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Integrating Climate Smart Development through Bioclimatic Planning and Principles: The Case of the World Heritage City of Vigan, Philippines

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ABSTRACT

With rapid and unplanned urban development, there is the emergence of Urban Heat Islands, altering the microclimate of the city. As a coping mechanism, several studies have integrated bioclimatic planning for climate-smart development in the Western context; however, there is an inadequacy of studies focusing on the application of bioclimatic design for a tropical urban climate like the Philippines. Furthermore, studies regarding city microclimate analysis are absent in the country. This study aimed to enumerate the factors contributing to warmer temperatures in the urban core of the heritage district of Vigan and provide bioclimatic environmental planning strategies to encourage climate-smart development on the site.

Keywords: *ENVI-met, Green principles, Microclimate, Passive cooling, Urban Heat Island effect*

INTRODUCTION

Increasing global population simultaneously occurs with rapid urbanization, which prompts land use for commercial, residential, and financial establishments. The alteration of urban form has caused degradation and destruction of the natural environment. Multiple urbanization development contributes to unhealthy living conditions such as highly dense development, lack of open spaces and green areas, traffic load, air, noise pollution, and urban heat island (UHI) effect (Axarli & Teli, 2008; Ramakreshnan et al., 2018; Salleh et al., 2013). Further, the built and natural environment in the cities influence microclimate. The conglomeration of buildings and the street configuration affect microclimatic and environmental conditions, raising the temperature and wind patterns (Rodríguez Algeciras & Matzarakis, 2016). This urban development often leads to UHI when there is a significant temperature rise within a city compared to its surrounding rural areas. Urban settlements have turned to warmer external temperatures than rural areas, and cities worldwide are experiencing more common urban heat islands (Skoulika et al., 2014; Taha et al., 2017).

Nowadays, urban development is continually prompted by the national government action plan (NEDA- Ilocos RDP 2017-2020) and the Vigan City Ordinance no. 4, S 2000 to further strengthen and implement the building design and construction regulations for addition, extension, renovation, restoration and adaptive reuse of old historic structures. Coupled with commercial and tourist establishments, Vigan has increasingly become urbanized, even sacrificing the area's decrease or the loss of green, open spaces and landscaping. Because of the compacted space, public streets are also developed for extended urban activity. With the changing urban morphology, there is a growing concern for the microclimate conditions of the city. The urban heat island effect worsens the experienced tropical, humid climate in the city that may lead to thermal discomfort to the external tourist activity and the city life. Especially since a large number of visitors travel to Calle Crisologo, the primary tourist site in the city (Alconis & Singun Jr., 2019).

There are many causes of UHI, such as paved and impermeable surfaces that not only absorb solar radiation as heat but also displace vegetation and soils, which in turn enhances heat retention by limiting the effectiveness of a natural cooling mechanism known as evapotranspiration (Stone et al., 2001). Dark-colored or low-albedo materials on road surfaces and external facades (O'Malleya et al., 2015). Intensive land use and high density in urban areas combined with buildings with high thermal masses and heat retaining properties (Harlan & Ruddell, 2011). Anthropogenic heat emissions, pollution, and reduced wind speed are caused by the design and layout of the built environment (Fernandez et al., 2015). Moreover, climatological studies in the context of tropical and equatorial climates are few in general.

A related study included for reducing heat-gain is by Din et al. (2012), who studied the thermal radiation effect of various material components (brick, concrete, granite, white concrete tiles) of a building's exterior wall surface in an urban area. They found that the most sensitive material that absorbs and stores heat is in the following order: brick>concrete>granite>white concrete tiles. The high heat capacity of the materials was the main influence contributor to the UHI. Furthermore, granite and white concrete tiles were suggested as the most suitable materials for the exterior wall building, which provide a thermally comfortable outdoor environment.

In a study by Lee et al. (2018), it was found that the shades provided by an umbrella, tree, and building provide a significant amount of cooling. The building was the most effective in mitigating heat from sunny weather; shade from a tree was less effective, and shade from an umbrella was least effective. They found that the determinant of the objects' rankings is its ability to prevent the absorption of short-wave radiation.

When it comes to natural structures, vegetation lowers the temperature in a specific area, contributing to microscale cooling (Duarte et al., 2015). However, the cooling does not spread. The effect of vegetation in preventing overheating in urban canyons and decreasing solar radiation absorption is through giving shade and increasing evaporative cooling by the leaves and soil coverage.

Many studies are focused on the effects of shading, vegetation, and building materials in urban microclimates and urban heat islands. But there is an inadequacy of studies focusing on the application of bioclimatic design for the tropical urban climate. Also, there are insufficient climatological studies on urban cities in the Philippines and none in the city of Vigan. Thus, this study adds to the knowledge on climatological assessment in the tropics and equatorial regions and corresponding climate-sensitive bioclimatic design.

Hence, the study aims to enumerate the critical factors contributing to the rise of air temperature in the Vigan. Likewise, passive cooling strategies were also tested for their effect on potential air temperature.

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METHODOLOGY

This study's method is a descriptive methodology, specifically evaluative and applied research, an approach using ENVI-met software Technology version 4.4.5. This was processed from the heritage district microclimate inputs of variables based on the urban setting of the protected zone's three-dimensional space. For this purpose, the Bioclimatic situation of the urban form was investigated through the microclimatic simulation using the micro-scale ENVI-met, applied in the heritage district block surrounded by streets of Gen. Luna, V. Delos Reyes, Crisologo, and Salcedo and nearby environment situated within the Central Business District (CBD) of Vigan. The methods used in this study are similar to the methods used by (Dela Cruz, J, 2022),

The microclimate in the city existed and was influenced by the interaction between natural and human-made factors. Natural factors consist of ~~the~~ prevailing climatic conditions, landforms, and precipitation. On the other hand, the human-made factor is the urban built environment and its characteristics, such as the buildings' orientation and geometry, materials used, colors, warm external temperature, and air pollution (Despoina & Kleo, 2018). Its urban setting influences the microclimate of Vigan. The natural and built environment are variables that dictate the result of the ENVI-met simulation.

Natural Factors, including precipitation (rain), relative humidity, air temperature, and wind speed and direction, are meteorological inputs from the local weather station in Ilocos Sur. The PAG-ASA database from the past ten (10) years up to the present was used as the microclimate data inputs of the environmental factor variable.

Another factor needed by the software for simulation is the human-made environment. It was manifested from the influence of urban development that serves as the basis for acquiring the data on urban heat. The materials used in the urban setting have their specific value in bioclimatology about urban heat. The urban albedo effect was observed on the materials used due to increased temperature.

The data collected from natural and man-made factors were investigated and appraised by the ENVI-met software to acquire specific urban heat and was processed to develop the simulation result.

The heritage core block was chosen as the study site since it has been a subject of constant repair, renovation, restoration, and establishment of commercial buildings in Vigan, the leading site for tourist activity. It is a dense part of the Vigan urban area due to the 3-major hotels within the tourist belt, mixed with the location of bottling company storage that creates a more expansive paved space facility. Vehicular of either tourist, local, and delivery of goods for hotels, commercial establishments, and nearby bottling companies passing thru within the site of study.

Specifically, the heritage core block is located within and adjacent to the streets of Gen. Luna, V. Delos Reyes, Crisologo, and Salcedo (refer to figure 1). To create a 3D model of the urban form and layout of the site, SketchUp 2019 was utilized. Then, via the ENVI-met INX SketchUp plug-in, it was exported to ENVI-met Spaces version 4.4.5. The software suite calculates microclimate dynamics using fundamental fluid dynamics and thermodynamics laws. It has been used as a primary bio-climatic tool in the microanalysis of design and

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planning studies, such as site development and environmental assessment (Alves et al., 2022; Graham et al., 2020). Hence, it is suitable for micro-scale experiments to assess this site, just like this study.

Figure 1
Location of the study area in the province of Ilocos Sur, Philippines

The data-gathering process involved collecting climatological data for numerical input and on-site investigation of urban morphology to create a model. First, on-site measuring of open spaces and building dimensions were done and modeled through Sketch-Up. Then, via the ENVI-met INX SketchUp plug-in, it was exported to ENVI-met Spaces

Table 1
Maximum/Minimum temperature on the 4-warmest months

Max. / Min.	MARCH	APRIL	MAY	JUNE	AVERAGE TEMP.
2020	32.6 / 23.9	33.0 / 25.5	35.5 / 24.4	34.0 / 25.1	33.8 / 24.7
2019	32.6 / 23.1	33.5 / 24.8	34.0 / 24.2	34.4 / 24.9	33.6 / 24.25
2018	34.0 / 21.5	35.0 / 23.6	34.5 / 25.8	33.2 / 26.5	34.2 / 24.5
2017	36.5 / 24.6	34.2 / 20.2	35.5 / 26.0	34.0 / 25.2	35.05 / 24.0
2016	32.5 / 22.5	35.0 / 24.7	35.3 / 26.5	33.5 / 26.3	34.1 / 25.0
2015	35.8 / 23.3	34.0 / 24.6	35.0 / 25.3	35.0 / 25.9	34.95 / 24.8
2014	35.0 / 23.9	33.5 / 24.7	35.5 / 26.1	35.0 / 26.5	34.75 / 25.3
2013	34.0 / 24.0	34.5 / 23.5	34.5 / 23.4	34.5 / 25.5	34.4 / 24.1
2012	34.7 / 24.9	33.8 / 24.0	34.7 / 25.2	32.7 / 25.8	34.0 / 25.0
2011	35.6 / 20.0	35.0 / 22.5	35.0 / 23.0	35.3 / 24.7	35.2 / 22.55

HIGHEST TEMPERATURE WITHIN 10-YEARS SPAN
HIGHEST TEMPERATURE OF THE YEAR

version 4.4.5. Second, the natural factors, including precipitation(rain), relative humidity, air temperature, and wind speed and direction from 2010-to 2020, were requested from the nearest local weather station.

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Figure 2

Annual temperature from the 4-warmest months for the past 10 years

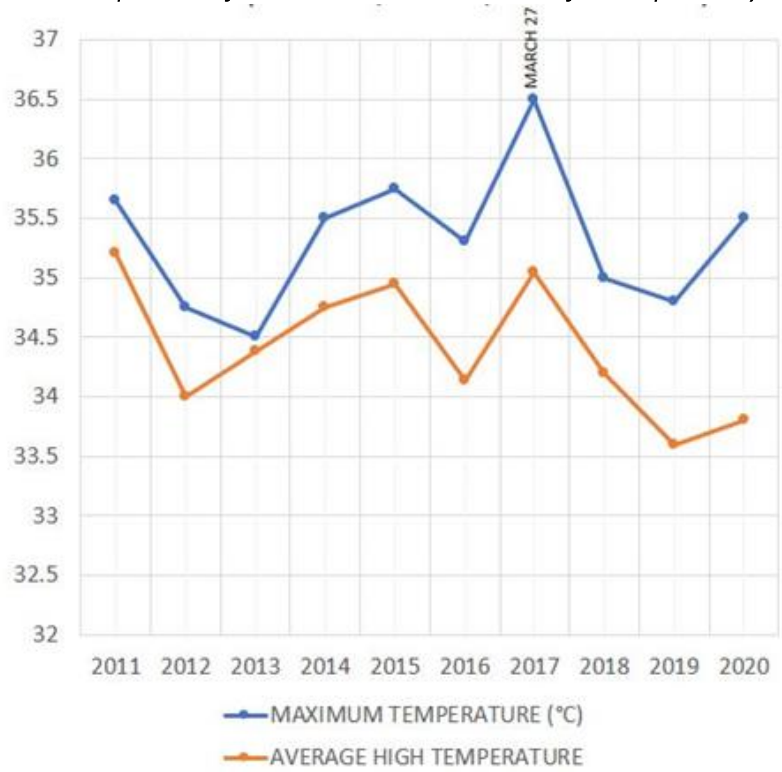

Table 2

Microclimate values of heritage block on March 27, 2017

Time	Temperature °C		Relative humidity (%)	Wind speed (m/sec)	Wind Direction (deg.)
	Min.	Max.			
8:00	19.62	28.63	72.5	2.07	93.6
9:00	19.67	30.64	69.0	2.06	91.6
10:00	20.72	32.20	65.2	2.03	94.9
11:00	22.08	33.42	61.1	2.15	100.2
12:00	23.53	34.87	56.9	2.29	99.1
13:00	25.0	34.88	55.4	2.34	97.0
14:00	26.30	35.82	55.2	2.37	97.1
15:00	27.4	35.93	54.3	2.38	98.7
16:00	28.82	36.87	53.8	2.39	100.5
17:00	28.70	35.40	55.3	2.38	101.7

From the given database, the day which recorded the highest maximum temperature, March 27, 2017, was selected as the simulation date for the model (refer to table 1 and figure 2). Factors such as wind speed and direction, maximum and minimum

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temperature, and relative humidity were derived from this date as input for the simulation software (see table 2). Furthermore, the generated microclimate maps presented in this study are based on the hottest temperature recorded on March 27, 2017, as highlighted in table 2.

After simulation, the microclimate maps were processed using the Leonardo software from the software suite. The resulting microclimate air temperature represents typical hot and cloudless summer days in an equatorial location. By most literature, air temperature is the most crucial variable in UHI. The UHI intensity could be denoted as air temperature differences between urban and rural areas (Klysik et al., 1999). So, the study focused its assessment on the factors affecting air temperature in the site.

Also, alternative ENVI-met scenario models were made to assess selected passive cooling strategies. Then, differences in the resulting local areas of maximum and minimum temperature were the basis of the cooling effect.

RESULTS AND DISCUSSIONS

Influencing Factors Contributing to Rising in Air Temperature in the Heritage Block

As mentioned earlier, results for the variation of air temperature maps were based on urban morphology, site materials, vegetation, and weather conditions on March 27, 2017. For this study, specific areas of varying temperatures were analyzed to identify the factors contributing to the heritage site's air temperature.

For the urban morphology, historically, the urban plan of the town closely conforms to the Renaissance grid plan specified in Ley las Indias (Laws of the Indies) (UNESCO Bangkok, 2009), since it was a guide for town development for Spanish colonies in the Philippine archipelago (Lozano et al., 2015). It has a traditional Hispanic checkerboard street plan that opens up into two adjacent plazas: Plaza Salcedo has an L-shaped open space that forms the longer arm, and Plaza Burgos is the shorter (UNESCO Bangkok, 2009). The gridiron or checkered street layout is evident on the site (refer to figure 1). At present, the rested front wall of the building sets as the front lot property line. The windows and doors are directly in the public space. Also, the columns in front protrude outside from the wall of the building, resulting in a decrease in public space width. This protrusion was measured to range from 4 inches to 6 inches in length. Additionally, roof eaves of either 2 or 3 storeys have covered the public sidewalks with a maximum width of 650mm. As a consequence of the extending roof overhang, the road and wall surfaces' shortwave radiation-exposed area were minimized.

Furthermore, ancestral houses that serve as tourist attractions in Vigan were constructed between mid-18th to late 19th centuries (UNESCO Bangkok, 2009). These comprise two-story structures built of bricks and wood (Lozano, 2016), with a steep roof similar to traditional Chinese Architecture. However, due to numerous past fire incidents and local ordinances for fire prevention and restoration, these were renovated by replacing wood with concrete. Most roofs placed on the heritage site are made of iron, such as corrugated galvanized iron sheets. Usually, the walls of these buildings are plastered with lime. However, some, particularly those with walls facing South at Gen. Luna and Salcedo

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near the corners of Crisologo St., and also those facing the eastern part of the midmost building on Gen. Luna corner V. De Los Reyes St., use concrete walls unplastered with lime.

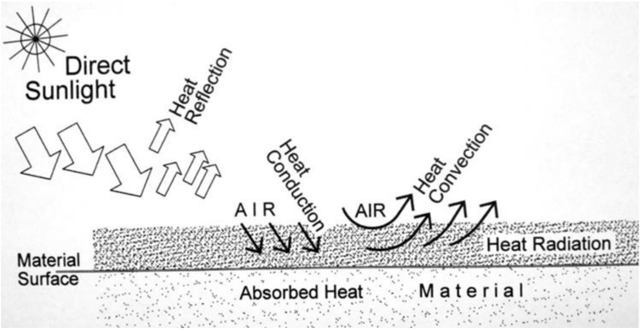
Moreover, the ancestral houses within Salcedo corner de Los Reyes St. maintained their historical design since the second-floor wall has prominent wood structures. Additionally, the most common ground pavement observed is yellow San Esteban stones (also called Piedra China). In contrast, concrete pavement is only situated in the open space on the central block adjacent to V. De Los Reyes St. (see figure 3) Such materials have varying albedo effect values. As such, those that have lower solar reflectance, or lower albedo, such as effect contribute to greater heating (Enriquez et al., 2017) (refer to figure 4).

Figure 3

Open space covered with concrete pavement

Figure 4

Albedo effect of material



In terms of the naturally built environment, trees such as Mango (*Mangifera indica*), Tamarind (*Tamarindus indica*), and Talisay (*Terminalia catappa*) are emplaced near Gen. Luna and V. De Los Reyes streets, although few. No trees or shrubs are present in Salcedo Street, aside from some wild grasses. Also, shrubs are scanty.

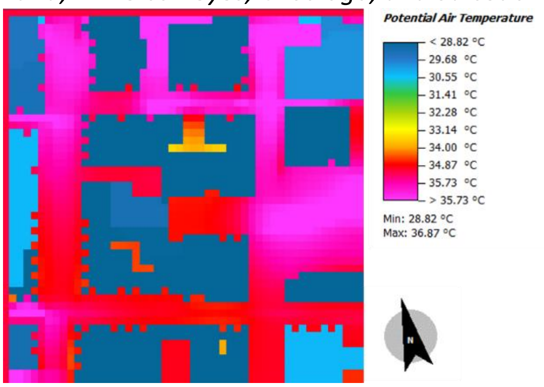
As shown in figure 5, areas with temperatures ranging from 35.73 to 36.87 are densely located at the upper part of the map, which is Gen. Luna St. This is the street where the concrete building walls are absent of lime plaster. These wall surfaces have increased thermal conductivity than those plastered since the thermal conductivity of mixtures using lime is low compared to cement, especially white cement (Stefanidou et al., 2010). Also, according to the findings of Stefanidou et al. (2010), lime is not an insulator, but it has good thermal properties. Since there is no insulation plastering material on the site, areas with walls of lime plastering recorded cooler temperatures than those with none. Moreover, the road intersections in this area, including Gen. Luna and V. Delos Reyes, have notable high temperatures. Intersections have more surface area, allowing them to openly receive the sun's heat and emit it (Kusumastuty et al., 2018), especially during afternoon direct solar beams. Consequently, it was shown to have hotter temperatures than the rest of the study site.

Additionally, the bungalow rise building, placed at the intersecting corner of the lower left part of the map, opens direct sunlight to the pavements during most times of the day, mainly because the sun's orientation in the afternoon times in the site is southwest. Furthermore, the narrow streets on the lower part of the map (Salcedo St. west of Crisologo St. intersection), the upper left part (Gen. Luna West of Crisologo St. intersection), and in the upper right (the road between Hotel Luna and Salcedo hotels) minimizes airflow, entrapping the heat between buildings (Rajagopalan et al., 2014).

Another area with temperatures above 35.73 °C is found on the middle right of the map, and a wide-open court is covered with the aged gray concrete pavement in the private space adjacent to Delos Reyes Street. Since it has a dark-colored surface, its solar reflectance is lower than the light-colored Esteban Stones common in the site. Thus, it tends to absorb more short-wave radiation, warming the air in that area.

Figure 5 Albedo effect of material

Potential Air Temperature map of Vigan Heritage Core Block Adjacent to the Streets of Gen. Luna, V. Delos Reyes, Crisologo, and Salcedo



Passive Cooling Strategies

To minimize the heat in the heritage core block, the authors tested three alternative scenarios as passive cooling strategies. These were based on the relevant areas throughout the site and designs that encouraged Vigan's aesthetic style and did not obliterate the Hispanic building designs. The scenarios are the following: trees and shrubs in protruded sidewalk columns, overhead vegetation, and shrubs on roof decks and upper floor balconies of private spaces, respectively.

As observed, there are blocking electrical posts, and some sidewalk spaces have been utilized for parking. Hence, open spaces such as sidewalks developed to be obstructed, narrow, and discontinuous for their functionality. Since it is stipulated under section 14 of the National Green Building Code of the Philippines to require a minimum of fifty percent (50%) permeable surfaces, it is suggested to convert nonfunctional paved sidewalks to an unpaved surface area (USA). According to this law, it shall be vegetated with indigenous and adaptable species (Department of Public Works and Highways, 2015). So, alternative scenario one is applied to pedestrian sidewalk spaces (refer to *figure 7*) that do not conform with the minimum sidewalk width. In this scenario, shrubs and palms were lined along the sidewalks of the buildings at General Luna St, along the streets of Crisologo and De Los Reyes. The addition of vegetation applies to sidewalks with little or no greenery (refer to figure 6).

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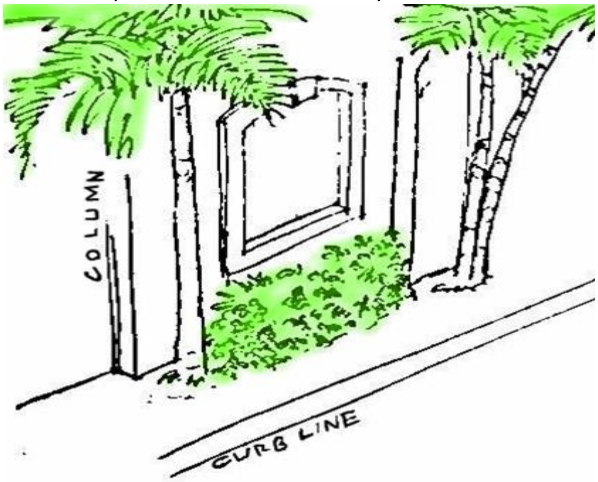
Figure 6
Bare Vegetation along Crisologo St. with Wall Facing West

Figure 7 Albedo effect of material
Placement of Vegetation in Protruded Sidewalk Columns (alternative scenario 1)



This scenario had a maximum temperature of 35. 09 °C, so it produced cooling by 1.78 °C (refer to figure 8). Many areas have notably cooled, including the intersections, narrow streets, and concrete pavement area, now having temperatures ranging from 34.37 °C to °C. Here, the cooling reduced the isothermal regions experiencing higher margins of temperatures. This is attributed to the evaporative cooling of vegetation spreading mainly to sidewalk areas, where the plant is located, characterizing findings of Duarte et al. (2015), where natural structures were limited to providing microscale cooling. Aside from that, the shading provided by the palms reduces heat storage in the adjacent ground by blocking incident radiation to the ground surface. The shrubs and trees also help deflect warm winds from the building facade (Foster, 2021).

Since it has been observed that there is existing overhead vegetation such as Bougainvilla (*Bougainvillea spectabilis*), evaluation and further application of this have been considered. Not only is the plant one of the trademark plants in Vigan, but promoting the landscape supports the kind of aesthetic apt for city tourism. Hence, in alternative scenario 2, overhead vegetation is applied above the functional existing sidewalks conforming with the minimum sidewalk requirements provisions of the National Building Code of the Philippines.

A shrub-like vine, specifically the indigenous Bougainvilla, was added to the sidewalk overhead along buildings in Crisologo, Salcedo, and V. De Los Reyes St., placed at 3 meters height from the ground, just above the usual door (refer to figure 9). This served the purpose of sun buffers to prevent direct sunlight radiation towards the building surface and absorb heat from the wall surfaces. This scenario had a maximum temperature of 34.97°C, producing the most cooling at 1.90 °C (refer to figure 10). Mainly, it is due to the higher surface area covered by the overhead vegetation compared to the shading provided by

Figure 8 Albedo effect of material
Potential Air Temperature of Alternative Scenario 1

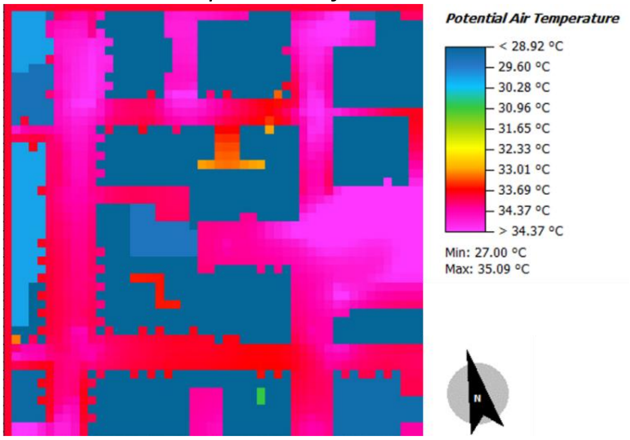
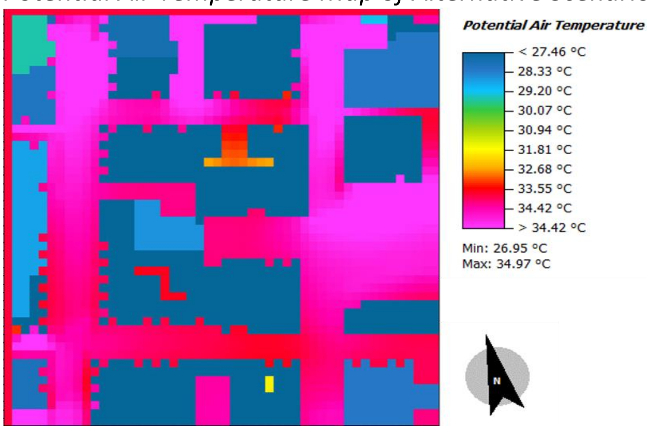


Figure 9 Albedo effect of material
Placement of Overhead Vegetation (Alternative scenario 2)

palms and shrubs in alternative scenario one. This vegetation orientation enabled the pavements and adjacent walls to receive more shading from direct, diffuse, and scattered radiation. Consequently, there are lower convective and radiative heat fluxes (Tsoka et al., 2020).

Figure 10 Albedo effect of material
Potential Air Temperature Map of Alternative Scenario 2



Not only that, the native variation of Bougainvilla is a leafy and flowery vine that increases the evaporative surfaces. Due to its high leaf density, it facilitates greater transpiration (Lin et al., 2017). This enables high heat conduction from building walls to the plant (Aram et al., 2019; Foster, 2021). However, its cooling did not spread enough to deviate from the microclimate isothermal regions in Vigan, comparing figures 4 and 6. Nevertheless, its impact lowered the temperatures in all areas.

To encourage green principles not limiting to public spaces, alternative scenario three is applied and recommended to the private entities interested in the rooftop and balcony vegetation (see figure 11). This involves shrubs or small trees with a minimum height of 1m. (3.28ft) so that it is higher than the rooftop and balcony guardrail, enabling incoming air to pass through the leaves (refer to figure 12). In the simulation, shrubs were added to

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the upper floor balconies and the roof deck of private spaces of buildings in General Luna and V. Delos Reyes St.

Figure 11 Albedo effect of material
Balcony of Cordillera Inn in General Luna & Crisologo St.

Figure 12 Albedo effect of material
Placement of Vegetation of Roof Decks and Upper Floor Balconies of Private Spaces

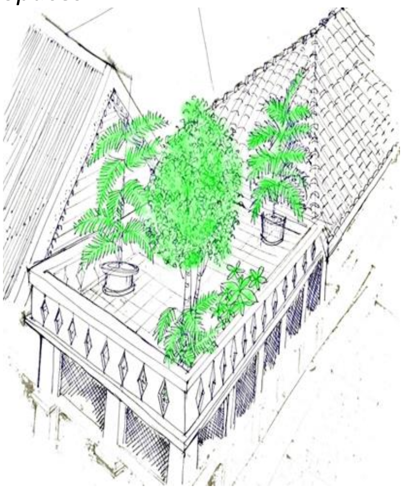

Figure 13
Placement of Vegetation of Roof Decks and Upper Floor Balconies of Private Spaces

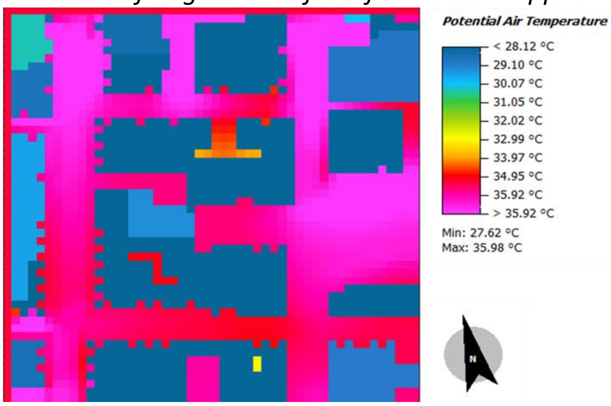

Table 3
Comparison of the Recorded Temperatures per Alternative Scenario Plans

Simulation	Description	Min. Temp. (°C)	Max. Temp. (°C)
SCENARIO -1	Along Sidewalk Level Vegetation	27.0	35.09
SCENARIO -2	Sidewalk Overhead Vegetation	26.95	34.97
SCENARIO -3	Roof Deck & Balcony Vegetation	27.62	35.98

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This scenario recorded the least cooling as it lowered the maximum temperature by 0.89 °C; overall, the various areas have cooled (refer to figure 13). Shading provided by the plants minimally reduces the sky view factor of the rooftop areas. However, just like the overhead vegetation scenario, it did not lessen the regions experiencing the upper range of temperatures. With that, a summary of the resulting temperature from the proposed vegetative cooling strategies is presented in table 3.

CONCLUSIONS

The study presented various factors for air temperature rise in the Vigan Heritage core block, contributing to the urban heat island. These include the following: absence of lime or insulating wall plaster, narrow spaces between buildings, low-albedo concrete pavement, and a general lack of vegetation. Overall, it was also shown that surfaces openly receiving short-wave radiation due to their orientation have higher air temperatures, such as the intersecting roads. Also, site-applicable passive cooling strategies to minimize the air temperature in the site have been tested. Generally, all vegetative placement has been able to lower the maximum temperature due to evaporative cooling. Moreover, the scenario that has the most impact on cooling at 1.90 °C is the overhead viny-shrub application. It is attributed to the higher surface area of shading it provides compared to palm trees and shrubs. This orientation landscape for vegetation is parallel to the principle of sun avoidance and reduction of heat gain from materials, a fundamental principle for environment-conscious design in the tropics, proposed by Emmanuel (2005). Thus, it is vital to consider bioclimatic planning done in equatorial regions of hot, humid climates to provide much shading in the designs, given the intense solar irradiation for areas in the equatorial belt. If not, urban heat islands would worsen existing discomfort brought by experienced high temperatures and high humidity in tropical cities. Its vulnerability to extreme heat events leads to increased air conditioning loads, reduced pavement lifetimes, and exacerbated heat waves, which are disadvantageous to site sustainability.

RECOMMENDATIONS

It is from this research outcome to come up with the different approaches and guidelines to be recommended to the Vigan LGU (Local Government Unit). The output of the study on bioclimatic planning and principle shall be included as a guide to reinforce the existing local ordinances. Plants, vines, and vegetation shall be provided on the site of study public spaces, especially in those areas suitable for its alternative location to decrease the urban heat island effect. These plants and vines shall be strategically located, showing the detailed architectural features of the Spanish colonial style of the Vigan heritage structures to be freely visible. Materials for public pavements shall be selected in nature, considering the effect of the solar heat shortwave. For private spaces, renovation and repair like the use of materials and the applied construction method for the old structures of Vigan houses shall not induce heat gain. The sky view in the heritage morphology is exposed to heat radiation from the roof structure. Private rooftops and balconies shall be recommended to provide clay potted higher plants that vegetation absorbs heat from this area of heightened temperature. There is a need for architects, engineers, and other professionals to conduct an assessment in the area of concern before planning and designing their proposed project within the Heritage zone, and may adopt the 3-alternative planning scenario to mitigate the urban heat island effect. Dues for the use of the approved materials for the proposed development will be commended for promoting sustainable preservation of the cultural heritage site of Vigan. These recommendations shall be considered an addendum to the Vigan Conservation Code to be applied for the conservation, restoration, renovation, and other development activities of the protective zone of the Heritage District of Vigan. These may be considered by the Vigan Conservation Council (VCC) as an additional requirement in applying for a building permit and repair within the core and buffer zone for the insertion of the environmental bioclimatic design principles in the heritage district. Since this study has investigated city microclimate in the outdoor setting, future studies can extend to examining indoor conditions of ancestral houses. As such, these include the hygrometric comfort perception of ancestral house occupants receiving natural ventilation.

ETHICAL STATEMENT

The authors declare that all confidential data regarding climate parameters have been obtained through an official letter to Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA).

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