

CLIMATE CHANGE IMPACT ON THE URBAN LANDSCAPE: AN ENVIRONMENTAL ANALYSIS OF PATNA MARINE DRIVE

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ABSTRACT

This study focuses on the effect of Patna Marine Drive, a rapidly developing urban region, on the climate and urban landscapes which majorly threaten surrounding environment and ecosystem. The research focuses on the concerns pertinent to establish the relationship between Patna marine drive and its surrounding ecosystems. The study identifies the factors that establish the relationship and determine how these factors affect the relationship. This study also ascertains the reasons behind the factors that influence the establishment of the relationship. Using a combination of ground-based observations, , technology and applications of multidisciplinary research, to better understand the Patna marine drive effect on the surrounding ecosystems. The findings suggest an exacerbation of heat islands effect, increased flood risk, and stress upon water resources. Moreover, the lack of efficient adaptation strategies is negatively impacting the city's socio-economic growth. Recommendations based on the results call for an integrative urban planning approach considering climate change impacts, to ensure the sustainability of Patna Marine Drive's urbanization process. The study underscores the urgency of climate change adaptation policies at city scales, highlighting the implications for other similar urban landscapes.

Keywords: Climate change, Urban planning & Patna Marine Drive.

INTRODUCTION

Patna, the ancestral city lying beside the Ganges, is on a rapid growth trajectory. This development, however, has intrinsically intertwined itself with the contemporary issue of climate change. Annually, the city is inundated with floods that ripple from melting Himalayan glaciers and an increase in torrential rain, both climate change side-effects. Despite this recurrent crisis, development, including the emblematic Marine Drive, remains a priority. The Marine Drive project in Patna is a symbol of urban progression, yet its conception raises multiple environmental questions - How is climate change influencing the urban landscape of Patna, especially the Marine Drive area? What are potential climate change mitigations with respect to urban planning in this context?

In the case of Patna's Marine Drive, Built along the southern bank of the River Ganges which has significantly effect on urban landscapes which majorly threaten surrounding environment and ecosystem. Unplanned urbanization and lack of proper drainage systems have made Patna's Marine Drive even more susceptible to these changes. The frequent floods in recent years have led to severe property damage and loss of lives. Climate change also impacts the urban temperature, with heat island effects becoming more pronounced. Urban areas like Patna's Marine Drive tend to be hotter than rural regions owing to the concrete structures and lack of greenery, leading to heatwaves that put at risk the health of the local population.

This study entails a detailed exploration of the Marine Drive's environmental implications under the trajectory of climate change. We'll scrutinize the existing infrastructure plans in light of diverse environmental risk factors such as adversities of local river ecosystem, Urban heat Island (UHI) formation, Impact on climate, flora and fauna. Furthermore, this research aims to bridge the gap by proposing adaptable strategies for climate-smart urban planning in Patna's burgeoning urban scape.

In conclusion, the impact of climate change on Patna's Marine Drive presents a case study of the environmental challenges faced by urban landscapes globally. As urban planning and development continue, it is crucial that climate resilience is incorporated into city landscapes, considering the potential for more extreme climate events in the future.

BACKGROUND OF THIS REGION AND IT'S SIGNIFICANCE

Patna Marine Drive, officially known as Loknayak Ganga Path, is a 23.5 kilometers long roadway constructed along the banks of River Ganga in Patna, the capital city of Bihar state in India. Inaugurated in 2013, the development project was taken up with the dual objective of

easing traffic congestion in the city while simultaneously providing a scenic route for locals and tourists. The road not only connects the city from one end to the other but also provides a beautiful view of the River Ganga.

Significantly, it has not just been acclaimed as a civil engineering marvel, but it also plays a critical role in socio-economic activities. It has enhanced connectivity within the city, boosting trade and commerce, and has become a popular recreational area where locals can enjoy the scenery or partake in various activities.

The Marine Drive's development has simultaneously led to a rise in real estate value in the surrounding areas and promoted environmental conservation efforts along the river banks. It continues to serve as a symbol of Patna's modernization.

REVIEW OF LITERATURE

The literature on the topic "Climate Change Impact on the Urban Landscape: An Environmental Analysis of Patna Marine Drive" can be categorized into three themes:

Climate Change and Its Impact

Several studies have revealed that urban landscapes are increasingly being affected by climate change. Rising temperatures, changing rainfall patterns, and increased frequency of extreme weather events are having profound effects on urban ecosystems.

Urban Landscapes and Impact

Research shows that urban landscapes, with vast concrete structures and minimal green covers, tend to exacerbate the impacts of climate change. Patna, like many other urban areas, is experiencing increased heat islands, heightened pollution levels, and other climate-related woes due to the lack of sufficient green spaces.

Patna Marine Drive as a Case Study

Studies that have examined the impact of climate change on the urban landscape have often taken individual cities or specific regions as case studies. In the case of Patna Marine Drive, however, focused literature appears to be scarce. Yet, one can infer from general literature on climate change and urban landscapes that it would be significantly impacted. Patna experiences severe heat waves driven by climate change. The extensive concrete structures along Marine Drive could worsen the situation by contributing to the heat island effect.

Therefore, there remain large gaps in the literature, especially regarding specific areas such as Patna Marine Drive. Given its representation of many increasingly urbanized areas in India and other developing countries, more insightful, site-specific research seems crucial.

Studies on urban landscapes and Impact on Environment

There has been a substantial amount of research on the relationship between urban landscapes and climate change. Numerous studies have shown that rapid urbanization directly drives the loss of wildland habitat and increases habitat fragmentation, and thereby threatens biodiversity (Seto et al. 2012). Urbanization also directly or indirectly changes the ecological processes of urban ecosystems, degrading urban ecosystems and resulting in adverse ecological and environmental impacts (Zhou et al. 2022). The impact of the changes in landscape structure (e.g., LCLU) on ecological processes and biodiversity have long been a research frontier in urban ecology, which will continue to be a research frontier in the context of rapid urbanization and changing climate.

CRITICAL ANALYSIS ON THE URBAN CLIMATE OF PATNA

The urban climate of Patna, the capital city of Bihar, India, is significantly influenced by its geography and land use patterns. Patna experiences a subtropical climate, with hot summers, cool winters, and moderate to heavy monsoon rains. Several critical studies focusing on Patna's urban climate have looked into various factors:

Urban Heat Islands (UHI) and it's effect

Research has shown that urban areas, due to their concrete structures and lack of vegetation, often have higher temperatures than surrounding rural areas, a phenomenon known as the urban heat island effect. This effect can exacerbate local effects of global warming and contribute to heat-related health problems.

Like most rapidly urbanizing cities, Patna suffers from Urban Heat Island (UHI) effect. This is due to concrete structures replacing green cover and the release of waste heat from vehicles and air conditioners. This leads to a higher temperature in the city compared to its surrounding rural areas. The rapid urbanisation impacts on environment, climate, agriculture, water resources trigger several problems to human beings. The present study was carried by (Barat et al., 2018) out to estimate intensity and trend of Urban Heat Island (UHI) as Surface UHI (SUHI) over towns/cities of the Gangetic plain of the state of Bihar, India, in which urban

areas show relatively greater Land Surface Temperature (LST) than its rural surroundings especially during night times. During winter months (January, February, November and December), UHI is more intense over all towns/cities. Mann-Kendall Test is applied on Surface Urban Heat Island Intensity (SUHII) in which MK-Test Statistic (S) shows a significant increasing trend. This trend would alarm a risk to increase in air pollution, heat related biohazards, energy demand in the region. This study shows the need of urban greening and proper town planning over the considered areas to mitigate the changes.

In another study (Rakesh et al., 2023) The pattern of urbanisation rate across all districts of Bihar Bihar has been done through Land use and land Cover (LULC) maps display the features and activities over a Geographical area, usually as seen from satellite and other Remote Sensing (RS) systems in terms of per capita Urban built-up area. Patna which is the capital of Bihar state and shows highest per capita of 27.19 (Sq.M. per person) Urban Built-up among all districts.

Green Infrastructure

Studies suggest that 'green infrastructure' like parks, green roofs, and street trees can help mitigate UHI effects, reduce energy consumption, and contribute to urban sustainability.

Impervious Surfaces

Urban landscapes typically have a high percentage of impervious surfaces (like roads and buildings), which can alter local climates by reducing soil moisture, increasing run-off, and changing local heat balances.

Urban Planning & Design

Research has highlighted how urban planning and architectural design can play a pivotal role in mitigating climate change effects. For instance, solar-oriented and compact urban designs can minimize energy use.

Impact on Precipitation

Urban landscapes can impact local weather patterns, including precipitation. Some studies show that urban areas can alter atmospheric convection, sometimes leading to more significant rainfall in or around cities.

Air Quality

Air pollution is another key issue impacting Patna's urban climate, with vehicle exhaust, construction activities, and waste burning contributing to low air quality. Seasonally, during winter, factors such as crop residue burning and cooler temperatures contribute to worsening air quality through trapping of pollutants. In the recent study of Patna region the atmosphere's heightened aerosol concentration was one of the key findings which can be due to factors like urbanization's quick speed, population growth, economic growth, and industrialization. These findings (Singhvi et al., 2023) were based on analysis of aerosol optical parameters such as Aerosol Optical Depth (AOD), Angstrom Exponent (AE), etc., of northern Indian cities which included Patna during the last decade 2011–2020. The higher Angstrom Exponent (AE) value (2 or More than 2) indicates the dominance of fine particles and the lower AE value (close to 1 or less than 1) indicates the dominance of larger particles from the combustion sources (Ångström et al., 1964). The AE was minimum among all the selected for Patna 0.85 ± 0.78 . These reduced data may be due to locally elevated dust which is compatible with a rise in dust loading under dry conditions and from numerous activities and Little natural cover (Lodhi et al., 2013). AODs were discovered to be considerably greater in Patna during all the seasons as compared to others, this finding indicated the particles major dominance of burning aerosol from biomass during the Post-Monsoon period. Irrespective of that during Pre-Monsoon and Monsoon seasons in Patna, it is due to coarse-mode Particle accumulation or cloud contamination (Sharma et al., 2014).

Cities' Carbon Footprint

Cities are often hotspots for CO₂ emissions due to high-density living, transportation demands, and consumption patterns. Consequently, they play a significant role in addressing climate change through mitigation strategies. This is a complex field, with many interrelated elements. Researchers are continuously studying to develop new strategies for making our cities more resilient to climate change.

Monsoon Rains and Flooding

Patna's geographic location makes it prone to annual monsoon flooding. Rapid urbanization without adequate attention to natural drainage patterns has exacerbated flooding problems. To address these issues, researchers often suggest increased green cover, better waste management, improved public transportation to reduce vehicular pollution, and creation of flood mitigation strategies.

GLOBAL IMPACT AND ROLE OF URBAN SPACES

Urban spaces play a crucial role in shaping society and have a global impact on various aspects of our lives. Here are the key points to consider:

Economic Impact

Urban spaces are often hubs of economic activity, attracting businesses and creating employment opportunities. They facilitate trade, innovation, and entrepreneurship, contributing significantly to regional and global economies.

Social and Cultural Exchange

Cities bring together diverse populations with different backgrounds, fostering social and cultural interactions. Urban spaces provide platforms for people to engage in art, music, sports, and other cultural activities, enhancing societal cohesion and cross-cultural understanding.

Environmental Challenges

Cities consume substantial resources, contribute to pollution, and face environmental challenges. However, well-planned urban spaces can also drive sustainability initiatives, such as efficient public transportation systems, green infrastructure, and sustainable building designs.

Health and Well-being

Access to quality healthcare, recreational areas, and community services in urban spaces can significantly impact public health and well-being. Prioritizing parks, green spaces, and promoting pedestrian-friendly neighborhoods enhances physical and mental health outcomes.

Technological Innovation

Urban spaces become hotspots for technological innovation and digital connectivity. Smart city initiatives utilize technology to enhance efficiency, improve infrastructure, manage resources, and create more accessible and inclusive urban environments.

Political and Governance Centers

Many urban spaces serve as centers of political power and governance. National and international decision-making bodies often have headquarters in cities, enabling efficient administration and political engagement.

Understanding the global impact and role of urban spaces allows policymakers and urban planners to create inclusive, sustainable, and resilient cities that positively impact the lives of individuals, communities, and the planet as a whole.

Climate Change: A Global Concern

Climate change refers to significant changes in global temperatures and weather patterns over time. While climate change is a natural occurrence, scientific evidence strongly suggests that human activities, particularly the burning of fossil fuels like coal, oil, and gas, have accelerated the pace dramatically. The burning of these fuels releases greenhouse gases like carbon dioxide into the atmosphere. These gases trap heat from the sun's rays within the atmosphere, a phenomenon known as the greenhouse effect. This leads to a rise in global temperatures, or global warming. Effects of climate change are not limited to just warmer temperatures. They also include more frequent and severe weather events like hurricanes, droughts, and floods, melting of polar ice which leads to rising sea levels, and shifts in wildlife populations and habitats.

The scientific consensus is that immediate steps are needed to drastically reduce greenhouse gas emissions in order to limit the severity of climate change's impacts in the future. These steps include shifting to renewable energy sources, improving energy efficiency, and implementing sustainable agricultural practices.

Indeed, climate change is a global concern with profound consequences. It's characterized by global warming due to increased greenhouse gas emissions, causing erratic weather patterns, rising sea levels, and loss of biodiversity. Global warming is primarily driven by the increased concentration of carbon dioxide in the Earth's atmosphere. The main source of this is the burning of fossil fuels such as coal, oil, and gas, as well as deforestation. Loss of biodiversity affects ecosystem stability. Many species are at risk due to changing climates and habitats, which could in turn impact our food chain and resources.

Erratic weather patterns can lead to increased frequency and severity of natural disasters like hurricanes, droughts, and floods, threatening people's homes and livelihoods. Rising sea levels, due to the melting of polar ice caps, endanger low-lying countries, leading to displacement of people.

Addressing climate change requires international cooperation - from adopting green technologies and renewable energies, to responsible consumption and conservation efforts. Each of us has a role in combating this global concern. Public education and active involvement are crucial elements in this endeavor.

Patna Marine Drive: An Urban Landscape

The concept of a marine drive typically refers to a coastal roadway or boulevard, often accompanied by scenic views of the sea or other bodies of water. However, Patna is a landlocked city situated on the banks of the Ganges River in the Indian state of Bihar. Therefore, Patna does not have a marine drive in the traditional sense.

However, Patna does boast an urban landscape characterized by its rich historical heritage and cultural vibrancy. The city is home to a number of iconic landmarks, such as the Golghar, a massive granary built during the British Raj, and the ancient Mahavir Mandir, dedicated to Lord Hanuman.

In recent years, efforts have been made to enhance the city's livability and promote recreational spaces. One such initiative is the development of the Ganga Path, a riverfront promenade along the banks of the Ganges. The Ganga Path offers a pleasant walking and cycling route, allowing visitors to enjoy the scenic beauty of the river while also providing them with a space for leisure and relaxation.

So, while Patna may not have a marine drive as found in coastal cities, it does have its own unique urban landscape that offers a glimpse into its architectural marvels, cultural heritage, and the serene beauty of the Ganges River.

DETAILED DESCRIPTION OF PATNA MARINE DRIVE

Patna Marine Drive is a popular destination located along the bank of the Ganges River in Patna, Bihar, India. It is a picturesque stretch which offers a beautiful view of the river and its surroundings.

Stretching over approximately 6 kilometers, Patna Marine Drive is a well-maintained road with a wide walking path and greenery on both sides. The road is lined with trees, benches, and street lights, making it an ideal place for a leisurely stroll or jogging.

The drive is especially enchanting during sunrise and sunset when the colors of the sky reflect on the river, creating a mesmerizing view. Visitors can also find several food stalls and tea shops along the way, where they can enjoy local delicacies and refreshments while enjoying the scenic beauty.

The stretch also houses a vibrant park called Gandhi Sangrahalaya, which is dedicated to Mahatma Gandhi. It has a statue of Mahatma Gandhi and various displays depicting his life and philosophy.

Apart from its natural beauty, Patna Marine Drive is often used for public events and

celebrations. It has become a popular spot for locals and tourists alike, who visit to relax, exercise, or simply soak in the serene ambiance of the river.

Overall, Patna Marine Drive offers a tranquil escape from the bustling city life, providing a serene and refreshing experience for those who visit.

RAPID URBANIZATION IN PATNA MARINE DRIVE REGION

Patna, the capital city of Bihar, has been experiencing rapid urbanization in recent years, particularly in the Marine Drive region. This phenomenon can have both positive and negative impacts on the city and its residents. On the positive side, rapid urbanization can lead to economic growth, job opportunities, improved infrastructure, and better access to services such as healthcare, education, and transportation. It can also attract investments and promote tourism, boosting the city's overall development.

However, rapid urbanization also brings some challenges. It can strain existing resources and infrastructure, leading to overcrowding, traffic congestion, and increased demand for housing, water, and electricity. Environmental concerns, such as pollution and strain on natural resources, also become more prevalent. To manage the effects of rapid urbanization in the Marine Drive region of Patna, it is crucial to focus on urban planning and sustainable development. This involves careful consideration of factors like land use, transportation, green spaces, waste management, and the preservation of cultural heritage.

By adopting a holistic and inclusive approach, the city can ensure that the benefits of urbanization are equitably distributed among its residents while mitigating potential issues. It is important for policymakers, urban planners, and citizens to work together to create a vibrant and sustainable urban environment in Patna.

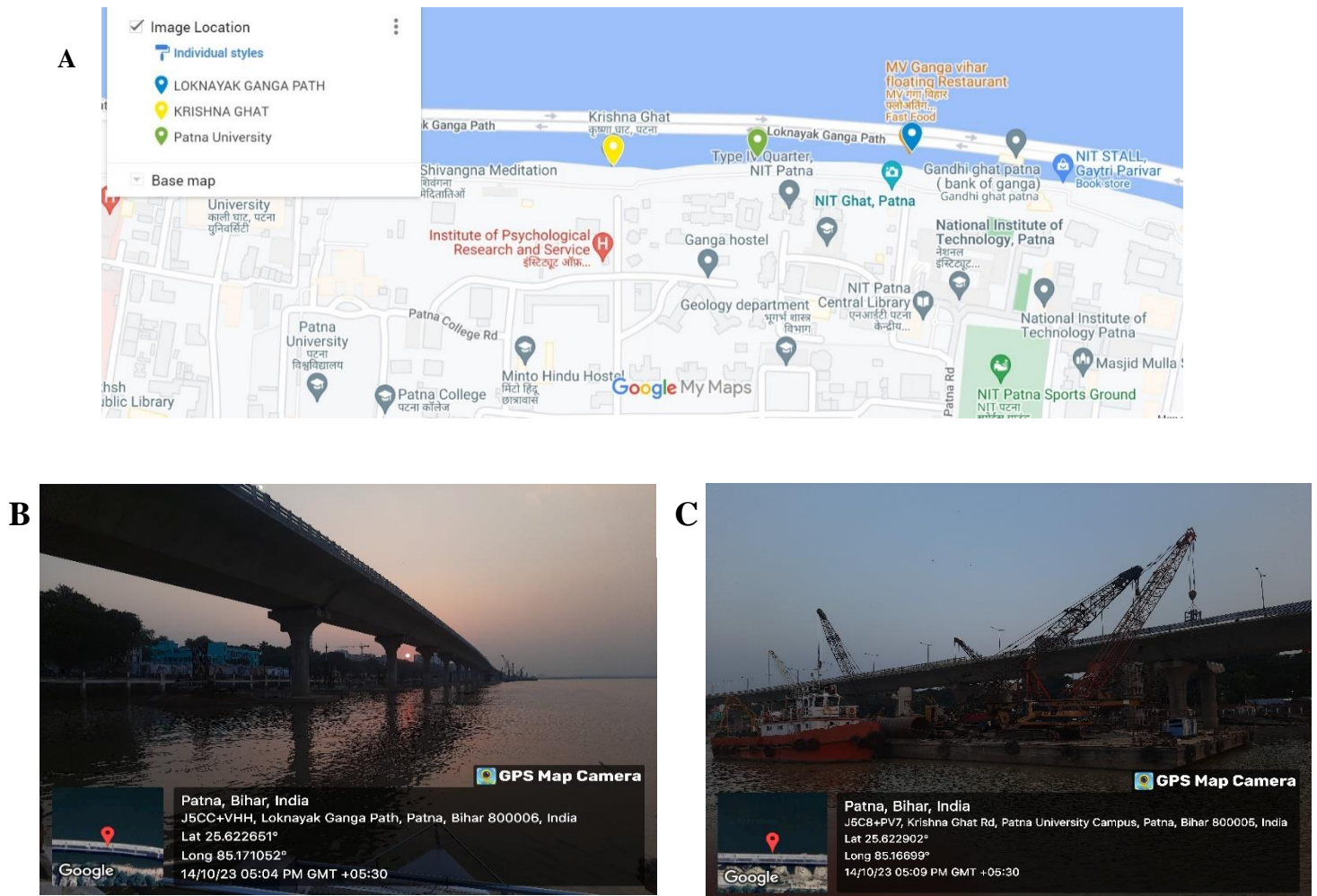


Fig : (A) Google map showing different location around loknaya gangapath for studying the impact of rapid urbanisation. (B) Loknaya gangapath. (C) Krishna Ghat, Patna University Campus.

CURRENT CLIMATE PATTERNS OF THE REGION

The climate of the region in Patna, including the area surrounding Patna Marine Drive, is classified as a humid subtropical climate. Summers (March to June) are hot and often accompanied by high humidity, with temperatures ranging from 30 to 40 degrees Celsius (86 to 104 degrees Fahrenheit). Monsoons (July to September) bring heavy rainfall, rejuvenating the landscape and providing relief from the scorching summer heat.

Winters (November to February) are mild and pleasant, with temperatures ranging from 12 to 20 degrees Celsius (54 to 68 degrees Fahrenheit). However, occasional cold spells can bring temperatures down to around 5 degrees Celsius (41 degrees Fahrenheit). It is advisable to check the local weather forecast before planning a visit to Patna Marine Drive, as weather conditions

can vary.

Impact of climate change on marine drive

Climate change has had significant impacts on Patna, the capital city of Bihar, India. Here are some of the key effects:

Heatwaves

Patna has experienced an increase in the frequency and severity of heatwaves. Rising temperatures can have detrimental effects on public health, leading to heat exhaustion, dehydration, and even heatstroke.

Erratic rainfall

Climate change has caused changes in the monsoon patterns, resulting in irregular and intense rainfall. This leads to both flooding and dry spells. Flooding disrupts infrastructure, damages crops, and poses threats to human lives, while prolonged dry spells affect agriculture and water availability.

Water scarcity

Changing rainfall patterns and rising temperatures have impacted water resources in Patna. Decreased water availability affects agriculture and poses challenges for the city's growing population's water needs.

Increased vulnerability to extreme events

Climate change heightens the vulnerability of Patna to extreme weather events such as cyclones and storms. These events can cause widespread destruction, including damage to infrastructure, displacement of people, and loss of lives.

Health risks

Climate change also poses health risks in Patna. It can contribute to the spread of vector-borne diseases like dengue and malaria, as warming temperatures create favorable conditions for disease-carrying mosquitoes.

Addressing these impacts requires a multi-pronged approach, including adaptation measures like improved infrastructure and urban planning, efficient water management, and steps to reduce greenhouse gas emissions at both local and global levels.

Increased flooding risk

Patna, the capital city of Bihar in India, does face increased flooding risks due to various factors. Patna is situated on the southern bank of the Ganges River, making it vulnerable to flood events during monsoon season or heavy rainfall. Additionally, urbanization, encroachment of riverbeds, inadequate drainage systems, and siltation of water bodies

contribute to the increased flood risk in the city (Chen et al., 2022). Climate change and deforestation further exacerbate the situation.

Historically, Patna has witnessed devastating floods, most notably in 1975, 1987, and 2019. These flood events cause damage to infrastructure, displacement of residents, loss of lives, and disruption of essential services. The government, along with local authorities, has taken measures to mitigate flooding risks, such as constructing embankments, improving drainage systems, and relocating vulnerable populations.

It is important for the city to continue implementing sustainable flood management strategies, such as proper urban planning, adopting innovative technologies, and raising public awareness about flood preparedness and safety measures. These combined efforts can help minimize the impact of flooding in the region and enhance the resilience of Patna against future flood events.

Impact on flora and fauna

Human activities have undoubtedly had a significant impact on the flora and fauna in the Marine Drive area of Patna. Here are a few ways these activities have affected the local ecosystem:

Habitat destruction: Rapid urbanization and infrastructure development have led to the destruction of natural habitats like wetlands, mangroves, and grasslands. This loss of habitat directly affects the flora and fauna that rely on these ecosystems.

Pollution: Urban areas often produce pollution from various sources such as industrial waste, sewage, and runoff from agricultural practices. This pollution can contaminate the water and soil, affecting both the aquatic and terrestrial species in the area.

Invasive species: Human activities, such as the introduction of non-native species, can disrupt the balance of the ecosystem. Invasive species can outcompete or prey upon native species, leading to a decline in the local flora and fauna.

Overfishing and destructive fishing practices: Overfishing and destructive fishing techniques like blast fishing or bottom trawling can deplete fish populations and damage marine habitats. This can directly impact the marine biodiversity in the Marine Drive area.

It is important to note that while human activities have had negative impacts, there are also conservation efforts and initiatives aimed at protecting and restoring the local flora and fauna. By raising awareness, adopting sustainable practices, and supporting conservation projects, we can mitigate some of the damage and contribute to the recovery of the ecosystem.

CAUSES AND IMPACT ON ENVIRONMENTAL DEGRADATION:-

Habitat loss is the greatest threat to biodiversity. Urbanization not only destroys and fragments habitats but also alters the environment itself. For example, deforestation and fragmentation of forest lands lead to the degradation and loss of forest interior habitat as well as creating forest edge habitat (Srinivas et al., 2020).

Stone and Mining materials

10,000–15,000 m³ of gravel and stone were needed during construction, according to the EIA. As a result, to address this, the mining materials were obtained from nearby quarries in order to support the area's economy and avoid overusing resources (Vandana et al., 2022). Utilizing the nearby quarries and stones helped some slum people find employment, boosting the local economy and employment rates.

Rise in dust production

Despite the fact that the project did not entail any significant construction work, breaking existing ghats caused a lot of dust to be produced. The building crew made plans to appropriately discard of the construction waste in order to minimize this problem. In order to ensure the amount of dust settled, the demolition was done in stages and enough water was sprayed.

Sanitation and waste generation

Worker camps were built with amenities including drinking water, solid waste disposal, and sanitary conditions; if due care is not maintained, these will find their way to the river. A proper septic tank, leech pit, and systems for disposing of biodegradable and non biodegradable waste were also installed in the camps. At least 200 meters separated each camp from the riverbank.

Impact on Utilities

According to the pollution control board, two sewers with a combined capacity of 6.64 MLD dumped untreated effluent into the Ganga River. The untreated waste was resolved as well because the two sewers were switched to the trunk sewer, which was linked to the Saidpur STP (capacity of 45 MLD).

Noise and vibration

Due to the requirement for excavations for ghats and promenades, tools like jackhammers were required. However, noise significantly hampered the Gangetic dolphins' use of echolocation, their main method of navigation. Hydraulic and Vibrio piling were only used between 7 p.m. to 6 a.m. to prevent this.

Impact on Dolphins

These seas are home to gangetic dolphins, which rely on echolocation for navigation. Near riverbeds, these mammals eat small fishes like gulleets, mudfish, larvae, and snails. As a result, dolphins misinterpret an upsurge sewage and trash disposal for food and eat it. Furthermore, these fish have been killed by numerous motorized vehicle collisions. Dolphins have been redirected using iron meshes. The majority of covered propellers have been used to safeguard dolphins, which has reduced the harm to them to an absolute minimum.

ENVIRONMENTAL EFFECTS AND PROTECTION STRATEGIES EMPLOYED DURING DEVELOPMENT STAGES

Several studies have demonstrated that the reduction of wildland habitat and the fragmentation of existing habitat are directly caused by rapid urbanization, which also led to endangering biodiversity (Seto et al. 2012). Additionally, urbanization modifies urban ecosystems' ecological processes directly or indirectly, which degrades urban ecosystems and has a negative impact on the environment and ecology (Zhou et al. 2022). The study on the effects of changes in landscape structure (such as LCLU) on ecosystem functions and biodiversity will remain to be leading research topic in urban ecology and so in the context of rapidly urbanizing cities and changing climate conditions.

Drainage Impact

Even though there isn't a noticeable change in the drainage pattern, the river's tempo increases as it approaches the Ghat, creating a drag that causes significant soil erosion. Therefore, to lessen in situ erosion, gabion structures and riparian plants are present.

Impact on water quality

The population has grown as a result of Ghat's overall development. Data from the pollution control board predicts 400–500 users per day at each ghat, for a total of 8000–10,000 users per day throughout 20 ghats. The anticipated total waste would be $0.6 \times 10,000 \times 5 \times 60\%$ of users, or 30,000 KLD. Consequently, toilets with a septic tank and soak pits are suggested in order to stop the pollution of water caused by open defecation. Additionally, portable restrooms are set up during events connected to the trunk sewer to avoid contaminating the water supply. Along the banks, meshes have been put in place to stop religious waste.

IMPACT OF URBAN HEAT ISLAND FORMATION

The Patna Marine Drive region is an urban area, and the formation of an urban heat island (UHI) is influenced by various factors. UHI refers to the phenomenon where cities or urban areas experience higher temperatures compared to their surrounding rural areas. Here are some key factors that can contribute to UHI formation in the Patna Marine Drive region:

Urbanization

The extent of urban development, infrastructure density, and land use patterns in the region can contribute to UHI formation. More buildings, concrete surfaces, and reduced vegetation can result in higher temperatures due to increased heat absorption and reduced cooling effects.

Lack of green spaces

The presence of green spaces, trees, and vegetation helps to mitigate UHI effects by providing shade and evaporative cooling. In the absence of ample green spaces, the Patna Marine Drive region may be more susceptible to UHI formation.

Heat-retaining materials

The use of heat-absorbing materials, such as asphalt and concrete, can contribute to UHI formation. These materials retain heat during the day and release it at night, leading to higher nighttime temperatures in urban areas.

Waste heat from human activities

The generation of heat from various human activities, including industrial processes, transportation, and energy consumption, can contribute to UHI formation. If the Patna Marine Drive region has significant sources of waste heat, it may amplify the UHI effect. To better understand the specific impact on UHI formation in the Patna Marine Drive region, it would be helpful to consider local climate data, land cover information, and any ongoing urban planning initiatives aimed at mitigating UHI effects in the area.

PATNA MARINE DRIVE - ENVIRONMENTAL CONSEQUENCES

In context of Patna Marine Drive region Assess the Environmental Consequences regarding; To assess the environmental consequences of the Patna Marine Drive region, we'll discuss public health, infrastructure vulnerabilities, and economic implications.

Public health

In this context, we need more specific information about the environmental factors affecting public health in Patna's Marine Drive region. For example, are we considering air quality,

water pollution, or other factors? Please provide additional details so I can provide a more accurate response.

Infrastructure vulnerabilities

Considering the Marine Drive region's proximity to rivers, it may be susceptible to flooding and erosion. Such vulnerabilities can impact infrastructure like roads, buildings, and utilities. Could you clarify if there are any specific concerns or existing issues related to infrastructure in this area?

Economic implications

Patna's Marine Drive region can have both positive and negative economic implications. Positive aspects may include tourism, recreational activities, and potential employment opportunities. However, it's vital to consider potential negative effects, such as the impact on local businesses, if there are inadequate infrastructure systems or environmental hazards. Is there a specific aspect or concern related to the economic implications you would like further information on?

PATNA MARINE DRIVE - MITIGATION AND ADAPTATION STRATEGIES

In the context of Patna Marine Drive region, Mitigation and Adaptation Strategies. In the context of the Patna Marine Drive region, mitigation and adaptation strategies can play a crucial role in addressing the challenges posed by climate change. Here are three strategies that can be employed:

Sustainable urban planning

This approach focuses on creating cities and urban areas that are environmentally friendly, socially inclusive, and economically viable. By incorporating principles such as compact development, green spaces, efficient transportation systems, and renewable energy, sustainable urban planning can help reduce greenhouse gas emissions and promote resilience in the face of climate change.

Climate-resilient infrastructures

Building climate-resilient infrastructures involves designing and constructing infrastructure systems that can withstand the impacts of climate change. This can include measures such as flood defenses, stormwater management systems, and infrastructure protection against extreme weather events. By enhancing the resilience of critical infrastructure, the region can better adapt to changing environmental conditions.

Community-based strategies

Engaging the local community is crucial for effective climate change response. Community-based strategies involve empowering local residents to actively participate in decision-making processes, promoting awareness about climate change risks, and implementing grassroots initiatives. By involving community members in the planning and implementation of adaptation and mitigation measures, it is possible to ensure that strategies are tailored to the specific needs and challenges of the Patna Marine Drive region.

These three strategies can work in tandem to contribute to a more sustainable and resilient future for the Patna Marine Drive region in the face of climate change.

CONCLUSION

In the environmental analysis of Patna Marine Drive's impact on climate change, several key findings have emerged. Firstly, it has been observed that the urban landscape of Patna is experiencing significant changes due to climate change, such as rising temperatures, increased frequency and intensity of heatwaves, and fluctuating precipitation patterns. These changes have led to various environmental challenges, including urban heat island effect, reduced air and water quality, and increased susceptibility to flooding.

Additionally, the study revealed that the development and expansion of Patna Marine Drive have further exacerbated these challenges. The construction of new infrastructure has led to the destruction of natural habitats, contributing to the loss of biodiversity. Furthermore, the increased use of vehicles and emissions from the drive have augmented air pollution levels in the surrounding areas.

FUTURE RESEARCH DIRECTIONS

To further deepen our understanding of the climate change impact on the urban landscape of Patna Marine Drive, future research should focus on several areas. Firstly, studying the effectiveness of mitigation and adaptation strategies can help identify the most suitable approaches for managing the environmental challenges posed by climate change. This could involve exploring green infrastructure development, sustainable transportation systems, and innovative waste management practices.

Furthermore, it would be valuable to investigate the social and economic consequences of climate change on the local community. Understanding how vulnerable populations are affected and identifying potential strategies to enhance resilience would be crucial in devising comprehensive climate adaptation plans.

Finally, assessing the long-term effects of climate change on the coastal ecosystems and biodiversity surrounding Patna Marine Drive is imperative. Studying the ecological dynamics and exploring restoration strategies can help mitigate the negative impacts and promote sustainable coexistence between urban development and the natural environment.

Overall, by continuing research in these areas, we can take proactive measures to safeguard the urban landscape of Patna and effectively address the challenges posed by climate change.

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