Potential of a Large Development Scheme of Independent Bungalows in Improving the Microclimate of The Neighbourhood

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Approval

The following study is hereby approved as a creditable work on the subject carried out and presented in a manner, sufficiently satisfactory to warrant its acceptance as a pre-requisite towards the degree of Bachelor of Architecture for which it has been submitted.

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Thesis Title: Potential of A Large Development Scheme of Independent Bungalows in Improving the Microclimate of The Neighbourhood

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Declaration

I, **Gresha Shah – 17BAR028**, give an undertaking that this research thesis entitled "**Potential Of A Large Development Scheme Of Independent Bungalows In Improving The Microclimate Of The Neighbourhood**" submitted by me, towards partial fulfilment for the Degree of Bachelor of Architecture at Institute of Architecture and Planning, Nirma University, Ahmedabad, contains no material that has been submitted or awarded for any degree or diploma in any university/school/institution to the best of my knowledge.

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This research thesis includes findings based on literature review, study of existing scientific papers, other research works, expert interviews, documentation, surveys, discussions and my own interpretations.

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Contents

Potential Of a Large Development Scheme of Independent Bungalows in Improving the Microclimate of The Neighborhood

Abstract

This research paper aims to study the opportunities for improving the microclimate around a development scheme of independent bungalows through the use of previous open spaces and green cover. It is widely accepted that urban areas have a distinct microclimate that is warmer than their peripheral regions. This is because urban environments include a lot of heat-absorbing surfaces, which are more common now that building density has increased. Extreme thermal discomfort is the result, especially in the summer, which causes problems including heat waves, heat-related ailments, a spike in energy consumption for cooling, and a decrease in outdoor pursuits. It is also generally recognized that vegetation can significantly contribute to the improvement of these circumstances. In addition to being economical and environmentally friendly, vegetation is also appealing to people in general. For this research, the method used is a combination of literature review, site analysis, case studies, and on-site temperature and humidity recording. Street canyons that trap heat and impede ventilation can be produced by the geometry of the built form, such as the height and distance between buildings. On the other hand, open areas can promote improved airflow and ventilation, which can enhance thermal comfort. This leads us to the outcome that these open areas operate more effectively if they involve the use of pervious surfaces with vegetation as opposed to artificial heat-absorbing surfaces. A bungalow development has the lowest density when compared to other dwelling typologies, increasing the amount of open space between them. In the modern era, when land is mostly exploited for construction, there is a lack of open spaces. A development scheme of bungalows has the potential of having that kind of open space and impacting the microclimate. The results of this study will help produce guidelines and suggestions for

architects, builders, urban planners, and policymakers so they may recognize this typology's potential and its effects on the neighborhood microclimate.

Keywords: Microclimate, residential environment, green cover, permeable open spaces

1. Introduction

Urbanization is an ongoing process in recent times, where a growing percentage of the population is concentrated in urban areas, resulting in the expansion of cities. This, in turn, leads to an increase in the proportion of urban areas, and the dominance of urban areas over rural areas. 55% of the world's population resided in urban areas in 2018. In 1950, 30 % of the world's population was urban, and by 2050, 68% of the world's population is projected to be urban (Division, 2019). There is a migration of people from rural to urban areas in seeing the opportunities in employment, education, and better infrastructure. As more people move to cities and towns, architects and urban planners play a critical role in designing the built environment to accommodate the needs of a growing population.

The built form can be significantly altered by urbanization. The built environment changes as cities expand, affecting the architectural design, function, and style of structures. Numerous factors, including population growth, economic development, technological advancements, and social changes, contribute to the transformation of built forms brought about by urbanization.

Urbanization and its effects on land use are closely related to the idea of converting horizontal expansion into vertical expansion. The availability of land decreases and increases in value as urban areas expand. In this situation, making effective use of smaller land parcels is crucial to meeting the needs of an expanding population. This strategy enables a higher population density and can stop urban sprawl, in which cities spread out horizontally and take up larger areas of land. It's crucial to remember that the success of vertical expansion depends on factors like sufficient green space, adequate transportation, and appropriate building regulations.

To accommodate these needs, a lot of open natural land is replaced by artificial heat-absorbing surfaces That are the built forms. This leads to higher temperatures in the urban centers than in the surroundings. Significant amounts of forests are wiped off at an alarming rate to fulfill the increasing demands of urban infrastructure. Temperatures are raised as a result of the tall buildings' extensive surface areas that absorb and re-emit heat. They also obstruct and confine the wind, thereby lowering the effectiveness of convection cooling. As temperatures continue to rise, the demand for artificial cooling increases, which leads to the release of the heat generated by them into the surrounding environment (Md. Nuruzzaman, 2015).

With the increase in population density, there is also an increase in emissions from vehicles, industrial activities, and other sources of air pollution that are discharged into the environment, causing the absorption of solar radiation. The heat generated from daily human activities is also one of the reasons for the increase in temperatures. (Md. Nuruzzaman, 2015).

The mitigation strategies according to the different research papers are as follows roof strategies including cool roofs and green roofs, cool pavements, cool facades and green facades, shading structures, passive cooling, green vegetation, and water bodies (Md. Nuruzzaman, 2015) (Zhu, Zhou, Wang, Ma, & Meng, 2021) (Khare, Vajpai, & Gupta, 2021). Here we understand that these climate changes create a local climate in the highly urbanized area which defers the larger regional climate. Thus, all these mitigation strategies are applied to soothe the particular local climate that is creating the discomfort. This local climate of any particular place is known as its microclimate.

2. Microclimate

“The microclimate of a particular location can hence be defined as the statistical state of the atmosphere in the layer being affected directly by the characteristics of the underlying surface” (Rotach & Calana, 2003). In simpler words, A microclimate is the climate of a small, localized area that differs from the climate of the surrounding region due to various factors such as topography, vegetation, and human activity and can have different temperatures, humidity, wind, and

precipitation patterns than the surrounding macroclimate (Lai, Liu, Liao, & Yu, 2023) (Rotach & Calana, 2003). The larger climate is mainly determined by solar radiation and its inclination, but when looking at a smaller local scale the global factors don't play a role as significant as the local surface properties. Certain variables are important for determining surface properties, specifically for simple and flat surfaces. These variables include radiative properties such as albedo and emissivity, thermal properties such as heat capacity and conductivity, and properties that influence moisture levels such as the hydraulic characteristics of the soil and the type of surface covering. The surface properties mentioned previously are not fixed and can change due to various factors such as the effects of the large-scale wind field, fluctuations in soil moisture levels throughout the day, and alterations in vegetation during different seasons (Rotach & Calana, 2003). Microclimates can occur in various settings, including urban areas, forests, and bodies of water. For this particular research, we are focusing on urban microclimates.

As talked about earlier Urban areas experience a phenomenon called the Urban Heat Island (UHI) effect which unpleasantly alters the microclimate disturbing the ecosystem and its dwellers. One of the examples of the following is the level of urban development that has a significant impact on the Urban Heat Island (UHI) phenomenon. A more compact urban environment leads to greater reflection of solar energy and affects the movement of air within the city's canyons as well as the city's wind "porosity" (Berardi & Wang, 2016).

To understand the microclimate of a particular place, understating the factors affecting it becomes more important. The climatic factors that affect the microclimate are Air temperature, humidity, Thermal radiation, and wind. The physical factors affecting the microclimate are vegetation, soil, water bodies, and the built environment.

2.1. Climatic Factors

2.1.1. Air temperature

Air temperature in simple words is the degree of hotness or coldness experienced in a certain area. It is mainly influenced by solar radiation. It is also dependent on the altitude or elevation of the

location, what time of day or year it is, how close it is to water or heat sources, and whether there are clouds or other things in the air that blocks the radiation.

2.1.2. Humidity

Humidity is the amount of moisture present in the atmosphere. It has a great role in influencing the microclimate as high humidity creates a warmer atmosphere by lowering our body's capacity to lose moisture thus not letting our body cool. Low humidity levels make the atmosphere cooler and dry having dehydrating effects on humans as well as the environment. Humidity also leads to the presence of clouds which lowers global radiation (Lai, Liu, Liao, & Yu, 2023). For most people, the ideal relative humidity is 30% - 50% (Nicole, 2022).

2.1.3. Thermal radiation

The electromagnetic radiation that almost every object or surface emits is referred to as thermal radiation. Thermal radiation can be emitted, absorbed, and reflected by these surfaces. Surfaces that reflect a lot of sunlight and emit a lot of infrared radiation are called cool surfaces. These surfaces help to lower the temperature of the surface they cover. This decrease in surface temperature leads to less heat being released, which ultimately results in a lower air temperature. Cool pavements have a greater impact on microclimate than other cool surfaces such as cool facades, cool roofs, and green roofs because there are more of them present in the environment. (Zhu, Zhou, Wang, Ma, & Meng, 2021).

2.1.4. Wind

Wind refers to the movement of air, which generally flows from areas of high pressure to areas of low pressure. It has a natural ability to disperse heat and increase evaporation, resulting in a decrease in temperatures. In any particular area, the trees or the building should always be placed on the leeward side to avoid a wind shadow region and keep the wind flowing through the area (Priya & Senthil, 2021) (Zhu, Zhou, Wang, Ma, & Meng, 2021). Similarly, an evenly distributed tree layout is not good as it does not promote a lot of shading and blocks the wind creating high

temperatures in the downstream areas. (Lai, Liu, Liao, & Yu, 2023). If we talk about streets, they need to face favourable wind direction to achieve maximum thermal comfort (Elbondira, Tokimatsu, Asawa, & Ibrahim, 2021). Thus, the knowledge of the wind direction plays a major role in the entire process.

2.2. Geographic Factors

2.2.1. Vegetation

Any type of Vegetation converts water to vapor by evapotranspiration, reducing the surrounding temperatures. Thus, the greater the amount of vegetation higher will be the relative humidity of that area, having a direct impact on the microclimate as discussed above (Lai, Liu, Liao, & Yu, 2023). The vegetation types include groves, single trees, shrubs, and grass. Out of all the types of vegetation trees plays a very important role. the Shield-cast of trees lowers the temperature below the trees from the upper radiation (Zhu, Zhou, Wang, Ma, & Meng, 2021). Trees that have a higher height-width ratio have a lower cooling impact than the ones with a lower height-width ratio. But if you overcrowd the trees, especially in the downstream region it will reduce the airflow and thus the increased humidity will make the Physiological equivalent temperature (PET) higher (Priya & Senthil, 2021). Evenly distributed tree layout is also not good as it does not promote a lot of shading blocking the wind and creating high temperatures in the downstream areas (Lai, Liu, Liao, & Yu, 2023). This gives us the idea that planting trees alone doesn't help but strategic orientation keeping the wind and solar radiation in mind helps us achieve our desired output more efficiently.

Grasses are also a kind of vegetation that has more effect on the surface temperature and thermal radiation of that surface. For surfaces, vegetation helps to keep surfaces cool more effectively than increasing the albedo (Md. Nuruzzaman, 2015). If the grass is planted in a shaded region, it will create a lot of humidity and thus will require good ventilation. Grass planted in a place with high solar radiation will require more water (Priya & Senthil, 2021). Looking at the trees and grass, the ratio of both of them together also becomes important. The ratio of the projected area of tree canopies to the area covered by grass is referred to as the Trees-grass area ratio (TAR). The optimal

design of trees and grasses is crucial due to limited land resources. Increasing the TAR in communities with low-rise buildings can also help reduce energy consumption and improve energy efficiency. (Xi, Wang, & Cao, 2023). Working with TAR we use tree canopies to shade the grass minimizing water loss and for it to reduce surface temperature most effectively.

2.2.2. Soil

When we talk about soil condition it is known that soil with higher moisture content can make the nearby air feel cooler and reduce wind speed. On the other hand, if the soil is dry, it can make the nearby air feel warmer and increase wind speed. Raising the level of moisture in the soil, whether in rural or urban settings, leads to a decrease in the maximum temperature near the surface during the daytime (Husain, Bélair, & Leroyer, 2014). Here this is because soil with sufficient water is necessary for the vegetation of that area to turn heat into a vapor through evapotranspiration to cool the area. Thus, making irrigation and maintenance an important factor in the microclimate. This is the reason that Private gardens are more advantageous compared to communal green spaces because they receive more regular watering (Elbondira, Tokimatsu, Asawa, & Ibrahim, 2021).

The soil here acts as a cool surface by the qualities of evaporative cooling. Cool surfaces are essentially surfaces that have high solar reflectance and high infrared emittance. Cool pavements have the most positive effect on the microclimate compared to other cool surfaces like cool facades, cool roofs, and green roofs (Zhu, Zhou, Wang, Ma, & Meng, 2021). Talking about soil, it can hold more heat than the air around it without getting hotter. This means that during the day, the soil absorbs the heat from the sun and keeps the area around it cooler. At night, the soil releases the stored heat, which helps to keep the area warmer. It acts as a heat sink keeping the surrounding temperatures in check (onwuka & Mang, 2018).

2.2.3. Water Bodies

Water bodies have a significant impact on the microclimate if oriented strategically. Water bodies absorb the heat during the daytime and thus lower the surrounding temperature during the day. Now at night time, it releases this heat in the surrounding, raising the temperature around. This has

an adverse effect on summer nights when the air is already warm (Priya & Senthil, 2021). Hence, it is crucial to strategically position water bodies in relation to trees and wind to reduce their adverse effects on the surrounding environment.

Placing trees around the water body can provide shade, intercepting the solar radiation this the water has a reduced amount of heat to absorb. Placing a water body in the direction of the wind also helps by dispersing the heat released by the water body during the night time, lowering its impact on the microclimate.

2.3. Built Environment

The built environment simply refers to the surroundings that are created by humans. These man-made surroundings include the buildings, the roads, the distribution system of water as well as electricity, the roads and other transportation services, and the landscape. The characteristics of the built environment—such as building heights, building and street orientations, spaces between buildings, amount of vegetation coverage, type of vegetation, and the amount of open space—affect how we experience weather.

All of the components of the built environment, including the roads, structures, bridges, landscaping, furnishings, lighting, etc., are composed of one type of material or another. The microclimate in a region can be greatly impacted by building materials.

2.3.1. Thermal Performance

High thermal mass construction materials, including concrete and brick, have the capacity to absorb and store heat, raising indoor and outdoor temperatures as a result. Insulation and other materials with low thermal mass can assist control temperature by preventing heat from entering or leaving the building. High thermal mass has the advantage of reducing temperature fluctuations. It is feasible to construct areas with more stable temperatures and less need for excessive heating or cooling by using high thermal mass materials (Chokhachian, Perini, Dong, & Auer, 2017) (Majerska-Palubicka & Cibis, 2019).

2.3.2. Albedo

The amount of sunlight or solar radiation reflected by a material is referred to as albedo. It gauges a surface's intensity of reflection. The enhanced reflectivity of high-albedo materials causes them to reflect more sunlight while absorbing less of it. This keeps the substance and the environment around it colder. White roofs, light-coloured pavements, or reflecting surfaces like aluminium are a few examples of materials with a high albedo. Low-albedo materials absorb more sunlight and reflect less of it because they have a lower reflectivity. They consequently tend to heat up more when exposed to sunshine. Dark asphalt, roofs, or pavements are a few examples of low-albedo materials. Because it has a big effect on local temperature and the overall heat balance, a material's albedo is crucial (Al-hafiz, Musy, & Hasan, 2017)

2.3.3. Permeability

More permeable building materials, such as wood and brick, have microscopic openings or pores that facilitate easier air flow. Airflow is made possible by this permeability, which may improve the building's and the surrounding area's temperature and humidity. Permeable construction materials allow for airflow that can affect the area outside the structure as well. For instance, if a building is made of permeable materials, like brick, it might make tiny gaps or channels that let air flow through. This could influence the environment in the nearby area by aiding in the dissipation of heat or humidity produced by the building. The possibility of stagnant air pockets is decreased and improved air quality may result from the increased airflow (Javanroodi & Nik, 2019).

In addition, the built environment can affect our perceptions of temperature by providing shade from the sun or shelter from the wind. Thus, Vegetation with the appropriate condition and amount is more important for streets where the height of the buildings on either side of the street is relatively low compared to the width of the street, than the street where the building height is relatively high compared to the width of the street which does not require trees to create favourable conditions. It uses building shadows for the same. Here the high sky view factor increases the

temperature and decreases the humidity in any built environment (Elbondira, Tokimatsu, Asawa, & Ibrahim, 2021).

A balance of open space and built form is essential to making a great urban environment. People and the climate of the urban environment benefit from open spaces. They provide opportunities for social, recreational, and physical activity, as well as fresh air, noise reduction, and wind filtration. A wider outlook improves the urban environment and affects the happiness of neighbourhood residents. As buildings with open space views increase their attractiveness and acquire higher value in the real estate market, the visibility of open spaces is crucial to assess their social and environmental benefits, as well as their economic value. Additionally, open spaces can also help in improving the microclimate of the surrounding areas (Meziani, 2016).

3. Microclimate Management

3.1. Global Initiatives

The Sustainable Development Goals (SDGs) are a collection of 17 global objectives that were established by the United Nations in 2015 with the aim of achieving sustainable development by 2030. While there isn't any particular SDG devoted to improving the microclimate, a number of them are directly linked to raising the resilience of urban areas and the environment, both of which can have a good effect on the microclimate.

SDG 7: Affordable and Clean Energy and SDG 9: Industry, Innovation, and Infrastructure both ensure that everyone has access to modern, sustainable, cheap energy. by encouraging the use of renewable energy sources and energy-saving techniques. They aspire to support innovation, industrialize in a way that is inclusive and sustainable, and develop resilient infrastructure. through creating buildings, urban planning, and transportation infrastructure that are sustainable and climate resilient. By minimizing the effects of heat islands and encouraging sustainable urban development, one can influence the microclimate favourably.

SDG 11: Sustainable Cities and Communities is about Making cities and human settlements inclusive, secure, robust, and sustainable is the main focus of this objective. SDG 11 covers a range of microclimate-related matters, including urban planning, disaster resilience, affordable housing, sustainable transportation, and green spaces. SDG 11 assists in improving urban microclimates by putting sustainable practises into practise. By promoting environmental, social, and health advantages in urban settings, green spaces are essential to achieving SDG 11. By reducing urban heat islands, managing stormwater, fostering biodiversity, assisting urban agriculture, and improving community well-being, they aid in the creation of sustainable and resilient cities. Urban design must include green areas if it is to build thriving, sustainable communities that place a high priority on the welfare of both residents and the environment.

SDG 13: Climate Action is about improving climate-related hazard resilience, lowering greenhouse gas emissions, and advancing climate-friendly policies and practises. SDG 15: Life on Land is all about terrestrial ecosystems and biodiversity conservation. SDG 15 encourages sustainable land management techniques, which in turn indirectly improves the microclimate. These methods, which can help control local temperature conditions and enhance microclimates, include reforestation, afforestation, sustainable agriculture, and ecosystem restoration.

All of these initiatives are done on a global level to address to the larger issue of sustainable development which can be achieved by addressing the major problem of urbanization becoming a threat to the natural climate (United Nations , 2015).

3.2. National Initiatives

The National Building Code (NBC) is developed and updated by the Bureau of Indian Standards (BIS). To make sure that the NBC represents the most recent developments in building practices and technologies, the BIS collaborates with numerous stakeholders, including specialists, professionals, and governmental organizations. The NBC acts as a reference for architects, engineers, and builders in India by offering thorough rules and regulations, ensuring that buildings are designed and built in

a way that takes the local climate into consideration and helps to a more favourable microclimate. It encourages environmentally friendly and climate-responsible behaviours that lessen the negative effects of urbanisation, increase energy efficiency, and produce more hospitable and durable built environments.

Under Part 10 section 1 of the National Building Code (NBC), landscape planning, design, and development talks in detail and provides us with a guide to the many kinds of vegetation and their potential uses. When we talk about planning greens, it also provides a thorough knowledge of its characteristics, which enables us to make better decisions. As was previously mentioned, maintaining green spaces has a significant impact on the microclimate, thus NBC also discusses the practical aspects of these landscapes. This section is also devoted to the necessary services and utilities. It provides comprehensive recommendations on what to plant, where, and for what purpose, as well as how to protect it and nurture it throughout all stages of development. This can be a really helpful guide for the individuals involved in any given project to comprehend and incorporate green spaces, as this will ultimately improve the climate of any given neighbourhood and the entire city.

Part 11 of the NBC approach to sustainability talks about microclimatic conditions in landscape design. They mentioned the average microclimatic factor of 1.0, which suggests that the building, pavements, reflective surfaces, and slopes have no impact on the evapotranspiration of the landscape. Additionally, they listed places with higher averages. Parking lots, west building faces, west and south slope sides, medians and places that experience wind tunnel effects are among them. In contrast, regions that are likely to have a lower average include shaded or wind-sheltered areas, north sides of buildings or slopes, courtyards, overhangs, or even areas beneath large building overhangs (Bureau of Indian Standards, 2016).

3.3. State-Level Initiatives

Urban planning, development, and construction activities are governed by the GDCR (General Development Control Regulations) for Gujarat in the Indian state of Gujarat. In compliance with the Gujarat Town Planning and Urban Development Act, the local planning bodies, such as municipal corporations or development authorities, develop the GDCR. The Gujarat Development Control Rules (GDCR) serve as guidelines and regulations for land use, building setbacks, height restrictions, zoning, road widths, parking requirements, and other factors that affect how Gujarat's metropolitan areas are physically developed. In Gujarat, the GDCR is essential for directing and controlling urban development operations. It attempts to create sustainable, well-planned, and inclusive urban environments that put citizens' overall quality of life, public safety, welfare, and environmental preservation first.

Protecting and conserving environmental assets such as open spaces, natural resources, historical places, and sensitive areas is one of the GDCR's mandates. Regarding green spaces, it includes regulations for creating and maintaining parks, gardens, playgrounds, and other public places. These regulations make sure that there are enough green spaces in the city to improve aesthetics, offer recreational areas, and encourage biodiversity. Regulations are also in place to protect trees in populated areas. It stipulates the planting of new trees as part of development projects and the protection of existing trees during construction operations. The preservation of trees aims to preserve greenery, enhance air quality, offer shade, and lessen the impact of the urban heat island.

Additionally, the GDCR identifies and safeguards eco-sensitive zones inside the state. These regions may have delicate ecosystems, animal habitats, or delicate natural features. Development operations inside these zones are subject to regulations that ensure minimal disruption of the ecological equilibrium. An Environmental Impact Assessment (EIA) may be required by the GDCR for specific kinds of development projects. An EIA assesses a project's possible environmental effects

and suggests ways to lessen or offset them. A thorough examination of the ecological effects of large development projects is ensured by the EIA mandate.

The GDCR acknowledges the value of natural resources and seeks to create a balance between development and environmental preservation by adopting these guidelines. The rules encourage the conservation of natural habitats, wise use of resources, and upkeep of open areas. This not only enhances the overall visual value of metropolitan areas but also guarantees Gujarat's environment's long-term resilience and sustainability (Government of Gujarat , 2017).

Intending to improve the human lifestyle, we witness the joint efforts of multiple agencies and different levels with different commitments. These organizations continually aim to establish comfortable microclimates that enhance people's well-being, whether they operate separately or jointly. By doing this, they hope to promote sustainable development and improve the overall quality of life.

4. Open Spaces and Their Impact on The Microclimate

In a built environment the built form and open spaces have different impacts on the microclimate. Built forms result in high temperatures outdoors, which increase energy demand and negatively impact human comfort (Schiano-Phan, Weber, & Santamouris, 2015) (Gál, 2014). On the other hand, open spaces can provide better microclimatic conditions and improve thermal comfort (Ragheb, El-Darwish, & Ahmed, 2016).

The geometry of the built form, such as the height and distance between buildings, can create street canyons that trap heat and reduce airflow. Open spaces, on the other hand, can provide better ventilation and air circulation, which can improve thermal comfort.

The microclimate in open spaces depends on the physical properties of the surfaces, such as the amount of vegetation, water, and shade (Latini, Grifoni, & Tascini, 2010). Greenery in open spaces can help lower temperatures by providing shade and through evapotranspiration, the process of

evaporating water from plants. Ground surface materials also play a role in improving microclimate conditions by influencing heat absorption and reflection. By carefully selecting the appropriate surface materials and vegetation harsh climatic conditions can be eased (Latini, Grifoni, & Tascini, 2010). Open green spaces in urban areas can significantly contribute to decreasing the ambient temperature of a city. When we look at urban green spaces it cools cities through evapotranspiration and solar control, creating cool islands in and around public green spaces. These cool islands offer improved comfort conditions and lower ambient temperatures around them and to a distance equal to their length. Additionally, the appropriate spatial distribution of parks and other open green spaces can significantly decrease the average surface and ambient air temperature of cities (Schiano-Phan, Weber, & Santamouris, 2015). Additionally, plants contribute to creating optimal humidity conditions and the microclimate of an urban environment, make for an acoustic barrier, and have a windproof, gasproof, and dust-collecting effect. both planting density and the composition of greenery should be taken into account when designing green spaces to have a significant impact on the formation of a favourable microclimate in an urban environment (Finaeva, 2017)

Here we understand that not just open spaces but the nature of the surfaces of the open spaces is equally important. A nonpermeable surface in an open space act very similar to the built form radiating heat, whereas a permeable surface would act as a layer of vegetation holding water and cooling down the atmosphere. When it comes to letting water seep into the soil, removing pollutants, and recharging groundwater, permeable landscaping surfaces, are effective. In densely populated urban areas where additional land may not be available, here permeable paving is especially helpful. A porous urban surface known as permeable pavement collects rainwater and surface runoff temporarily stores it, and then gradually allows it to seep into the underlying soil. Pervious surfaces, like pervious concrete or asphalt, encourage water percolation rather than causing runoff. Water can seep through permeable pavers, which are made of stone or concrete and have gaps between them (Un, 2010). Thus, permeable surfaces hold water which in turn cools the climate by the method of evaporation as disused earlier.

5. Ahmedabad and Its Housing Typologies

Figure 1: Location of Ahmedabad

Ahmedabad, situated in western India, rests along the Sabarmati River in the state of Gujarat. The city is geographically divided by the river, creating two distinct regions: the eastern and western parts. In the eastern region, the older section of Ahmedabad, traditional row houses line the streets, giving it a characteristic charm. This area also includes industrial zones and homes primarily occupied by lower-income households. On the other hand, the more recently developed western Ahmedabad features modern buildings and is predominantly inhabited by wealthier individuals. (Adhvaryu, The Ahmedabad Urban Development Planmaking Process: A Critical Review, 2011)

The built-up area has undergone a significant transformation. In 1991, this area made up 28% of the Ahmedabad City total area; by 2010, that percentage had risen to 76%. The high rate of urbanization is the cause of such rapid transformation. In 1991, agricultural land accounted for 50% of the entire area; by 2010, it had decreased to 7% of the total area. (Sikarwar & Chattopadhyay, 2016).

5.1. Typologies of Housing in the City

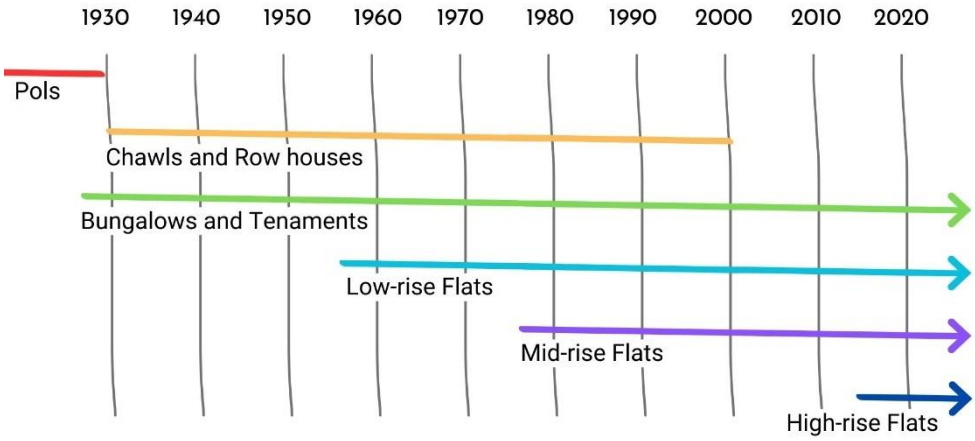

Figure 2: Timeline of the typologies of housing in the city

In *pols*, which are enclosures, people are frequently connected by ties to their communities and their faith. The *Pols* regularly entered by a single gate. This arrangement appears to be a reaction to the unrest in politics. Since the buildings in the *Pol* were built in a staggered pattern, the streets did not follow a straight line. Instead, they frequently turned and created *Chawks* of various sizes that served groups of houses. It's interesting to observe how the spaces change within a *Pol*, aside from the security issues that the *Pols* addressed. Additionally, due to the street's narrowness, it was shadowed for the majority of the day. This might have provided some relief from Ahmedabad's intense summer heat (Inger, 2020).

The inhabitants of Ahmedabad appear to have welcomed the arrival of the British. Under British authority, Ahmedabad's fortunes were about to shift after a time of upheaval and decline under Maratha's rule. A new era in Ahmedabad's history began with the arrival of mills in the city. Elite shopkeepers and mill owners developed become powerful industrialists. When mills were established in Ahmedabad, the city experienced a huge increase in the number of job possibilities they offered. Around 50% of the population worked in mills by the 1900s. Leaders like Mahatma

Gandhi took note of the predicament of the mill workers, and the local government intervened to improve their living conditions The government established brand-new housing complexes called "chawls," which offered lodging at reasonable rates. Within a few decades, the city's landscape was speckled with several Chawls, which were commissioned by the private mill owners. There was a change in the type of dwelling built with the establishment of chawls. It included cramming as many people as possible into a given piece of land. To give workers accommodation, the mill owners build chawls, creating an owner-worker connection (Inger, 2020) (Karia, 2020).

The Gujarat Housing Board's operations were visible during the 1960s. The layout of the homes is quite close to the layout of the traditional houses. The layout is linear, the walls are parallel, and the sewer lines run along the rear lanes. The model was incredibly cost-effective for the government to construct. The housing board was also involved in building homes for the middle class. Four tenements have been grouped in one such colony from the late 1960s, and there are many parallel roadways and a shared open area. It is significant to highlight that the colony has amenities available. The colony has a badminton court and an outdoor theatre. The Gujarat housing board appears to be experimenting a lot during this stage (Karia, 2020).

Owners of mills moved from the old town to the region west of Sabarmati in the early 20th century. They adapted the design of existing colonial bungalows for their homes. It positioned the house in the middle of a designated plot with areas like those of a British bungalow but altered to meet Indian needs.

In Ahmedabad, mid-rise and high-rise construction first began in the late 1960s and early 1970s. The riots, among other factors, provided another impetus for residents to leave Ahmedabad's historic centre. These G+9 and G+10 structures were marketed as ideals for contemporary cities (Inger, 2020) (Dubey, Pooja, Priyanshi, & Smriti).

Following the Kutch earthquake in 2001, the restriction was raised to 70 m (22–23 stories) in 2017. The new regulation enables developers to build to their desired height. The Comprehensive General

Development Control Regulations (CGDCR)-2017 will include a new chapter, and the Urban Development and Urban Housing Department solicited public comments and objections in a notification released in 2020. The CM declared that roadways with a width of 45 meters or more will be permitted to have an FSI of 4. Similar to this, constructions along the 36-44-meter-wide highways will be permitted with an FSI of 3.6. The 200-meter zone on either side of the road is where this FSI is applied. The remaining FSI will be regarded as chargeable FSI if the existing FSI is 1.5 or higher, Rupani said. "The government has no plans to completely alter these cities' skylines. The main goal is to draw attention to some iconic structures in these locations. We don't offer any incentives to developers. However, we are confident that our action will support attracting FDI to the real estate sector", according to Prakash Datta, the department's deputy secretary, and officer on special duty. One of the other reasons stated for this was to lower the rates of housing in the city with the increasing land prices (Express News Service, 2019) (Nair & Varghese, 2020).

5.2. Bungalow Typology of Housing in the City

The development in the city follows the TPS method for development. The TPS is a procedure that involves pooling and readjusting the land, and appropriating elements for use by the general public. It was utilized more frequently following a 1999 modification to Gujarat State's Town Planning and Urban Creation Act. It includes discussions between the neighbourhood planning. authorities and landowners. The TPS has made it possible for urban land to be distributed more fairly for public uses like helping the poor, Ahmedabad is acquiring land housing, public areas, roads, underlying utility infrastructure, and societal comforts. (Mahadevia & Mahendra, 2018). With this system in place, larger plots under residential use were available with all the provided infrastructure. The permissible building types and sizes, it has played a major role in making the bungalow typology of housing popular on this side of the city.

Many locals are attracted to bungalows because they offer a unique lifestyle. The single-level design offers independence, privacy, and plenty of space. Bungalows often have private gardens, parking spaces, and outdoor spaces, allowing residents to take advantage of outdoor living while living in the

city. A bungalow community is often associated with exclusivity and prestige. The open floor plan, carefully manicured gardens and overall aesthetic create a sense of luxury and elevated social status. They see bungalow societies as a status symbol and luxury, which attracts them to choose this type of housing.

6. Potential of Development Scheme of Independent Bungalows

Based on the factors affecting the micro-climate, we understand that how any land is used is important. Either it's used to build or kept open with any other surface finish. Here the built-open factor becomes important. When we start seeing open spaces all we think of are the large city-level open spaces like parks, plazas, and waterfronts. They serve an important recreation purpose as well as an environmental purpose. They help in improving the overall livability as well as the quality of an urban environment. These urban spaces are government-managed. When we start scaling down and looking at neighborhood-level spaces, which are they?

A neighborhood is an area that is basically within a 15-minute walking distance radius, approximately 1-1.5 km (Nadh, 2023). Very few neighborhoods have an open-spaces in their surroundings. These neighborhoods with mostly residential land use have a combination of quite a few housing typologies, detached housing is one of them. These are a colony of detached bungalow-type houses under gated premises. Comparing the density between different housing typologies this particular one has the lowest thus, increasing the percentage of open spaces between them. In the absence of public open space, if a housing typology offers that amount of open space, it would help similarly. A development scheme of bungalows would have the potential of having that kind of open spaces both private and public in residential land use.

One major point of this is that public open spaces are generally managed by the government. Due to this a lot of them are in bad condition due to a lack of timely maintenance. For a public open space which is green maintenance becomes an important factor as the water level in the soil and conditions of the vegetation are the foremost factors impacting the climate. When we talk about

private greens, they are always well maintained by the owner due to their sense of ownership to it. A similar thing happens to the public greens within the society's limits. It directly affects the image of their house. Living in a house with a poorly maintained open space also affects their living conditions.

The microclimate is affected by irrigation and upkeep since the vegetation there needs moist soil to convert heat to a vapor through evapotranspiration, which cools the area. Private gardens, which receive more irrigation, are therefore more advantageous than green public places. Private gardens typically have evergreen trees having leaves almost around here providing maximum shading which is a very important factor in a hot and dry climate. Thus, the shade effect is also more noticeable there than in public open places (Elbondira, Tokimatsu, Asawa, & Ibrahim, 2021). Here the purpose of having an open space is more successfully solved in a private setting rather than a public one.

7. Methodology

Site Selection: A suitable housing cluster is selected for the study based on its size, location, and level of urbanization. The cluster has a mixture of private and communal open spaces. Data like the open-built, road network, individual plot size, individual plot built-up street orientation, and aspect ratios will be collected and presented in the form of drawings and charts.

Site Area Assessment: The areas of the selected site are divided into built and open spaces. the open spaces are further divided into pervious or green and impervious areas.

Microclimate analysis: Basic data like temperature and humidity are collected on different typologies of housing around the site and will be compared to the data obtained from the site. the comparison will bring us to the reasons and consequences of the pervious and impervious areas on any particular piece of land.

Implementation: Based on the results of the meteorological data an ideal proportion of open versus built will be derived and its consequences for the surroundings will be discussed and understood. How can an open space be dealt with can also be discussed.

Conclusions and Recommendations: Based on the results of the study, conclusions and recommendations for the use of green open spaces to mitigate microclimate will be drawn. These conclusions and recommendations will be useful for future microclimate mitigation projects in similar urban environments.

8. Study Area

8.1. Bopal, Ahmedabad

In the years 1983–1984 in Bopal, there was a change in land use from agricultural to residential purposes, both public and private. There was a rapid change in how people lived. People began relocating from the city's center to its outskirts, choosing low-rise detached homes. The region was covered by AUDA from 2003 to 2005 and received housing projects. The SP ring road united the region in 2006. 2011 saw the expansion of AMC's boundaries to include Bopal till the SP ring road. The area's T.P. scheme was established in 2011 (Ravikumar, 2022). Earlier the residential typologies mainly consisted of the low rise semi-detached or detached housing. When bopal was included in the AMC the shift to mid-rise as well as the high-rise was seen. Thus, the older parts of the city are low rise whereas the newer developments are predominantly high-rise high density. Bopal's key problems as a transitioning peri-urban region to a municipality were a lack of physical infrastructure and amenities, higher initial costs than benefits, a proliferation of authorities and poor coordination, as well as environmental degradation and disruption of natural ecosystems (Vakharia, 2016).
The study area chosen is a neighborhood area around a scheme of bungalow society in bopal. For this particular study, an area of a 1-kilometer radius around the society is studied. The society selected for this particular study is the Basant Bahar Society. Basant Bahar Bungalows is located in South Bopal. It is a bungalow scheme of 95 bungalows with a total area of 39 acres. The society was

built between 1996-1999. Thus, it is an old society even before the area of bopal was developed.

Figure 3: Basant Bahar Society satellite image

With urbanization, society started to surround by a lot of new high-density settlements. These new housing settlements were more compact than this one and had a very less quantity of open green spaces compared to the society.

8.2. Context of the Neighbourhood

Figure 3 is the earliest satellite image of the society. It is from 2003. During this time there was a sparse haphazard development going around in the area. The area still had a lot of open plots and some development along the widest road during that time. This was also the same time AUDA came into the picture and also developed a few housing schemes. During this time the society had not reached its full occupancy and had around 60 – 65 bungalow units.

Figure 4: Satellite image of Basant Bahar in 2003

Figure 5: Satellite image of Basant Bahar in 2017

The image figure 4 here is a satellite image of the year 2017 of the society and its surrounding areas. The town planning scheme for this area was laid in 2017 as part of Bopal TPS 3. The image shown depicts the area soon after the scheme was implemented. By this time the society had almost reached its full occupancy of 95 units.

Figure 6: Satellite image of Basant Bahar in 2023

Figure 6 is the current and existing situation of the society and its surroundings. The area is mostly covered by residential areas with a majority of low-rise residential typologies.

Figure 7: Built vs Open map of the neighbourhood

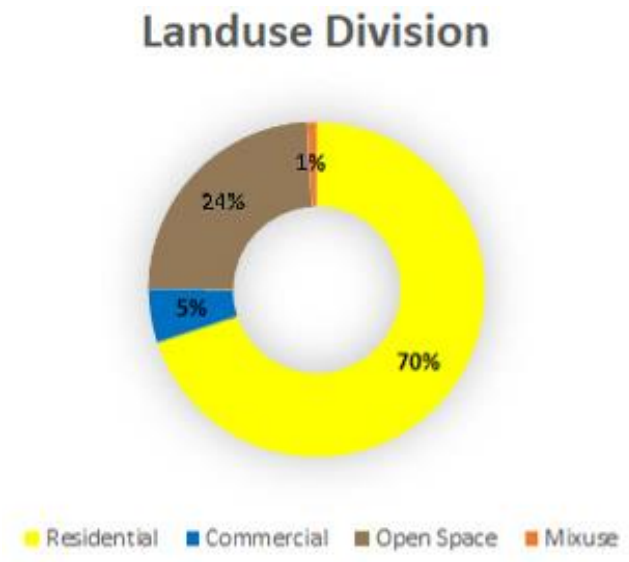

Figure 8: Land use division pie chart

Figure 8 is the land use distribution pie chart of the neighbourhood. It is clear from the pie chart the majority area in this neighbourhood is covered by residential use which is 70% with the next largest use the open spaces around. A lot of these open spaces are also up for development. Commercial and mixed-use buildings are comparatively less with almost all needful shops in day-to-day life.

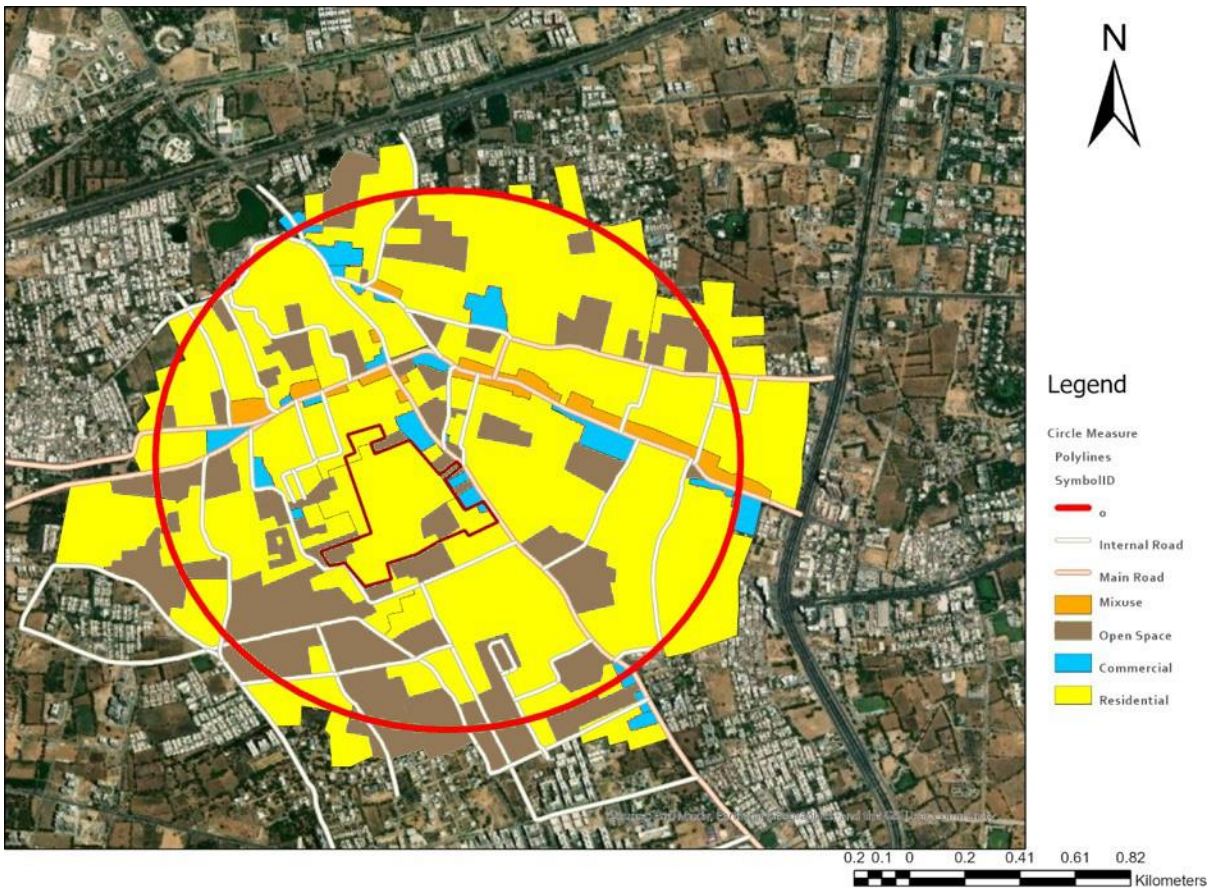

Figure 9: Land use map of the neighbourhood

8.3. Housing Typologies in the Neighbourhood

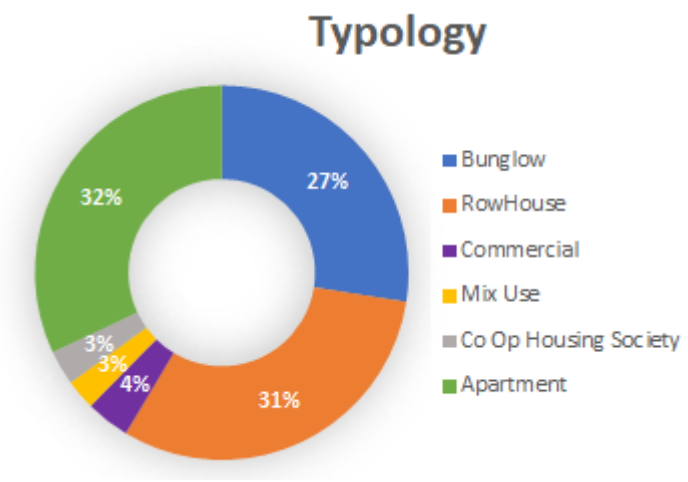

Figure 9: Typology chart of the neighbourhood

This chart Figure the typologies of housing around are divided into Bungalows, row houses, cooperative housing societies, apartments, Mixed use housing, and commercial buildings. This chart shows an almost equal majority of bungalow schemes, row houses, and apartments. But this also tells us that low-rise housing is almost double that of mid-rise or high-rise as both bungalows and row houses fall under low-rise housing. The majority area is a low-rise area till now.

In Figure 8 we also see 24 % of land still open in the area. but given the pace at which Bopal is developing, those will soon be developed. Construction projects are going on in several of them. all of the more recent buildings are mid or high-rise. Many vacant plots will soon be mid or high-rise buildings looking at the current building trends in that area. Thus, soon this area is going dominated by mid-rise and high-rise.

Understanding the typologies of the built form around it becomes important to understand their density and also the type of open spaces they have. Thus, through random sampling, the following societies or complexes were selected.

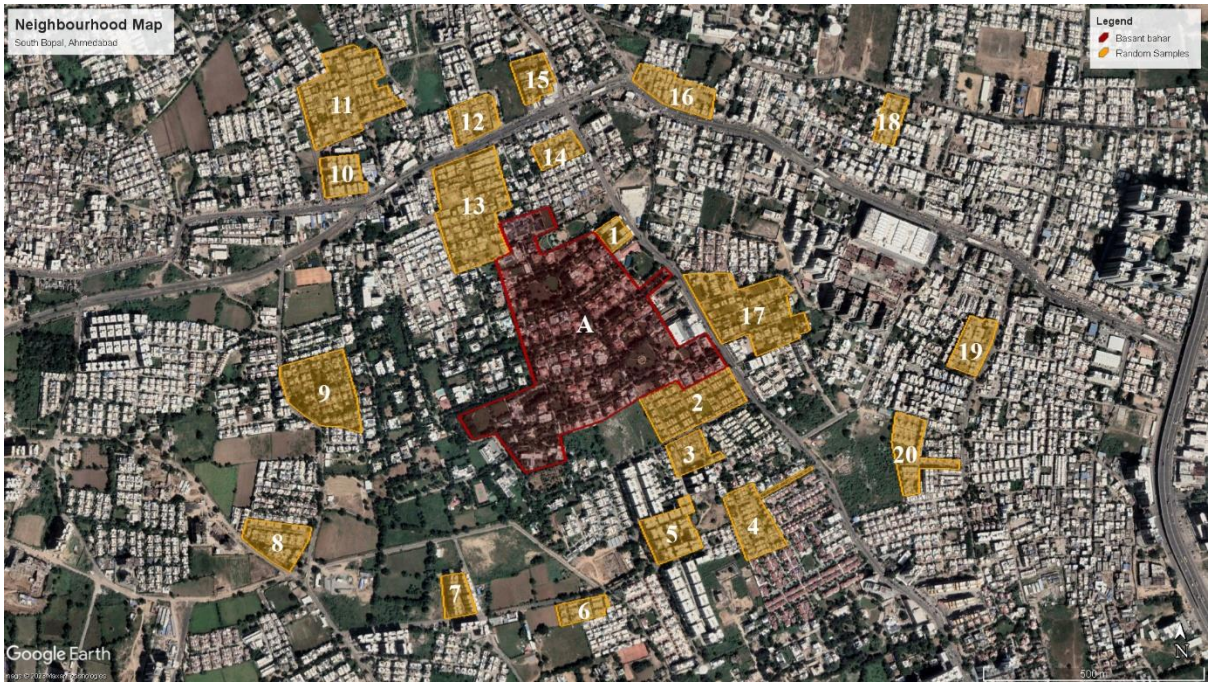

Figure 10: Neighbourhood map of Basant Bahar

A. Basant Bahar Society

1. Gala Hub	2. Shyam Villas 2	3. Dev Bhoomi	4. Jaldhara Society
5. Garden Residency	6. Maruti Kutir	7. Shreelaxminivas residency	8. Nand
9. Binori Bungalows	10. Kabir Enclave	11. Pujan Bungalows	12. Baleshwar Gold
13. India Colony	14. Anandnagar	15. Aishwarya Apartments	16. Purushotamnagar
17. Vraj Vihar	18. Nayan Darshan	19. Kadamb Flats	20. Shivaalay Bungalows

Figure 11: Gala Hub

Figure 12: Shyam Villas 2

Figure 13: Dev Bhoomi

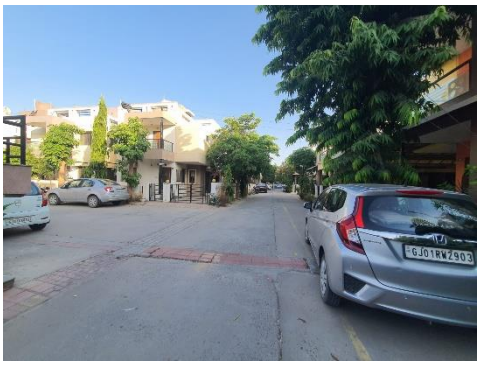

Figure 14: Jaldhara

Figure 15: Garden Residency

Figure 16: Maruti Kutir

Figure 17: Shreelaxminivas Residency

Figure 18: Nand

Figure 19: Binori Bungalows

Figure 20: Kabir Enclave

Figure 21: Pujan Bungalows

Figure 22: Baleshwar Gold

Figure 23: India Colony

Figure 24: Anandnagar Cooperative Society

Figure 25: Aishwariya

Figure 26: Purushotam Nagar

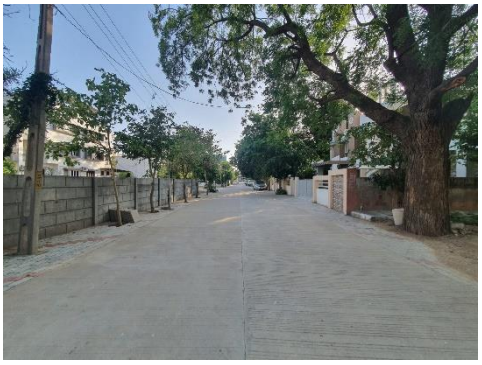

Figure 27: Vraj Vihar

Figure 28: Nayan Darshan

Figure 29: Kadam Flats

Figure 30: Shivalay Society

Typology	Area (Ha)	Num. of Units
Bungalows		
Basant Bahar Bungalows	15.81	95
Vraj Vihar Society	1.8	20
Commercial complex		
Gala Hub	0.36	2
Commercial+Residential		
Kabir Enclave	0.86	9
Shreelaxminivas Residency	0.55	5
Residential appartment		
Aiyshwariya	0.75	6
Garden Residency-2	1.43	13
Kadamb Flats	0.94	9
Row houses		
Baleshwar Gold	0.86	25
Binori Bungalows	4.5	150
Dev Bhoomi	0.45	35
Jaldhara - 2	1.42	55
Maruti Kutir	0.68	45
Nand	1.13	55
Nayan Darshan	0.68	30
Shayam Villas-2	2.1	65
Shivalay Bungalows	1.4	35
Cooperative Society		
Anandnagar co-operative society	0.34	35
India Colony	0.74	75
Pujan Bungalows	2.5	135
Purushottam Society	1.19	50

Table 1: Sample typologies of the neighbourhood

Typology	G+1	G+4	G+7	P+5	P+7	P+4	Grand Total
Bungalows	2						2
Commercial complex		1					1
Commercial+Residential			1	1			2
Residential appartment		1			1	1	3
Row houses	9						9
Cooperative Society	4						4
Grand Total	15	2	1	1	1	1	21

Table 3: Heights of the sample typologies

Figure 10 is the map of the neighborhood of Basant Bahar society. A neighborhood is an area that is a 15 mins walking radius thus a 1-kilometer radius. All of the sample societies are marked in orange, while the Basant Bahar society, which is the main focus of the study, is highlighted in red.

Here, Table 2 provides information on the density of these societies. To reveal this information, the area occupied by the society and the number of units are mentioned. Here, Table 3 provides information on the heights of each typology, which confirms that a majority of structures are low-rise.

8.3.1. Area Break-up of the sample typologies

Typology	Average built	Average paved	Average green
Commercial complex	1897.6	1620.7	0
Commercial+Residential	3135.5	3709.3	234.1
Cooperative Society	12026.5	7122	201.9
Residential appartment	5457.7	4621.9	501.8
Row houses	6723.4	22133.3	729.2

Table 4: Area break-up for sample typologies

An average of each typology's area distribution is taken to produce Table 4 to better understand the quantity of open spaces in each and to identify whether they are pervious or paved. By examining the area division of various typologies within a 1 km radius of Basant Bahar, we can see that the only typology here that provides the most open space is unquestionably the Basant Bahar bungalow layout. This furthers our topic on the need for open places to reduce the microclimate. To understand the impact of these variations in open spaces a study of temperature and humidity needs to be done.

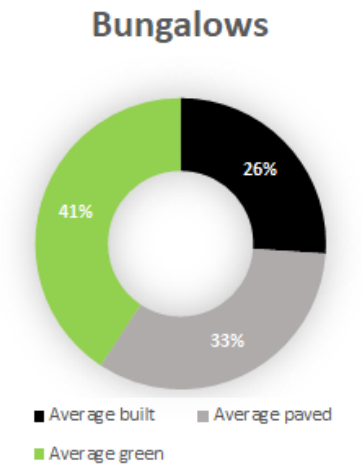

Figure 31: Area break-up of Bungalows

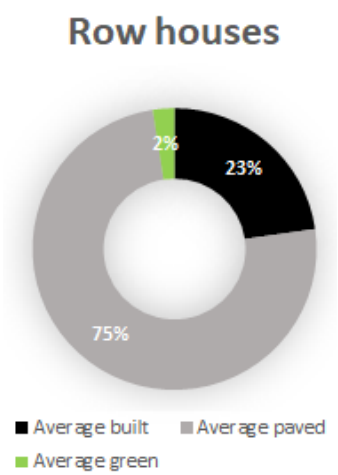

Figure 32: Average area Break up of row houses

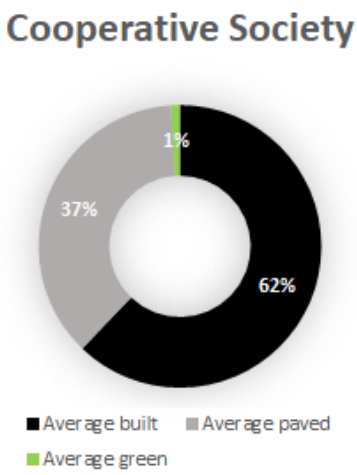

Figure 33: Average area breaks up of co. op. society

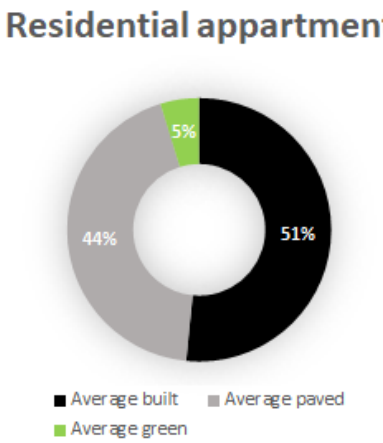

Figure 34: Average area break up of residential apartments

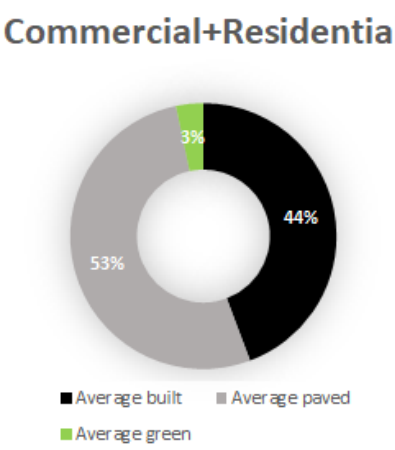

Figure 35: Average area break up of mixed-use buildings

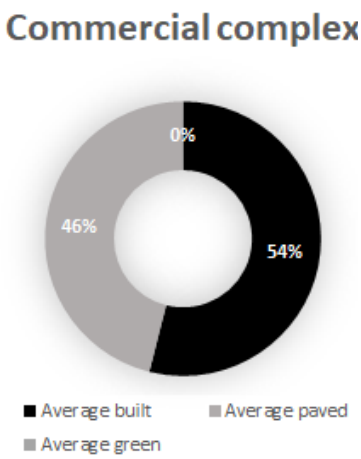

Figure 36: Average area break up of commercial complex

8.4. Environmental Conditions in the Study Area: Temperature and Humidity Analysis

Understanding the environmental variables and their impact on thermal comfort requires a thorough understanding of how open spaces affect temperature and humidity. The results of this study help us understand how different types of housing affect the microclimate's temperature and humidity. The temperature graph shows trends, with noon temperature peaks and evening temperature declines. Additionally, it highlights temperature fluctuations among various typologies, highlighting which are more vulnerable to heat buildup or cooling impacts. Similar to temperature fluctuations, humidity levels also change over time, showing trends like higher humidity in the mornings and lower humidity in the afternoons. Additionally, it evaluates humidity levels across various typologies to show which regions offer more comfortable moisture control.

8.4.1 Temperature Analysis

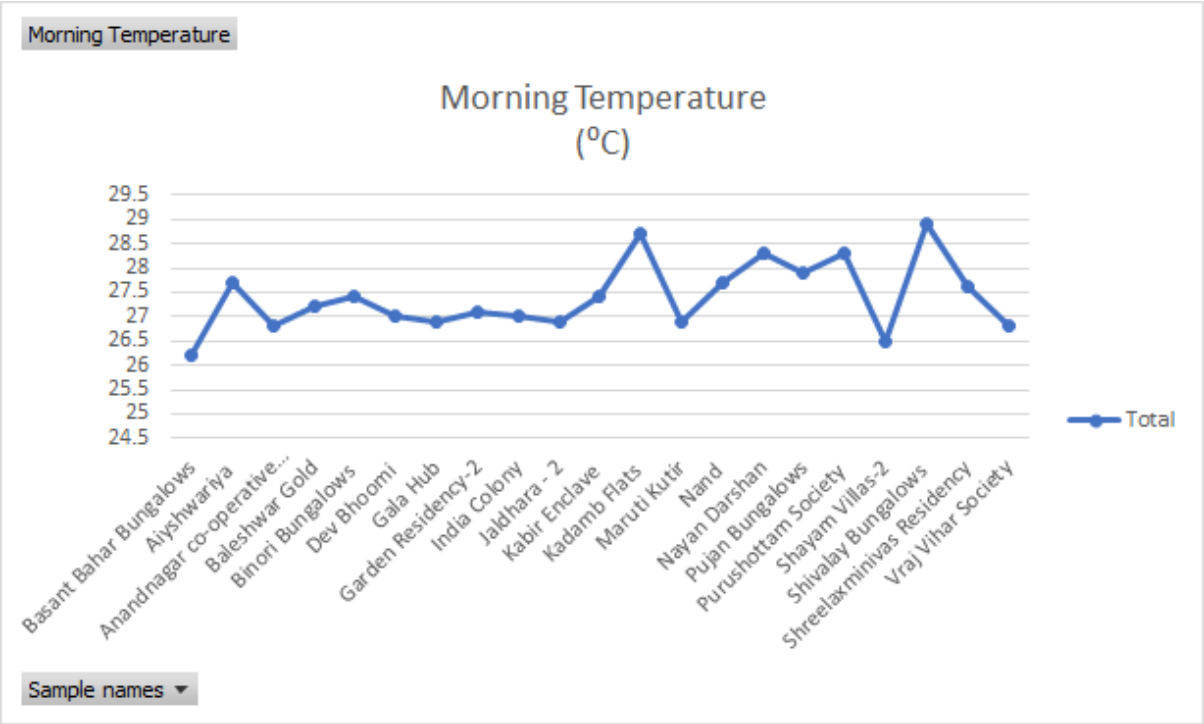

Figure 37: Morning temperature chart of all samples

Figure 37 gives us an insight that the early morning temperature data show that the society is cooler than the neighbouring residences. This illustrates how society after a night of darkness takes longer to warm up than its surroundings.

Figure 45 shows us that compared to many other residence typologies of the same kind, the midday temperature shows once again how cool the society is. However, the mid-rise has a cooler temperature than the others. Building height contributes to shade, which improves the temperature while reducing surface heating from direct sunshine.

In the evening, we observe a different situation from Figure 46 in which the temperature of society is higher than a few of the readings, leading us to conclude that both warming up and cooling down require time. The increased relative humidity compared to other locations may be one cause for this.

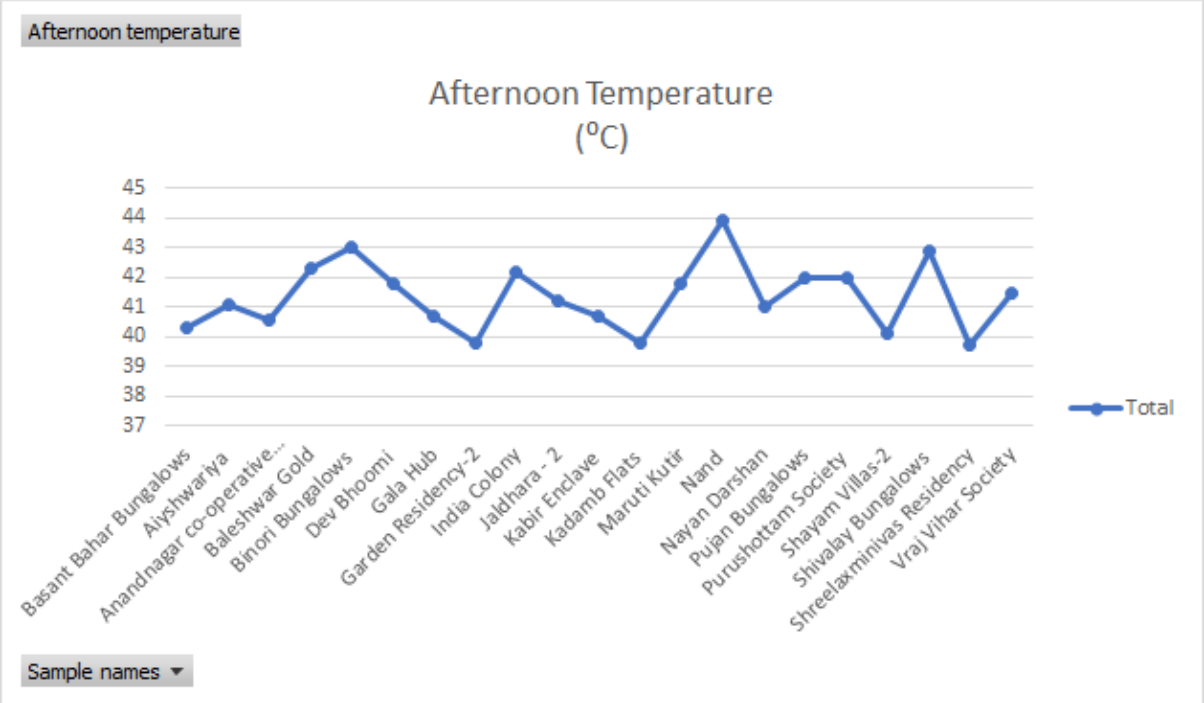

Figure 38: Afternoon temperature chart of all samples

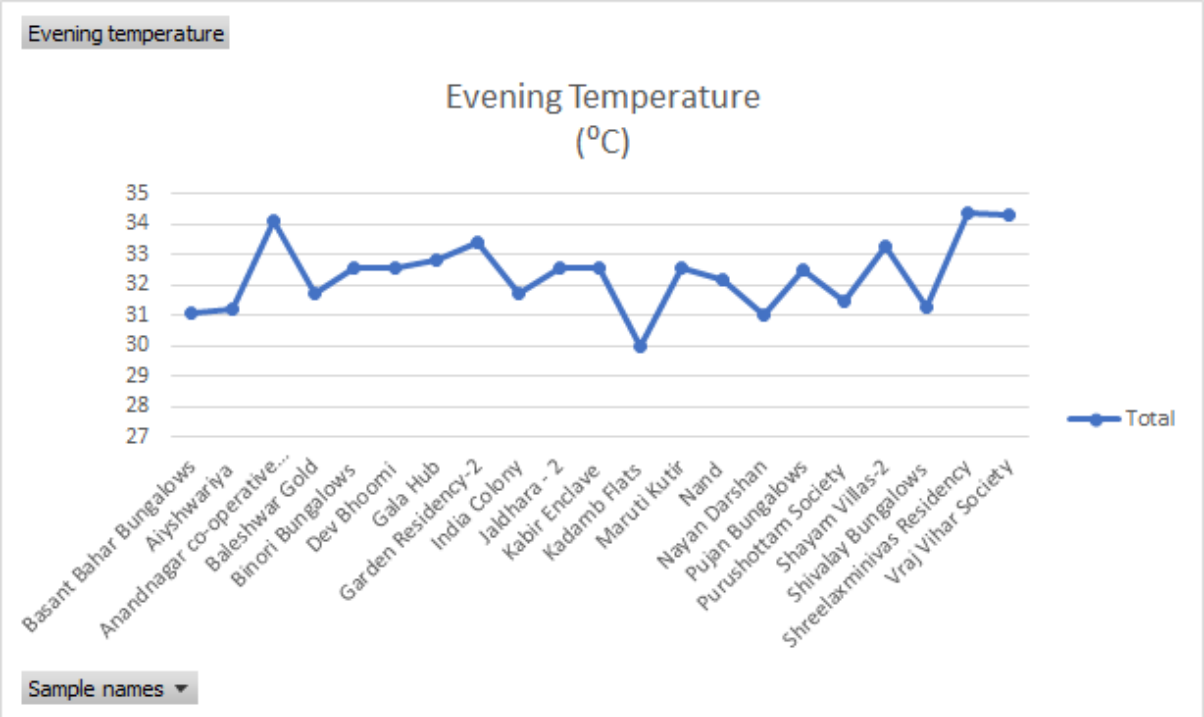

Figure 39: Evening temperature chart of all samples

8.4.2. Humidity Analysis

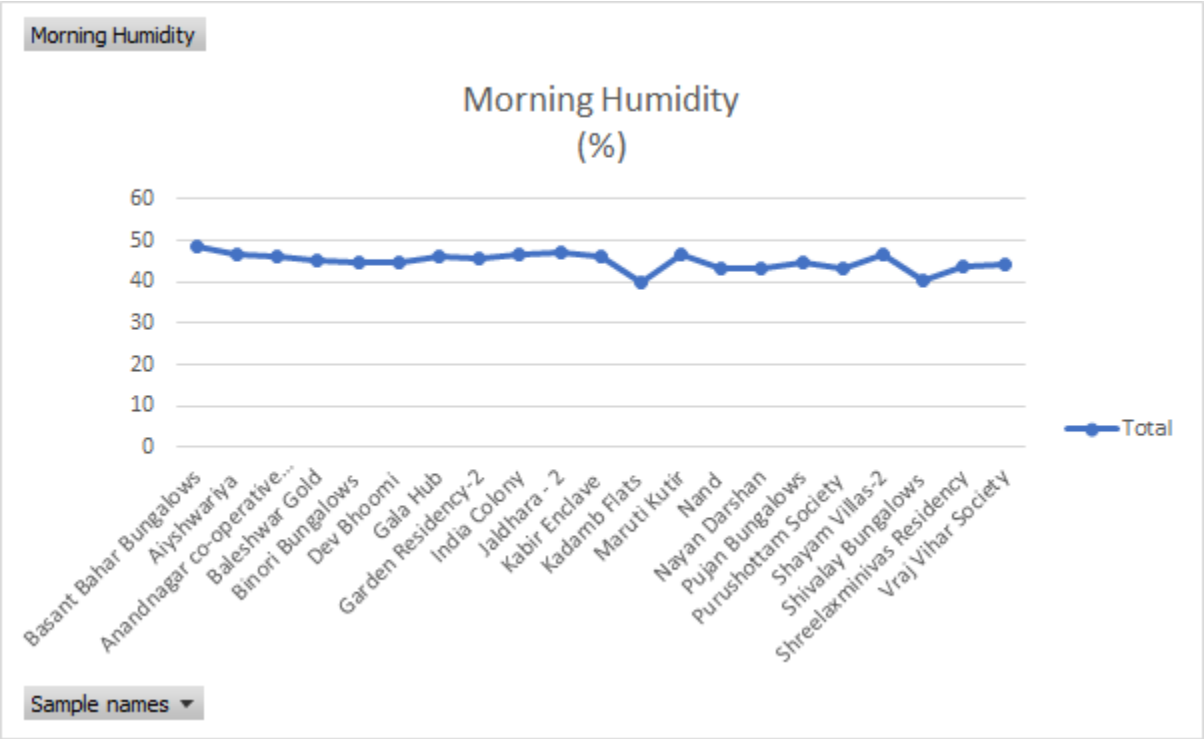

Figure 40: Morning humidity chart of all samples

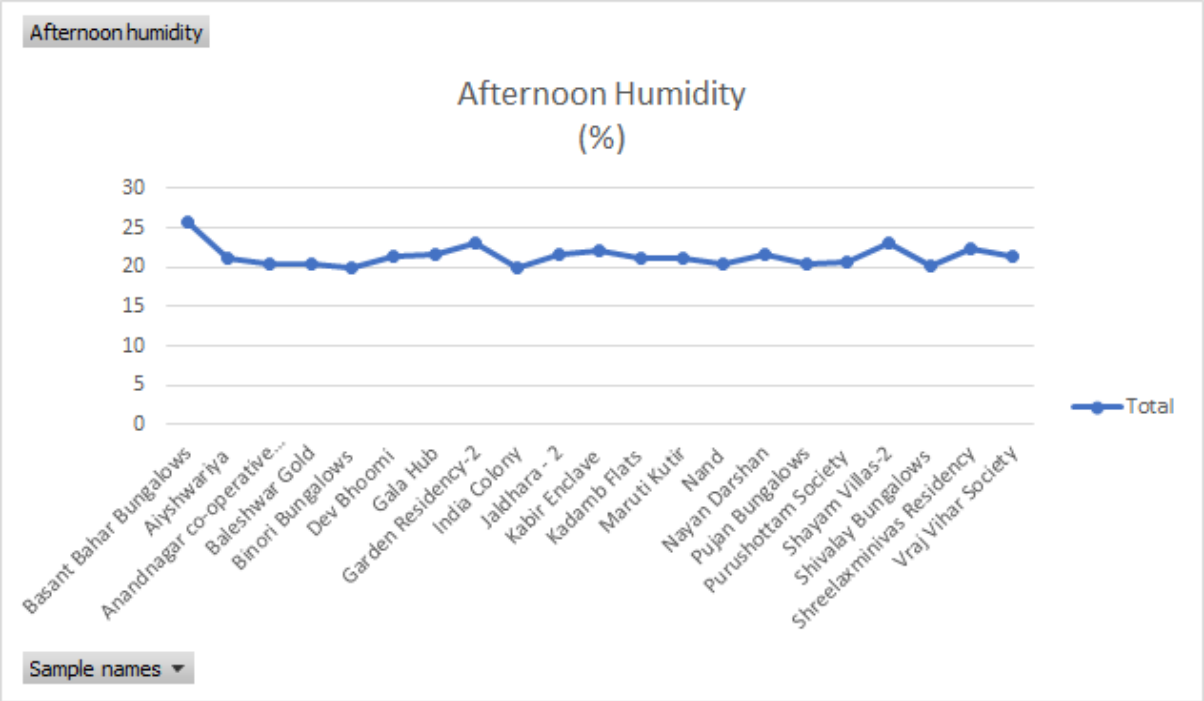

Figure 41: Afternoon humidity of all samples

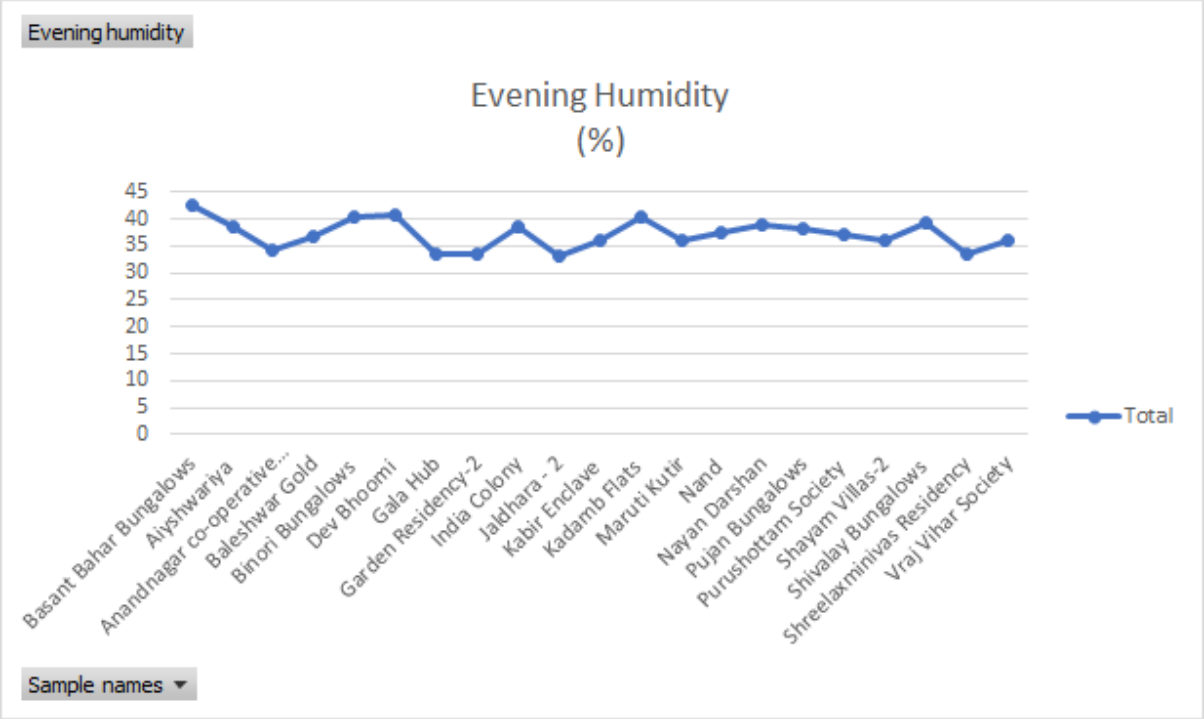

Figure 42: Evening humidity of all samples

As deduced from Figure 40, Figure 41, and Figure 42 Basant Bahar is the most humidity than the sample areas around it. The reason for this is that society has a lot of open spaces, majority of which are green or pervious. Here Any surface that gathers water will increase evapotranspiration, raising the air's moisture content. Because slower evaporation happens at higher humidity levels, a person feels cooler. It can also reduce the rate at which temperatures change here because moisture in the air absorbs and releases heat more gradually than dry air. This also clarifies the comparatively high temperatures in the evening.

Here we understand that temperature and humidity go hand in hand. The humidity in the society remains in the comfortable range helping the temperature from not spiking or dropping. Thus, the physiologically equivalent temperature (PET) stays in a comfortable range.

8.5. Basant Bahar Society, South Bopal, Ahmedabad

Basant Bahar bungalows are located in South Bopal, Ahmedabad. It is a bungalow development with 95 bungalows spread across 39 acres. The society has three common gathering places, with a water body in one of them. The project started in 1996 and ended in 1999. It was designed by architect

Kamal Mangaldas. The average plot size of the society is 1280 sq. m. and the average built-up area is 375.5 sq. m. Each house has its own private open space which is further divided into the garden which is the green open spaces and open spaces like parking, wash-yards, and driveway as their paved open spaces. The society is old all the vegetation in the society is also old which includes tall and dense trees, fully grown shrubs, and non-patchy grass. The green as well as paved open spaces are very well maintained and are used actively. The public open spaces are used in the morning and evening by children to play and the old people use their walkways to walk or just sit and catch up with their neighbors. The roads in the society are not only used for vehicles but are used by the residents to walk and jog also as they are mostly shaded all day long. The private gardens usually have to sit-out spaces or are used as outdoor family gathering spots. Occasionally there are used to host small parties and events.

Figure 43: Satellite image of Basant Bahar Society

Figure 44: Internal Road of Basant Bahar Society

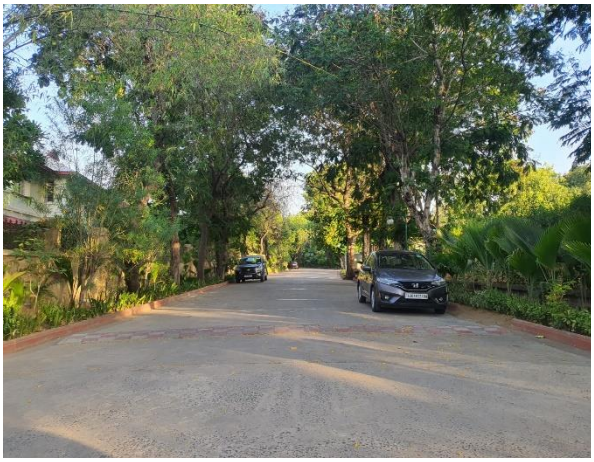

Figure 45: Internal Road of Basant Bahar Society

Figure 46: Basant Bahar Society layout plan

8.5.1 Area Break-up of Basant Bahar Society

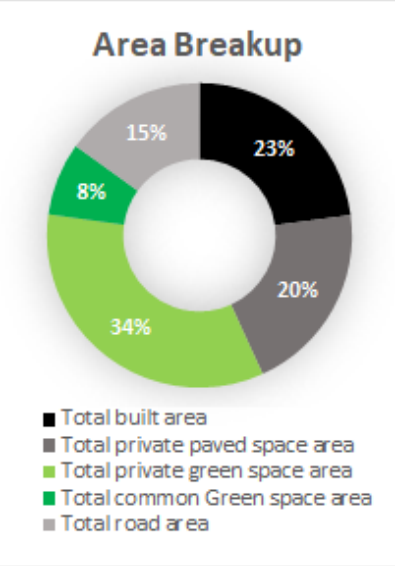

Figure 47: Area breakup pie chart of Basant Bahar

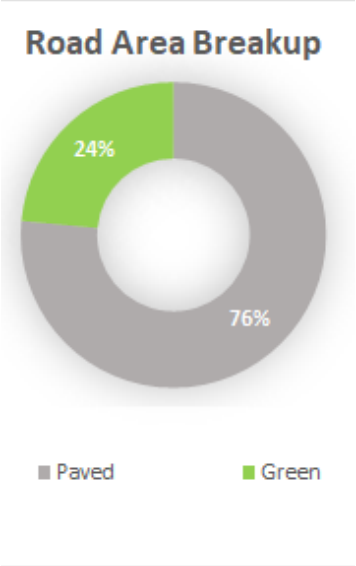

Figure 48: Road area breakup pie chart of Basant Bahar

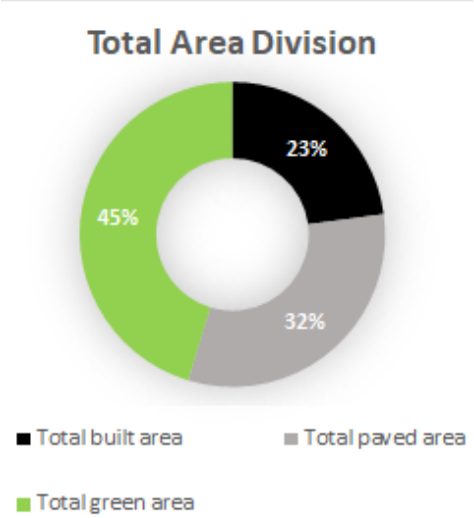

Figure 49: Total area breakup of Basant Bahar

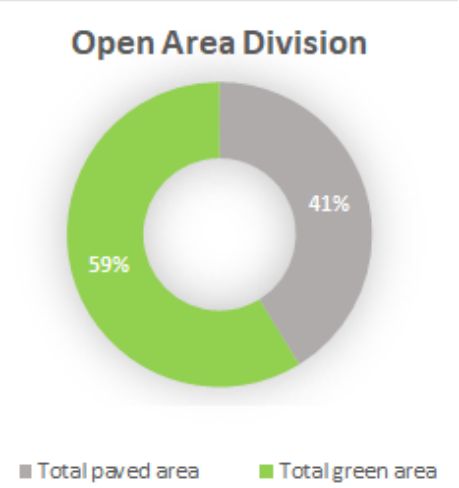

Figure 50: Open area division pie chart of Basant Bahar

The area breaks up of the entire society tells us that the private green spaces take up the majority of the land which is 34% and the total coverage on the site of the greens is 43%. The total built area compared to the open is very less. When we see the open spaces in society, there are more green open spaces than paved open spaces.

Site Area breakup (sq. m.)		
Total site area	158202	
Total built area	34172	22%
Total private paved space area	30373	19%
Total private green space area	50832	32%
Total common Green space area	11575	7%
Total road area	22460	14%

Total road area	22460	
Paved	17175	76%
Green	5285	24%

Total site area	158202	
Total built area	34172	22%
Total paved area	47548	30%
Total green area	67692	43%

Total open space area	115240	
Total paved area	47548	41%
Total green area	67692	59%

Table 2: Area Break - up of Basant Bahar

9. Discussion and Findings

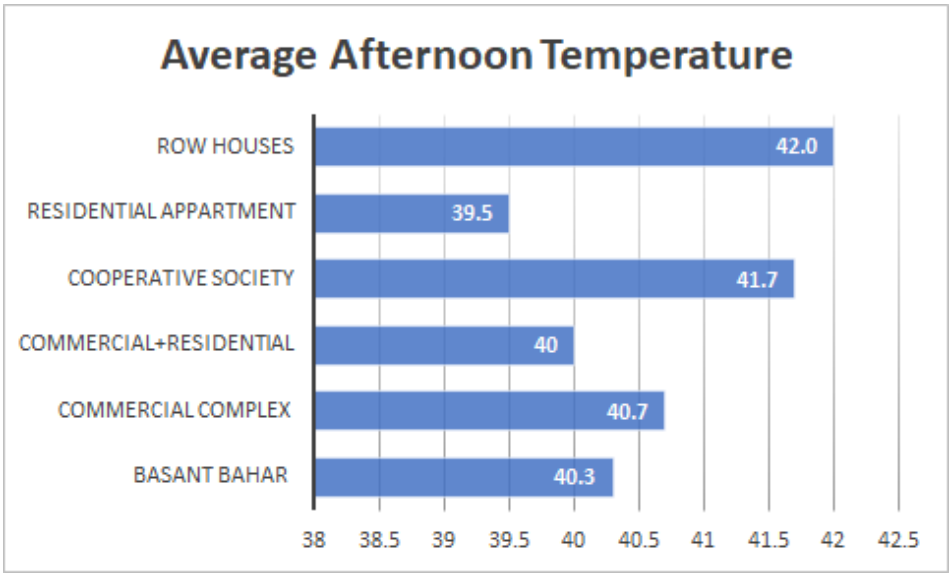

Figure 51: Average afternoon temperature

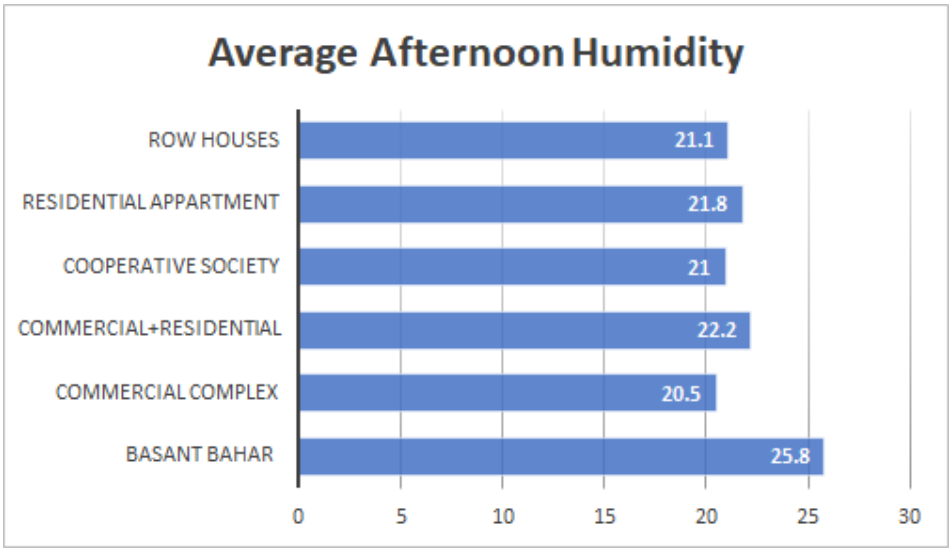

Figure 52: Average afternoon humidity

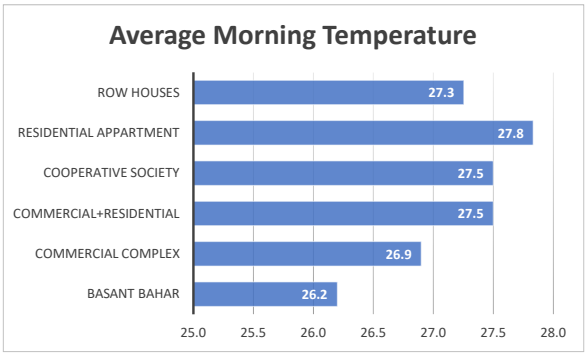

Figure 53: Average morning temperature

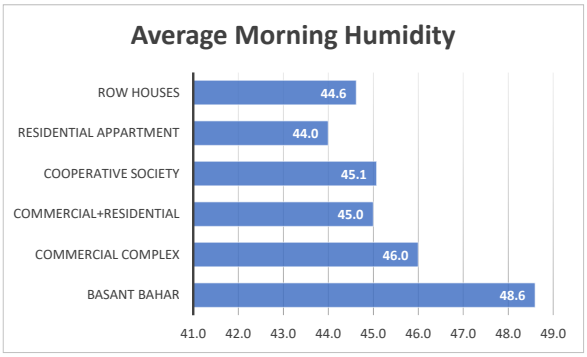

Figure 54: Average morning humidity

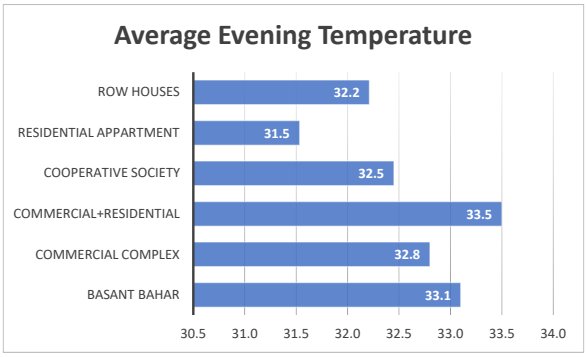

Figure 55: Average evening temperature

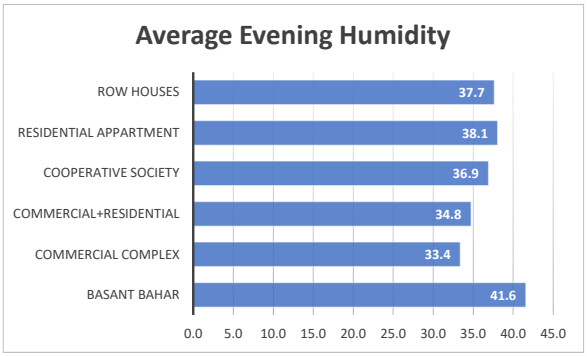

Figure 56: Average evening humidity

In the above Figure 51 and Figure 52, we see the average temperatures of the different housing typologies and Basant Bahar. Similar data on humidity is also seen. This leads us to conclude that Basant Bahar has the lowest afternoon temperatures and the highest humidity. So, in this case, the relationship between humidity and temperature is inversely proportional. This also suggests that

more humidity, as opposed to a dry atmosphere, lowers the temperature. While higher humidity may have a cooling impact, it's crucial to remember that extremely high humidity combined with high temperatures can cause discomfort and raise the risks associated with heat-related illness. In order to create a comfortable and healthy environment, humidity and temperature must be balanced.

In summary, because evaporative cooling affects heat perception, higher air humidity can have a cooling effect. When compared to dry surroundings, this phenomena might offer relief from the heat and give the impression that the temperature is lower. When assessing the total effect of humidity on the human experience, it is crucial to take into account the wider context of temperature, humidity levels, and personal comfort.

10. Role of Stakeholders

10.1. Role of the Government

To look at the ordered process of urbanisation and a sustainable way to achieve so, the government develops a set of laws and regulations. National Building Codes (NBC) and Development Control Regulations (DCR) have been developed in response. A national building code known as the NBC offers technical recommendations for building planning and construction in India. It prioritises energy conservation, sustainability, and safety. The DCR, on the other hand, is a set of rules created by local planning authorities to control urban development in a particular area or locality, including land use, construction setbacks, and other issues. In order to ensure deliberate expansion and development within a city or region, the DCR focuses on urban planning.

The best thing to do is to look into the manner in which it is carried out and implemented. Giving greater incentives to the developers to follow it can be another approach since groups like Leadership in Energy and Environmental Design (LEED) and the Indian Green Building Council (IGBC) are actively looking to achieve comparable goals in the construction industry.

Green open spaces are very important, as was previously discussed, and if they are planned and implemented according to standards and with frequent updates and modifications to them in relation to newer and current situations, a lot greater impact can be seen.

10.2. Role of a Developer / Builder

As per LEED, there is a credit under the open space section of sustainable sites. Its goal is to create outdoor open space that promotes social contact, passive recreation, physical activity, and interaction with the environment. Provide outdoor space that is greater than or equal to 30% of the site's total size (including the building footprint), according to the clause. Turf grass does not count as vegetation, however, at least 25% of that outdoor space must be covered in vegetation. Extensive or intense vegetated roofs can count towards the minimum 25% vegetation requirement for projects that achieve a density of 1.5 floor-area ratios (FAR) and are physically accessible, and qualifying roof-based physically accessible pavement areas can count towards credit compliance. IGBC asks for a minimum of 15% vegetated spaces or a minimum of 30% vegetated spaces over the built structures and on the ground to Restore disturbed site area.

By mimicking the site's natural hydrology and water balance, based on historical circumstances and undeveloped ecosystems in the area, they hope to reduce runoff volume and increase water quality for rain collection. Increased natural land cover on sites is one of the alternatives offered for this reason.

Credit for decreasing heat islands is also highlighted with the goal of minimizing effects on microclimates, human habitats, and wildlife habitats. Within ten years of planting, use the existing plant life or add shade-producing plants to the site's paved surfaces (including playgrounds). Install planters with vegetation. Artificial turf is not permitted among the plants, which must be present at the time of the occupancy permit. Another one is to use a vegetative roof or high reflectance roof.

Thus, in this way, we see that the green rating systems be it LEED or IGBC, both have given credits to certain things which in turn supports the cause of microclimate enhancement. These incentives are

given to the developer or the architect to create a stable built environment in return, LEED and IGBC certifications are advantageous to them because they increase marketability, lower operating costs, raise property values, offer regulatory incentives, improve occupant well-being, show responsibility for the environment, and ensure durability. It becomes the responsibility of the developer to take it up.

10.3. Role of a Customer / Buyer / Tenant

A portion is set aside for the buyers or tenants. Developers are hoped to inform and empower tenants to make sustainable decisions while organizing and carrying out their tenant improvement initiatives by making this illustrated booklet available to them. It acts as a tool that promotes the use of environmentally friendly behaviours, fosters cooperation between the building's developer and tenants, and advances the building's overall sustainability objectives. Additionally, it ensures that tenant areas adhere to the sustainable design concepts used in the project's core and shell, helping to establish a coherent and cohesive approach to sustainability throughout the entire building. Thus, it becomes the duty of the customer/tenant to adhere to it and try to understand the value behind it. Further, the buyers can be involved in community initiatives and events focused on protecting and promoting these initiatives.

11. Conclusion

In conclusion of this research, the data studied, we can say that a development scheme of an independent bungalow can easily function like a public open green space due to the percentage of green space in its boundary although having built. This space available is a lot more than available in any other typology of residences.

The greens are quite helpful when considering the temperature and humidity in more detail. This evapotranspiration process aids in temperature reduction and the creation of a more pleasant environment. In addition to reducing direct sunlight exposure, trees and vegetation provide shade,

which further reduces heat buildup and produces a cooler microclimate. Plants produce water vapour into the atmosphere through transpiration, which raises the relative humidity in the area. This can be especially helpful in our region's dry, arid climate because of the low levels of innate humidity. Green areas help to regulate and balance humidity by adding moisture to the air, improving the comfort of the surrounding area.

Another finding from this is that, with the right amount of shade, even a paved surface may be made cooler for temperature. In this situation, shade becomes a crucial element for thermal comfort. It could be trees or some man-made structures that may provide that shade. If all the streets were covered in shade throughout the afternoon, society would be mor**e** comfortably cooled. In the study, a comparable instance could be seen where the society had narrow streets and the building form was closer to one other, achieving mutual shading. These buildings that cast shadows on one another are exposed to less direct sunlight, which minimises heat absorption. These shaded spaces between buildings offer protection from the sun's rays and create welcoming areas for people to meet in public. This promotes outside activities and boosts social interactions.

In conclusion, this research provides insight into the potential of a development scheme of independent bungalows in easing the microclimate. It also provides hints and recommendations to achieve an efficient microclimate using open spaces as well as other design tactics. There are multiple layers to understanding microclimate and its factors which can be further explored in other typologies as well, which gives us an idea of their potential.

On a larger scale, while planning the HRHD area, a network of these typologies can be created to ease the climatic pressures in the neighbourhood and make a green network not only of public spaces but also through the residencies. In addition to better air quality and climatic regulation, a green network in HRHD also reduces noise, boosts biodiversity, provides recreational possibilities, fosters social cohesion, and manages stormwater sustainably. By introducing green spaces and

natural features into the highly populated urban fabric, the HRHD environment becomes more sustainable, functional, and conducive to the health and welfare of its residents.

12. List of Figures

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