coal.
	Complete penetration of surface miner technology.	Reduction in the amount of loose coal susceptible to self-oxidation.
	Speedy and transparent afforestation.	Increase in heat sink potential.
Industry	Management of coal stockpile (reduce inventory in summer months keeping production schedule constant).	Reduction in coal purchase cost as follows: Plant A: ₹60 to 190 lakh (136878 MTPY sponge iron), Plant B: ₹36.7 crore (0.8 million MTPY pig iron), Plant C: ₹152 crore (0.5 million MTPY aluminium), Plant D: ₹95.5 crore (960 MW), Plant E: ₹55 crore (360 MW)
	Change of coal stockpile design	Heat released can be lowered by 11%.

Sector	Description of Intervention	Impact of Intervention
Urban Planning	New flyover on the left flank of the existing flyover in the NH-49 after crossing the railway line.	Reduced traffic flow can ease congestion and avoid fugitive and idling vehicular emissions which increase the ambient temperature of the region.
	Shifting of the entire bus stand from the southern part of the railway line to the northern part.	
	Develop two approach roads – a) From NH-49 and b) SH-10 to the proposed bus stand.	
	Plantation of short height trees and trees with higher LAI bordering the pavements of NH, SH and newly proposed roads. **Highway & Road Dividers***: Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Bougainvillea, Cascabela thevetia* **Highway sides:** *Ficus religiosa, Ficus recemosa, Syzygium cumini, Ficus benghalensis, Alstonia scholaris, Azadirachta indica, Tamarindus indica* **Municipal Roads:** *Capparis grandis, Carissa congesta, carvia callosa, cassia auriculata, woodfordia fructicosa, Alstonia scholaris, bouganvillea, cascabela sp, oleander plants, etc.*	Reduction of influx of solar radiation and amount of heat absorbed by the asphalt material.
Agriculture	Increased adoption of conservation tillage in the agricultural areas.	Increase in surface albedo by 0.2 over that of the normal tilled crop land, decreasing temperature by 2^0C.

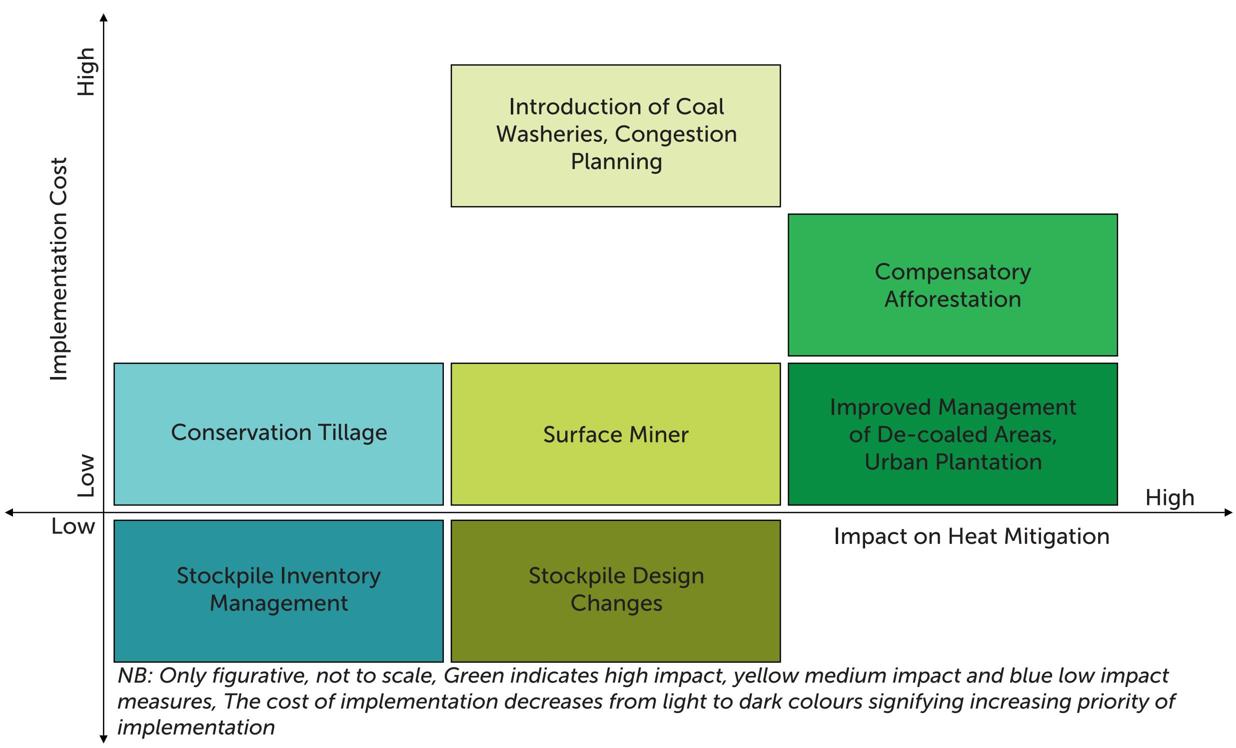


Figure 6: Cost vs. Impact plot of heat mitigation measures

Adaptation Measures

Odisha has been one of the leading states to address the problem of heat wave through a systematic heat wave action plan involving all stakeholders. The state's action plan outlines the responsibilities of the different wings of the state government. Additional roles have been proposed for these agencies over and above their current roles in the heat wave action plan as elaborated in Table 3.

An institutional framework has also been designed to coordinate the different adaptation response strategies as shown in Figure 3. An institutional framework along the lines of heat wave action plan for implementing and tracking the progress of measures for heat island adaptation will go a long way in adressing this challenge.

Table 3. Proposed roles for adaptation in heat island for different government agencies

Level	Name of Department Agency	Relevant Role
Central	Indian Meteorological Department	■ Installation of more automatic weather stations (AWS) in heat-wave prone districts ■ Analyse data from the different AWS to obtain real-time spatial distribution of temperature and heat index in each of the heat-wave prone districts ■ Provide zone-wise or block-wise early warning forecasts for each of the heat-wave prone districts.
State	Special Relief Commissioner (SRC)	■ In addition to disseminating warnings through AIR (All India Radio), Doordarshan and other private TV channels, SRC could help create local radio networks in Sambalpuri and organize discussions and other programmes for creating public awareness on specific regions in the district which are more vulnerable to heat stress. Information on 'do's and 'do not's, during heat stress should be highlighted in several strategic and heat stressed locations as posters, billboards, and hoardings in the local language ensuring information is widely accessible amongst different groups of people. ■ To deploy adequate number of water tankers in water-scarce areas based on a careful analysis of the heat-stress prone regions and the population density of these regions within the district. The Department of Water Resources to be mobilized for release of water in the canals.
	OSDMA	■ To arrange for drinking water supply arrangements and access to medical facilities that are equipped to cater to both genders. ■ To reschedule working hours in educational institutions, for those performing physical labour, veterinary measures, etc. ■ Distribute leaflets among school children to educate them on heat stress and its prevention. ■ To reschedule timings of public transport, etc. in accordance with early warning forecasts. This should be done only if timings for work, schools, and different government and non-government offices are also rescheduled simultaneously in the summer months.
	Dept. of Housing & Urban Development	■ Give directives to urban local bodies (ULBs)/development authorities to create more public parks and water bodies in hotspot areas for the general public. ■ Give directives to ULBs to identify temperature hotspots in the built-up areas and incentivize white painted roofs (albedo paint) in these regions. ■ Give directives to ULB/development authorities for the use of K-glass, doubly glazed glass in buildings and vehicles which prevent extra entry of heat inside, especially in the built-up areas which are located in hotspot regions.
	Department of Labour and Employee Welfare	■ Increase awareness among construction workers and factory labourers working in temperature hotspots through lunchtime meetings and labour union meetings.
	Department of Woman and Child Development	■ Sensitize female agriculture and brick labourers about the health effects of walking long distances to fetch water during the summer months. ■ Understand the concerns of the women labourers better with regard to working long periods in the heat and design guidelines to optimize such prolonged exposure. ■ Create awareness among female labourers on the locations of water kiosks in the district.

	Department of Health	■ Setting up of additional health dispensaries in heat stress zones in the district as well as equipping existing dispensaries with additional facilities, such as life saver ambulances, available mobile personnel, 24 hour back-up power supplies, air conditioned rooms, availability of cold drinking water, appropriate housing design, etc. ■ Ensure adequate training and supply of health professionals (doctors, nurses, etc.) to meet the demand of heat stress, induced morbidity cases, due to long hours of exposure in heat stress prone areas. ■ Capacity building of district medical officers (DMOs) on their roles and responsibilities towards heat stress and heat islands.
Local Govt.	Urban Local Bodies (Municipalities)	■ Conduct Focus Group Discussions (FGDs) at block - level to identify vulnerable regions in the municipality to implement immediate coping measures. The FGDs should represent people from all the strata of the society and specifically from women, women with children, aged and daily wage labourers. ■ Provide public shelter structures on highways and crowded areas, such as open markets. ■ Provide drinking water through *jal chhatras* (water kiosk) at strategic points. It is to be ensured that more number of kiosks is located at hotspot regions and their maintenance takes place at a healthy frequency. ■ Alert public transport systems on the heat stress - prone regions, especially in the summer months, to enable them plan alternate routes, if feasible. ■ Exploring light-coloured concrete roads as an option to replace asphalt roads near hotspot regions.
	Panchayats	■ Conduct FGDs at village level to identify the heat-stress vulnerable regions to implement immediate coping measures. Similar to the ULBs above, FGDs should strata of the society and specifically from women, women with children, aged, and daily wage labourers. ■ Based on the FGDs, the Provision of water kiosks at strategic as well as heat-stress vulnerable points.

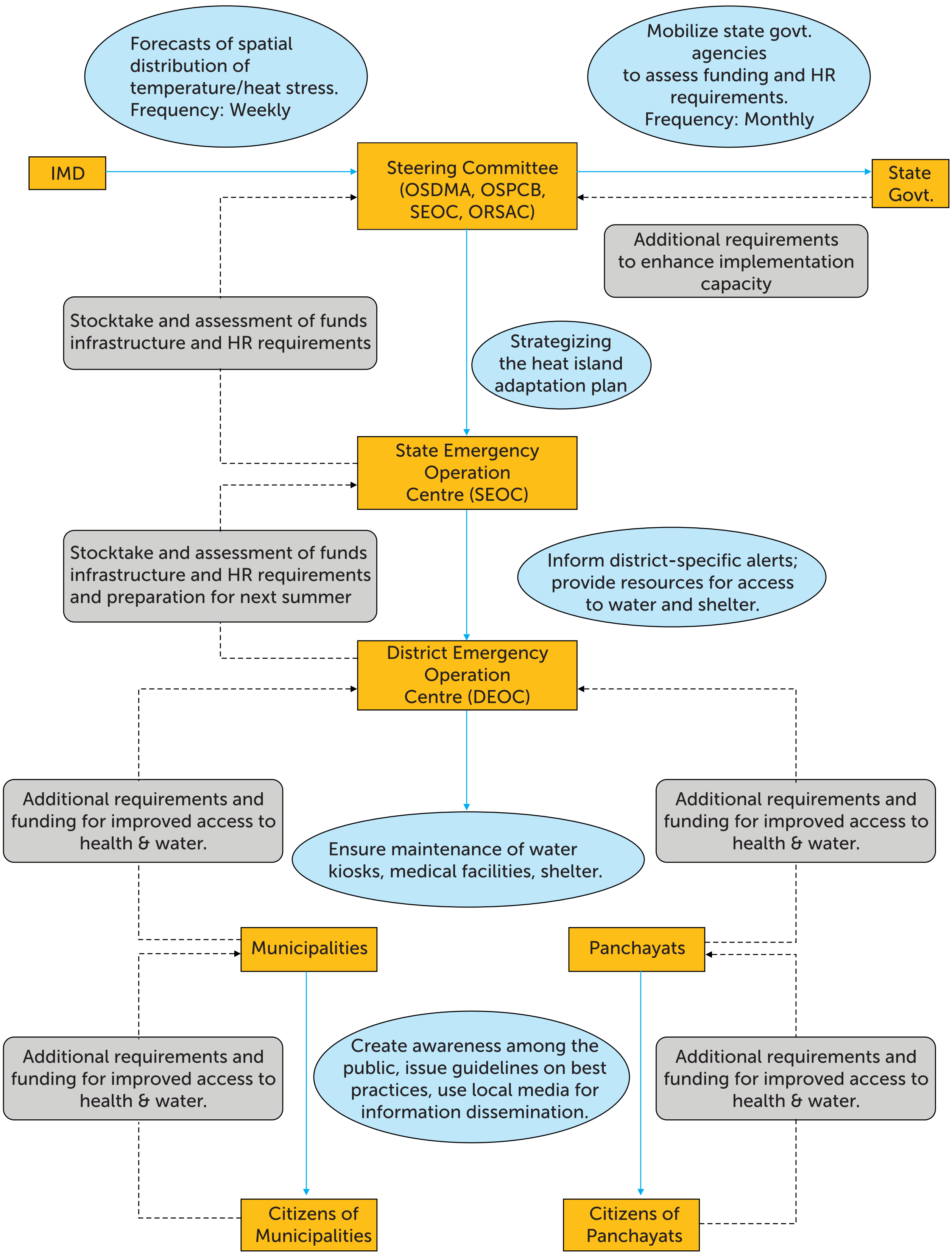


Figure 7: Institutional implementation framework for coordinated adaptation response

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