



Microclimate baseline and wind-driven environmental exposure for climate-responsive residential development

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Received Date: May 20, 2026

Revised Date: August 02, 2026

Accepted Date: August 24, 2026

ABSTRACT

Background: Peri-urban housing expansion in tropical Indonesia requires environmental baselines that are not limited to rainfall, but also capture wind direction, wind speed, temperature, solar radiation, humidity, and atmospheric pressure as interacting microclimatic controls. This study develops an integrated microclimate and wind-driven exposure baseline for the planned Sunville Residence area in Paccinongang, Somba Opu District, Gowa Regency, South Sulawesi. **Methods:** The manuscript applies a descriptive quantitative design using secondary meteorological data for 2015-2024 and a 2025 windrose overlay map. Variables included wind direction and speed, air temperature, solar radiation, relative humidity, and air pressure. The analysis combined descriptive statistics, seasonal interpretation, Beaufort-scale wind classification, wind-driven receptor interpretation, and climate-responsive site-planning synthesis. **Findings:** The site is characterized by dominant easterly flow toward the west, low average wind speed of approximately 1.5-2.0 m/s, and a dominant wind-speed band of 2-3 m/s representing about 35%-40% of observed conditions. Monthly mean air temperature ranged from 27.40 °C in July to 29.23 °C in November, while maximum temperature reached 33.12 °C in October. Mean solar radiation ranged from 1.77 kWh/m²/day in July to 2.90 kWh/m²/day in March. Relative humidity remained high, with mean values from 70.42% in September to 84.20% in February, while mean pressure was stable between 99.70 and 99.90 kPa. **Conclusion:** The study shows that climate-responsive residential planning in Gowa should combine westward dust and nuisance control, shade-oriented thermal mitigation, moisture-resilient design, passive ventilation, and microclimate monitoring. **Novelty/Originality of this article:** The article converts a local environmental baseline into an internationally structured planning approach by integrating windrose exposure, Beaufort classification, and tropical microclimate parameters into practical recommendations for peri-urban residential development.

KEYWORDS: air pressure; climate-responsive planning; microclimate baseline; solar radiation; windrose.

1. Introduction

Rapid peri-urban development is one of the most visible spatial transformations in tropical cities. In many metropolitan fringes, former agricultural land, open fields, and mixed settlements are converted into housing estates, commercial nodes, and transport corridors (Setiawati et al., 2021). This transformation is not only a land-use change. It also modifies surface roughness, vegetation cover, soil moisture, heat storage, drainage response, and local airflow. As a result, environmental planning for new residential developments increasingly needs site-specific climatic evidence before design decisions are finalized (Priya & Senthil, 2021). A microclimate baseline provides this evidence by

Cite This Article:

Hammado, N., Humaerah, S. A., & Janwar, Z. (2026). Microclimate baseline and wind-driven environmental exposure for climate-responsive residential development. *EcoVision: Journal of Environmental Solutions*, 3(2), 234-251. <https://doi.org/10.61511/evojes.v3i2.2026.3898>

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describing how wind, temperature, solar radiation, humidity, and atmospheric pressure behave around a project site and how these variables may influence exposure pathways, construction impacts, outdoor comfort, and operational performance (Surya et al., 2021).

The importance of local climate evidence is reinforced by the growing relationship between urbanization and climate risk. Intergovernmental Panel on Climate Change (IPCC) assessments emphasize that cities and settlements face increasing exposure to climate-related hazards when development patterns interact with heat, rainfall, flooding, and air-quality stressors (Priya & Senthil, 2021; Setiawati et al., 2021). The World Meteorological Organization also recognizes the need for integrated urban services because urban areas concentrate people, assets, infrastructure, and climate-sensitive activities (World Meteorological Organization, n.d.). Although most environmental impact assessments focus on water, waste, biodiversity, and social impacts, microclimate variables are equally important because they influence the dispersion of airborne nuisance, the thermal performance of buildings, the comfort of pedestrians, and the resilience of green infrastructure. In tropical regions, where humidity and solar loading remain high for much of the year, these variables can determine whether a residential estate becomes environmentally adaptive or merely physically built (Priya & Senthil, 2021).

Wind direction and wind speed are particularly important in the environmental assessment of residential development. During construction, wind controls the direction of dust movement, the transport of fine particles from exposed soil, and the movement of odors or other nuisance sources from temporary storage areas (Duan et al., 2021). During operation, wind contributes to outdoor comfort, natural ventilation potential, pollutant dispersion, and thermal moderation (Lee & Mak, 2021; Li et al., 2022). Yet wind is also highly local. The direction and speed observed at a site can be affected by topography, river corridors, building density, vegetation, and the position of road networks (Duan et al., 2021; Li et al., 2022). For this reason, a windrose overlay is useful because it can connect meteorological direction with surrounding receptors. In the Sunville Residence site, the supplied windrose overlay indicates a dominant east-to-west wind pathway and identifies the western side as an important receptor zone containing residential areas.

Temperature and solar radiation complete the thermal component of the baseline. Tropical residential areas often experience high daytime heat loads from impervious surfaces, building roofs, asphalt roads, and limited canopy cover (Priya & Senthil, 2021). Recent urban heat island literature shows that land-cover change, surface materials, road networks, building density, and building geometry influence air and surface temperature patterns (Setiawati et al., 2021; Yin et al., 2022). In such contexts, early attention to shade, reflective surfaces, tree canopy, street orientation, and open-space design can reduce future heat stress (Setiawati et al., 2021; Chen et al., 2023; Yin et al., 2022). Green infrastructure, including trees, vegetated corridors, permeable surfaces, rain gardens, and green roofs, can reduce heat exposure through shade and evapotranspiration, while also supporting stormwater management and urban ecological quality (Alonzo et al., 2025).

Humidity and air pressure provide additional information about atmospheric stability and moisture conditions. High relative humidity can reduce evaporative cooling from the human body, intensify perceived heat, increase the likelihood of condensation in poorly ventilated spaces, and support biological growth on damp materials (Sadagopan et al., 2025). It can also affect the drying rate of construction materials and the performance of landscaping. Air pressure tends to be more stable in lowland tropical environments, but monthly pressure variation can still reflect broader seasonal circulation patterns. When interpreted together with wind, temperature, and radiation, humidity and pressure help to define whether a site requires stronger emphasis on ventilation, moisture control, shade, and climate-sensitive material selection (Guan et al., 2026; Sadagopan et al., 2025).

The study area is located in Paccinongang Urban Village, Somba Opu District, Gowa Regency, South Sulawesi. This area is part of the peri-urban landscape influenced by the growth of Makassar and surrounding settlements. The planned Sunville Residence by Limited Liability Company/*Perseoran Terbatas* (PT) Bumi Surya Persada is positioned in a mixed landscape containing settlement, roads, open land, river or drainage features, and

remaining agricultural or undeveloped areas. Such settings are environmentally sensitive because new housing can change runoff, surface temperature, traffic, dust generation, and local ventilation patterns. Baseline data must therefore be translated into design and management implications rather than treated only as descriptive background.

Previous environmental baseline documents for the same project have already examined rainfall and climate classification. The present article expands that logic by focusing on wind-driven exposure and non-rainfall microclimatic variables. This is important because drainage planning alone cannot address all climate-sensitive impacts. A residential estate also needs dust control during construction, passive ventilation during operation, shaded pedestrian networks, moisture-resilient building envelopes, green corridors, and monitoring systems that can detect changes after land conversion (Priya & Senthil, 2021; Setiawati et al., 2021). The literature on climate-resilient urban planning increasingly recommends integrated approaches that combine grey infrastructure, green infrastructure, and local environmental data (Li et al., 2022).

Accordingly, the objective of this paper is to develop an integrated microclimate baseline for the Sunville Residence planning area by analyzing wind direction and speed, air temperature, solar radiation, relative humidity, and air pressure. The paper also interprets the implications of these variables for climate-responsive residential site planning. The original contribution lies in converting a local environmental baseline into a structured international manuscript that connects windrose evidence with receptor exposure, Beaufort-scale interpretation, and site-level adaptation recommendations. The analysis is not intended to replace detailed computational fluid dynamics, air-quality modelling, or building energy simulation. Rather, it provides a reproducible baseline framework that can guide environmental management, design review, and future monitoring for peri-urban residential projects in humid tropical settings.

2. Methods

2.1 Study area and planning context

The study focuses on the planned Sunville Residence area located on Jalan Tun Abdul Razak, Paccinongang Urban Village, Somba Opu District, Gowa Regency, South Sulawesi, Indonesia. The project area sits within a peri-urban landscape where residential growth, road access, open land, river or drainage corridors, and surrounding settlements interact (Surya et al., 2021). The study area was selected because it represents a typical transition zone in which agricultural or open landscapes are being converted into residential use. Such sites require environmental baselines that address both construction-phase impacts and long-term operational climate performance (Priya & Senthil, 2021; Setiawati et al., 2021).

The supplied windrose overlay map positions the project boundary in relation to dominant wind sectors and surrounding receptors. The map indicates that wind-driven impacts from the project area are likely to be directed mostly toward the western side of the site. The western receptor area includes existing settlements, making it environmentally relevant for dust, nuisance, and air-quality management (Duan et al., 2021). This receptor-based interpretation was included because wind direction has limited planning value unless it is connected to the location of people, buildings, roads, drainage corridors, and sensitive land uses (Lee & Mak, 2021).

2.2 Data sources and variables

This study used secondary climate data and graphical evidence derived from the project environmental baseline. The variables were wind direction and wind speed, air temperature, solar radiation, relative humidity, and air pressure. The 2015–2024 monthly data series were used for the non-wind variables, while the windrose overlay represented the 2025 site condition. The baseline document identifies Meteorology, Climatology, and Geophysics Agency/*Badan Meteorologi, Klimatologi, dan Geofisika* (BMKG) Online as the

source for air-temperature data and NASA POWER as the source for solar radiation, humidity, and air-pressure data (Marzouk, 2021). NASA POWER provides solar and meteorological data derived from satellite observations, reanalysis, and assimilation models in hourly, daily, monthly, annual, and climatological formats, which makes it widely used for environmental, sustainable-building, agroclimatic, and renewable-energy applications (Marzouk, 2021).

The use of secondary data is appropriate for this baseline study because the objective is to characterize general microclimatic conditions and planning implications rather than to test a causal experimental hypothesis. Nevertheless, the interpretation is limited by the spatial resolution and representativeness of the source data, because NASA POWER solar data are provided at approximately $1^\circ \times 1^\circ$ grid resolution, while meteorological data are derived from MERRA-2 at approximately 0.5° latitude by 0.625° longitude resolution (Marzouk, 2021). For the purpose of environmental planning, the data were not treated as exact on-site measurements at every point within the project boundary. They were interpreted as a baseline context that should be supplemented by future field monitoring during construction and early operation.

2.3 Windrose and Beaufort-scale classification

Wind direction and wind speed were interpreted using the windrose overlay map and the descriptive wind-speed information in the baseline document. The windrose indicates the dominant direction of airflow and the approximate distribution of wind-speed classes. The main analytical step was to identify the dominant wind pathway, compare the reported speed with Beaufort-scale categories, and connect the direction of dispersion with nearby receptors. For consistency, the present study adopts the metric Beaufort thresholds reported by Deutscher Wetterdienst (DWD, n.d.) and applies the same terminology throughout the manuscript. The Beaufort scale relates wind speed to standardized descriptive categories ranging from calm (force 0) to hurricane (force 12).

Table 1. Beaufort wind-force classification adopted in this study

Beaufort force	Mean wind speed (m/s)	Standard descriptor
0	0.0–0.2	Calm
1	0.3–1.5	Light air
2	1.6–3.3	Light breeze
3	3.4–5.4	Gentle breeze
4	5.5–7.9	Moderate breeze
5	8.0–10.7	Fresh breeze
6	10.8–13.8	Strong breeze
7	13.9–17.1	Near gale
8	17.2–20.7	Gale
9	20.8–24.4	Strong gale
10	24.5–28.4	Storm
11	28.5–32.6	Violent storm
12	≥ 32.7	Hurricane

(Deutscher Wetterdienst, n.d.)

The project baseline reports an average wind speed of approximately 1.5–2.0 m/s and a dominant wind-speed class of 2–3 m/s, representing around 35%–40% of the windrose distribution. Under the adopted Beaufort thresholds, 0.3–1.5 m/s corresponds to force 1 (light air), whereas 1.6–3.3 m/s corresponds to force 2 (light breeze) (DWD, n.d.). Accordingly, the reported average lies at the transition from force 1 to force 2, while the dominant 2–3 m/s class is consistently classified as force 2 (light breeze). The non-standard descriptor “very weak” used in the project baseline is therefore not used as a Beaufort category in this manuscript. This low-speed regime may limit atmospheric dilution and contribute to localized accumulation of dust or heat when sources and receptors are close (Lee & Mak, 2021; Li et al., 2022).

2.4 Descriptive statistics and seasonal microclimate analysis

Monthly descriptive statistics were prepared for air temperature, solar radiation, relative humidity, and air pressure. For each variable, the analysis considered monthly maximum, minimum, and mean values where available. The seasonal interpretation focused on identifying the highest and lowest monthly means, the highest monthly maximum, the lowest monthly minimum, and the overall amplitude of variation across the year. This approach is suitable for environmental planning because monthly patterns provide clearer design guidance than annual averages alone, especially for tropical microclimate variables such as air temperature, relative humidity, wind speed, wind direction, and solar radiation (Fong et al., 2023). For example, the month with the highest solar radiation may guide shading strategies, while the month with the lowest humidity may influence landscape irrigation assumptions (Fong et al., 2023; Priya & Senthil, 2021).

The analysis also examined the variables as a connected microclimate system. Temperature was interpreted together with solar radiation because both influence heat stress, roof performance, and outdoor comfort (Fong et al., 2023; Priya & Senthil, 2021; Setiawati et al., 2021). Humidity was interpreted with temperature because high humidity at elevated temperatures can increase physiological strain, thermal discomfort, and perceived indoor air-quality problems (Zuo et al., 2021). Air pressure was interpreted as a background variable reflecting atmospheric stability and seasonal circulation. Wind was interpreted as a directional exposure pathway rather than merely a meteorological average (Fong et al., 2023).

2.5 Environmental exposure and planning synthesis

The study translated numerical and graphical results into planning implications for climate-responsive residential development. This synthesis considered four practical domains: construction-phase environmental management, operational outdoor comfort, building and landscape design, and monitoring. Construction-phase management includes dust control, soil stabilization, stockpile placement, wheel-washing, watering of exposed surfaces, and scheduling of dust-generating activities (Choi et al., 2023; Duan et al., 2021). Operational design includes street orientation, shade provision, vegetated corridors, permeable surfaces, ventilation pathways, and moisture-resilient materials (Fong et al., 2023; Priya & Senthil, 2021).

The exposure synthesis followed a precautionary approach. If the dominant wind direction points toward existing settlements, then western receptors should be prioritized for dust and nuisance control even if measured wind speeds are weak (Choi et al., 2023). If temperature and humidity indicate warm-humid conditions, then design should prioritize shading and ventilation rather than relying solely on mechanical cooling (Fong et al., 2023; Guan et al., 2026). If solar radiation is seasonally high, then roof materials, tree canopy, and pedestrian shading become important adaptation measures (Alonzo et al., 2025; Priya & Senthil, 2021). If pressure variation is limited, then changes in nuisance dispersion are likely to be driven more by local wind, source control, and land-cover change than by large monthly pressure swings (Duan et al., 2021; Lee & Mak, 2021).

2.6 Data quality, assumptions, and limitations

The study is subject to several limitations. First, the windrose overlay provides an important planning visualization but does not replace continuous on-site wind measurement at multiple heights. Second, secondary satellite- and model-derived climate products may not capture all microscale variations produced by buildings, vegetation, water bodies, or road surfaces. Third, the supplied humidity table contains source-reported values that should be verified in future data audits, especially for the distinction between maximum and minimum relative humidity. To avoid overinterpretation, the discussion

emphasizes robust patterns such as high humidity, low wind speed, and seasonal variation in mean values rather than unsupported fine-scale differences.

Table 2. Data sources, variables, and analytical use

Variable	Temporal coverage	Source stated in baseline	Analytical use
Wind direction and speed	2025 windrose overlay	Project windrose analysis	Dispersion pathway, receptor orientation, Beaufort-scale interpretation
Air temperature	Monthly 2015-2024	BMKG Online, 2025	Thermal baseline, heat mitigation, seasonal comfort interpretation
Solar radiation	Monthly 2015-2024	NASA POWER, 2025	Solar exposure, shade planning, roof and public-space design
Relative humidity	Monthly 2015-2024	NASA POWER, 2025	Moisture risk, comfort, ventilation and material resilience
Air pressure	Monthly 2015-2024	NASA POWER, 2025	Atmospheric context and stability interpretation

Despite these limitations, the data are sufficient for preparing an environmental baseline paper because the objective is to identify planning-relevant patterns. The recommended next step is to combine this baseline with site-based monitoring during the construction stage. Such monitoring should include portable anemometers, temperature and humidity loggers, dust measurements at western receptors, and periodic review of complaints or nuisance reports. This would allow the baseline to be converted into an adaptive environmental management system.

3. Results and Discussion

3.1 Wind direction, speed distribution, and receptor orientation

Table 3. Beaufort interpretation of reported wind-speed conditions

Indicator	Reported condition	Environmental interpretation
Dominant direction	East to west	Western receptor area becomes the priority for dust and nuisance control
Average wind speed	Approximately 1.5–2.0 m/s	Transition from force 1 (light air) to force 2 (light breeze); limited natural flushing
Dominant speed class	2–3 m/s, approximately 35%–40%	Force 2 (light breeze); most observed conditions occur in this low-speed band
Beaufort implication	Force 1–2 overall; force 2 dominant	Use standard Beaufort terminology consistently; source control remains more important than reliance on dispersion

(Deutscher Wetterdienst, n.d.)

The windrose overlay shows that the dominant airflow at the project site is from the east toward the west. This directional pattern is critical because the western side of the project contains settlement receptors. The result means that airborne nuisance from exposed soil, construction traffic, temporary material handling, and other activities may be transported toward existing residential areas when wind is aligned with the dominant sector (Choi et al., 2023). The effect is not necessarily severe in all periods, because the reported average wind speed is low, but the direction is environmentally significant because wind direction and surrounding built form can strongly influence airflow, dilution, and contaminant distribution (Lee & Mak, 2021).

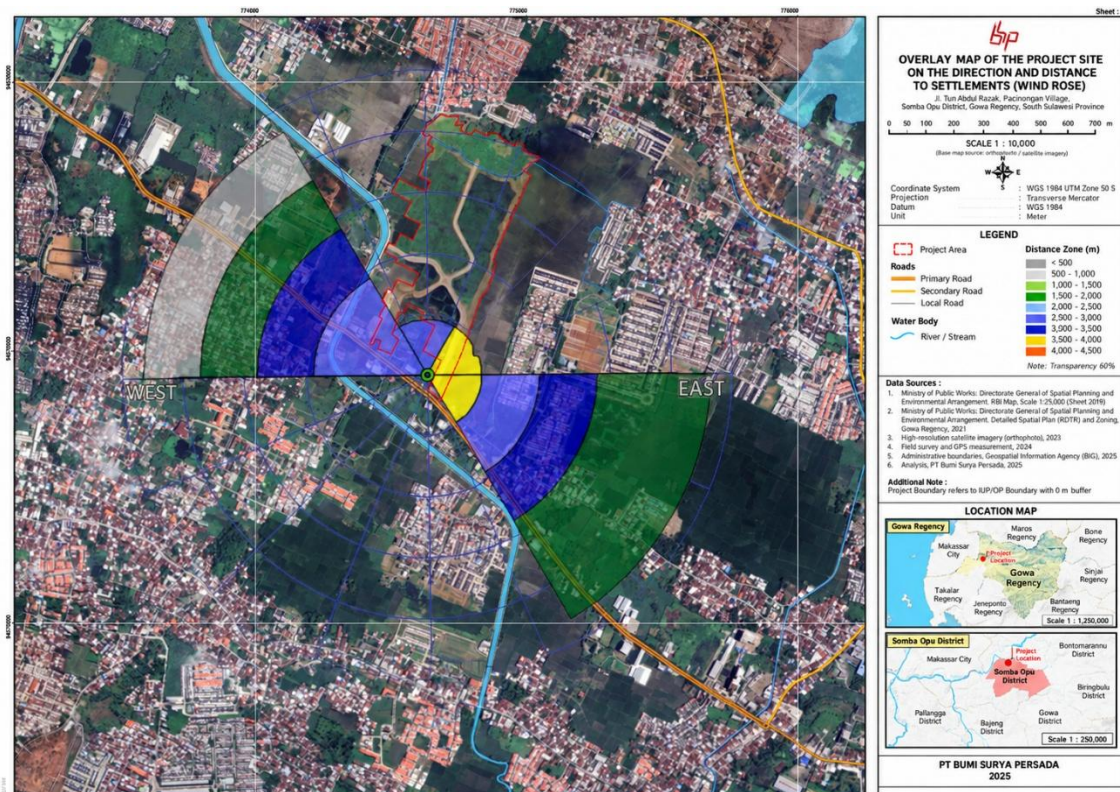


Fig. 1. Windrose overlay and receptor setting of the planned Sunville Residence site

The reported average wind speed is approximately 1.5–2.0 m/s, while the dominant wind-speed class is 2–3 m/s and accounts for about 35%–40% of the windrose distribution. Using the Beaufort classification adopted in Table 1, the average wind speed spans the upper limit of force 1 (light air) and the lower range of force 2 (light breeze), whereas the dominant 2–3 m/s class corresponds to force 2 (light breeze). Thus, the site is characterized by low-speed wind conditions rather than by a separate “very weak” Beaufort category. These conditions indicate limited natural flushing: long-range dust transport may be constrained, but dilution near source areas can also be reduced. Therefore, source control remains more reliable than reliance on wind-driven dispersion.

3.2 Air temperature baseline

Table 4. Monthly air-temperature baseline, 2015–2024

No.	Month	Minimum (C)	Maximum (C)	Mean (C)
1	January	25.24	29.98	27.61
2	February	25.05	30.20	27.62
3	March	25.25	30.58	27.92
4	April	25.41	31.80	28.60
5	May	25.34	31.56	28.45
6	June	24.68	30.90	27.79
7	July	23.96	30.85	27.40
8	August	23.91	31.69	27.80
9	September	24.01	32.57	28.29
10	October	25.00	33.12	29.06
11	November	25.59	32.86	29.23
12	December	25.61	31.66	28.63

The monthly temperature baseline shows a warm tropical regime with limited annual variation in mean temperature. Mean monthly temperature ranges from 27.40 °C in July to 29.23 °C in November. The lowest monthly minimum temperature is 23.91 °C in August,

while the highest monthly maximum temperature reaches 33.12 °C in October. This pattern indicates that the hottest maximum condition occurs before the highest monthly mean, suggesting a transition period in which clear-sky solar heating and seasonal humidity patterns may combine to elevate thermal exposure.

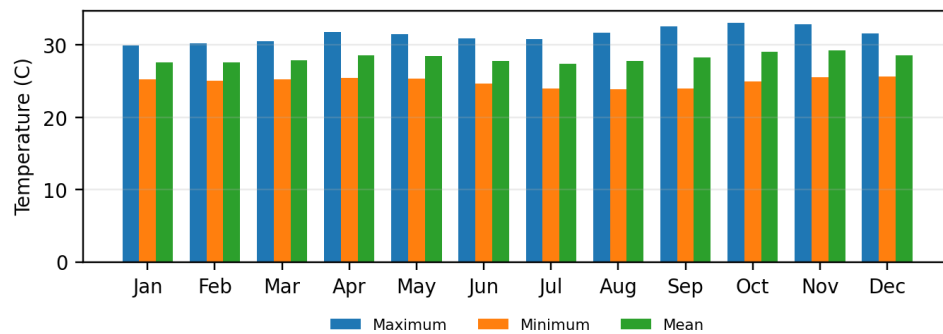


Fig. 2. Monthly air-temperature profile for the project location, 2015-2024

The annual amplitude of mean monthly temperature is 1.83 °C, showing that the site does not experience strong seasonal cooling. From a planning perspective, this means that thermal mitigation is needed throughout the year rather than only in a short hot season. Shade trees, roof reflectance, ventilated building forms, and shaded pedestrian corridors should therefore be treated as baseline design requirements rather than optional landscape features.

3.3 Solar radiation baseline

Table 5. Monthly solar-radiation baseline, 2015-2024

No.	Month	Minimum (kWh/m ² /day)	Maximum (kWh/m ² /day)	Mean (kWh/m ² /day)
1	January	1.96	2.81	2.39
2	February	2.12	3.36	2.74
3	March	2.23	3.56	2.90
4	April	2.18	3.26	2.72
5	May	2.01	2.86	2.44
6	June	1.75	2.51	2.13
7	July	1.01	2.52	1.77
8	August	1.77	3.18	2.48
9	September	1.87	3.52	2.70
10	October	1.23	3.57	2.40
11	November	1.45	3.21	2.33
12	December	1.00	3.10	2.05

Solar radiation values show clear monthly variation. Mean monthly solar radiation ranges from 1.77 kWh/m²/day in July to 2.90 kWh/m²/day in March. The highest monthly maximum reaches 3.57 kWh/m²/day in October, while the lowest monthly minimum is 1.00 kWh/m²/day in December. The highest mean in March indicates strong solar energy availability near the early dry-season transition, while the low mean in July reflects the period of reduced radiation in the data series.

The solar radiation baseline has two planning implications. First, the site has sufficient solar exposure to support daylighting and rooftop solar potential, although detailed design would require roof orientation, shading, and energy-yield analysis (Wang et al., 2025). Second, strong radiation increases the need for heat mitigation on paved areas, building envelopes, playgrounds, sidewalks, parking areas, and open spaces (Setiawati et al., 2021; Sobhaninia et al., 2025). Unshaded impervious surfaces can intensify heat storage and reduce outdoor comfort (Priya & Senthil, 2021; Setiawati et al., 2021).

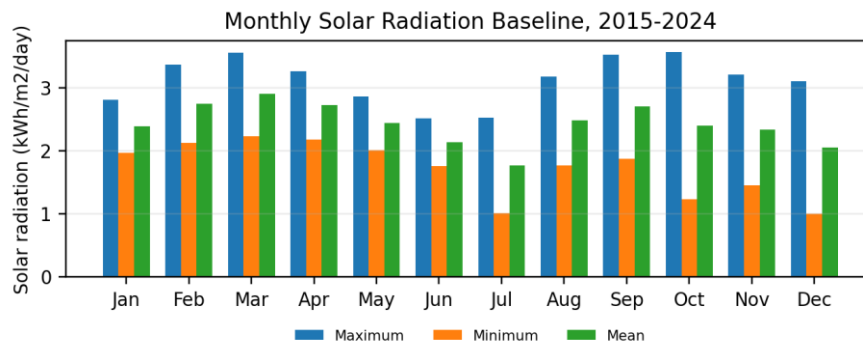


Fig. 3. Monthly solar-radiation profile for the project location, 2015-2024

3.4 Relative humidity baseline

Table 6. Monthly relative-humidity baseline, 2015-2024

No.	Month	Maximum (%)	Mean (%)
1	January	87.19	83.47
2	February	86.79	84.20
3	March	83.57	82.53
4	April	82.04	79.99
5	May	81.50	80.14
6	June	81.41	79.62
7	July	81.39	77.87
8	August	77.54	73.69
9	September	75.60	70.42
10	October	80.43	72.15
11	November	81.24	74.74
12	December	86.06	82.08

Note: The duplicated values previously presented in the minimum-humidity column were removed because they did not represent verified monthly minimums. The baseline narrative identifies 63.87% in October as the lowest verified minimum relative humidity during the analyzed period.

Relative humidity remained high throughout the annual cycle. Mean monthly relative humidity ranged from 70.42% in September to 84.20% in February, while the highest monthly maximum was 87.19% in January. The baseline documentation identifies 63.87% in October as the lowest verified minimum relative humidity during the analyzed period. The previously tabulated monthly minimum values were excluded from Table 6 because they duplicated the corresponding maximum values and therefore could not be interpreted as valid minimum observations. Overall, the verified data indicate a persistently warm-humid environment, although lower-humidity conditions occur during the latter part of the dry-season period.

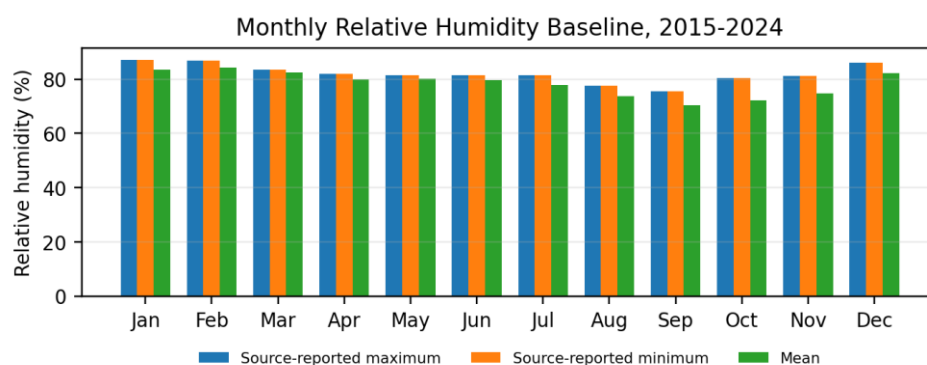


Fig. 4. Monthly relative-humidity profile for the project location, 2015-2024

The persistently high mean relative humidity can reduce evaporative cooling and intensify thermal discomfort when combined with elevated air temperature. From a building and landscape perspective, these conditions support the incorporation of cross-ventilation, moisture-resistant finishes, effective drainage, and vegetation arrangements that provide shade without obstructing airflow. The decline in mean relative humidity from February toward September, together with the lowest verified minimum of 63.87% recorded in October, indicates a relatively drier seasonal period in which dust control and landscape irrigation may require greater attention.

3.5 Atmospheric pressure baseline

Table 7. Monthly air-pressure baseline, 2015-2024

No.	Month	Minimum (kPa)	Maximum (kPa)	Mean (kPa)
1	January	99.61	99.91	99.76
2	February	99.70	99.97	99.84
3	March	99.68	99.93	99.81
4	April	99.70	99.86	99.78
5	May	99.72	99.92	99.82
6	June	99.75	99.90	99.83
7	July	99.77	99.99	99.88
8	August	99.79	100.00	99.90
9	September	99.78	99.98	99.88
10	October	99.72	99.96	99.84
11	November	99.61	99.78	99.70
12	December	99.63	99.87	99.75

Atmospheric pressure is stable across the annual cycle. Mean monthly pressure ranges from 99.70 kPa in November to 99.90 kPa in August. Maximum pressure reaches 100.00 kPa in August, while minimum pressure reaches 99.61 kPa in January and November. The small range of mean monthly pressure indicates that pressure variation is not the main driver of microclimate exposure at the site.

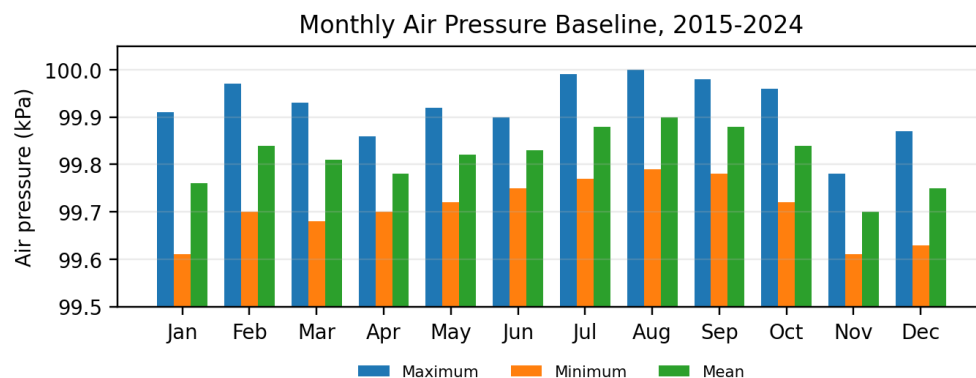


Fig. 5. Monthly air-pressure profile for the project location, 2015-2024

Because air pressure is stable, environmental management should focus more on variables that directly influence site impacts: wind direction, wind speed, surface exposure, vegetation, dust sources, moisture, and heat storage. Pressure data are still useful as part of the baseline because they show that atmospheric background conditions remain within a narrow lowland tropical range and do not introduce large monthly differences in dispersion interpretation.

3.6 Integrated microclimate profile

When the variables are interpreted together, the site can be described as a warm-humid, low-wind, seasonally solar-exposed peri-urban environment with a dominant

westward exposure pathway. The most important receptor implication is the western settlement area, which lies downwind from the project under the dominant wind direction. The most important design implication is that shading, ventilation, moisture control, and dust prevention should be integrated from the planning stage. The site is not defined by extreme wind hazard, but by the combination of low wind speed, high humidity, warm temperatures, and potential land-cover conversion.

Table 8. Integrated microclimate implications for planning

Baseline finding	Main environmental concern	Recommended planning response
Dominant east-to-west wind	Dust and nuisance movement toward western settlement receptors	Prioritize western buffers, stockpile control, watering, and monitoring
Light air to light breeze (Beaufort forces 1–2)	Limited natural dispersion and reduced passive flushing	Maintain ventilation corridors and reduce local emission sources
Warm mean temperature throughout the year	Year-round thermal discomfort risk	Provide shade, cool materials, tree canopy, and ventilated building forms
Seasonally high solar radiation	Heat gain on roofs, pavements, and open spaces	Use reflective/insulated roofs, shaded public space, and solar-responsive orientation
High relative humidity	Moisture discomfort, condensation, and material degradation	Promote cross-ventilation, drainage, moisture-resilient materials, and mold prevention
Stable atmospheric pressure	Exposure controlled more by local source-receptor geometry	Use local monitoring rather than pressure-based assumptions

The integrated profile also suggests that climate-responsive planning should be multi-functional. Vegetation can reduce heat, intercept dust, improve visual buffers, and support infiltration (Alonzo et al., 2025; Priya & Senthil, 2021; Sobhaninia et al., 2025). Permeable surfaces can reduce runoff while reducing surface heating compared with dark impermeable paving. Open corridors can preserve airflow while functioning as drainage and landscape space. These integrated measures are more suitable than isolated engineering responses because the microclimate variables interact rather than operate independently.

3.7 Wind-driven exposure and western receptor protection

The dominant east-to-west wind pathway has direct relevance for environmental management (Li et al., 2022; Lee & Mak, 2021). Although the average wind speed lies across the Beaufort force 1–2 transition (light air to light breeze), the western receptor area should be treated as a priority in the environmental management plan (Choi et al., 2023; Duan et al., 2021). Low wind speed does not eliminate dust risk. Instead, it can cause particles to remain near local sources and move gradually toward nearby receptors when construction activities generate repeated emissions. For a residential development, the most common nuisance sources include exposed soil, unpaved access routes, stockpiles, excavation, vehicle movement, and material loading or unloading (Choi et al., 2023; Duan et al., 2021).

The planning response should therefore prioritize source suppression. Exposed soil should be minimized through phased clearing, temporary ground cover, or rapid stabilization (Choi et al., 2023; Duan et al., 2021). Stockpiles should be located away from the western boundary where possible and covered during dry periods. Construction traffic should be managed with speed limits, wheel cleaning, and regular surface watering. If activities must occur near the western boundary, temporary screens or vegetated buffers can reduce dust movement (Choi et al., 2023; Li et al., 2022). These recommendations align with the broader environmental principle that controlling emissions at source is more

reliable than depending on dispersion after release (Choi et al., 2023; Duan et al., 2021; Li et al., 2022).

3.8 Low wind speed and passive ventilation potential

The low wind-speed regime has mixed implications for residential design. On one hand, light air to light breeze conditions reduce the likelihood of wind discomfort, wind damage to lightweight structures, or strong wind-driven rain under normal conditions. On the other hand, it limits the capacity for natural flushing of heat and pollutants (Li et al., 2022; Lee & Mak, 2021). In a warm-humid climate, passive ventilation is valuable because it can improve indoor comfort, reduce reliance on mechanical cooling, and lower energy demand. However, passive ventilation works best when buildings, streets, and open spaces are oriented to capture available breezes rather than obstruct them (Fong et al., 2023; Lee & Mak, 2021; Zuo et al., 2021).

For Sunville Residence, site layout should avoid continuous wall-like building rows perpendicular to the dominant airflow (Lee & Mak, 2021). Open corridors, staggered building placement, and connected green spaces can help maintain low-speed airflow through the estate. Because the dominant wind comes from the east and moves toward the west, road orientation and open-space planning should consider whether east-west ventilation corridors can be preserved without increasing dust exposure to western receptors. This requires balancing comfort and nuisance control, particularly during construction.

3.9 Thermal comfort in a warm-humid residential environment

The temperature baseline shows that the site remains warm throughout the year. The mean monthly range is narrow, but values above 27 °C indicate that outdoor and indoor heat management should be continuous (Fong et al., 2023; Priya & Senthil, 2021; Setiawati et al., 2021). In humid climates, thermal comfort cannot be addressed only by reducing air temperature (Sadagopan et al., 2025). It also depends on shading, air movement, mean radiant temperature, humidity, metabolic activity, and clothing. Urban climate studies show that tree canopy, cool materials, and reduction of impervious surfaces can moderate urban heat exposure (Alonzo et al., 2025; Priya & Senthil, 2021; Setiawati et al., 2021).

Residential planning should therefore include shaded walking routes, shaded waiting or social areas, canopy trees along streets, heat-reflective roof materials, and minimized dark asphalt exposure. Playground and community facilities should not be placed in fully exposed areas without shade. Parking lots should include canopy cover or high-albedo surfaces. Building setbacks should allow airflow and prevent trapped heat between structures. These measures are not only aesthetic; they are climate-adaptation measures that respond directly to the baseline temperature pattern (Alonzo et al., 2025; Priya & Senthil, 2021; Setiawati et al., 2021).

3.10 Solar radiation, daylighting, and heat-control trade-offs

Solar radiation data indicate both opportunity and risk. Mean radiation is highest in March, while the maximum value occurs in October. These periods may support solar energy use and daylighting, but they also increase roof and surface heat gain (Wang et al., 2025). Solar-responsive design should therefore avoid a single objective. Roofs may be optimized for photovoltaic potential while also using insulation, reflective finishes, or ventilated roof spaces to reduce indoor heat (Wang & Wang, 2024). Windows may be arranged for daylight but protected by overhangs, louvers, vegetation, or recessed openings to reduce glare and heat gain.

At the neighborhood scale, solar radiation strengthens the case for tree canopy and shaded public space. Tree selection should consider local climate tolerance, root behavior, maintenance requirements, and the need to avoid blocking drainage channels (Alonzo et al.,

2025; Priya & Senthil, 2021). Urban greening can provide cooling benefits, but the design must avoid creating stagnant humid pockets. A mixture of shade trees, open grassed areas, and ventilated green corridors is more suitable than dense planting that blocks airflow in already low-wind conditions (Fong et al., 2023; Priya & Senthil, 2021).

3.11 Humidity, moisture risk, and material resilience

The humidity baseline indicates a persistently moist atmospheric environment, with mean monthly relative humidity ranging from 70.42% to 84.20%. Although the lowest verified minimum relative humidity reached 63.87% in October, the annual pattern remained predominantly humid. This distinction is important because the occurrence of a lower short-term minimum does not contradict the generally high monthly mean humidity. Instead, it indicates seasonal variability superimposed on a consistently humid tropical baseline (Zuo et al., 2021). Such conditions can influence both construction and building operation. High humidity may slow the drying of concrete, plaster, paint, and soil surfaces, while prolonged moisture exposure during operation may increase the risks of condensation, mold development, and material deterioration in inadequately ventilated spaces (Guan et al., 2026; Sadagopan et al., 2025).

The analysis shows that the site is characterized by dominant east-to-west airflow, light air to light breeze conditions (Beaufort Forces 1–2), warm tropical temperatures, moderate to high solar radiation, and a predominantly humid atmospheric environment. Mean monthly relative humidity ranged from 70.42% to 84.20%, while the lowest verified minimum relative humidity was 63.87% in October. These findings indicate that occasional lower-humidity conditions occur seasonally but do not alter the generally humid microclimatic character of the site. Consequently, moisture-resilient materials, effective drainage, cross-ventilation, and appropriate landscape placement remain important components of climate-responsive residential planning.

3.12 Air pressure stability and interpretation of dispersion risk

The air-pressure baseline is stable, with only minor monthly variation. This finding suggests that local environmental management should not overemphasize pressure as an operational control. Instead, dispersion and exposure are more likely to be shaped by wind direction, wind speed, source strength, land-cover roughness, and receptor proximity. The role of pressure in the paper is therefore contextual: it helps confirm that the study area reflects a stable lowland tropical atmospheric setting rather than a site with strong pressure-driven seasonal contrasts.

In practical terms, pressure stability means that dust and nuisance management should rely on direct controls and monitoring. If complaints occur in western settlements, the response should examine construction activity, surface moisture, wind direction, and buffer effectiveness rather than attributing the issue to broad pressure changes. This reinforces the value of a receptor-oriented management system (Lee & Mak, 2021).

3.13 Climate-responsive site planning framework

The integrated baseline supports a climate-responsive site planning framework with five components. First, preserve or create ventilation corridors that respect the dominant east-west airflow while reducing dust exposure. Second, use green infrastructure as a multifunctional system for shade, dust interception, stormwater management, and ecological quality. Third, select building and landscape materials that reduce heat storage and moisture damage. Fourth, design drainage, infiltration, and open spaces as connected systems rather than isolated facilities. Fifth, implement monitoring that compares construction and operational conditions with the baseline.

This framework is consistent with international approaches to urban climate adaptation and nature-based solutions. Green infrastructure can reduce heat island effects

through shading and evapotranspiration, while also supporting stormwater control and air-quality improvement (Li et al., 2024; Sobhaninia et al., 2025; Zhang et al., 2023). However, the baseline also shows that green infrastructure must be locally calibrated. In a low-wind, humid site, vegetation should enhance comfort without eliminating airflow. In a westward exposure pathway, buffers should protect receptors without trapping dust inside the project boundary (Choi et al., 2023; Duan et al., 2021).

3.14 Construction-phase environmental management

Construction is the phase in which wind-driven exposure is most likely to create immediate social concern. Dust can affect visibility, respiratory comfort, household cleanliness, and perception of project responsibility. The baseline indicates that construction management should be stricter on the western side of the project and during dry or high-radiation periods. A simple monitoring plan can include daily visual checks of dust, recording wind direction, measuring wind speed during dusty activities, and documenting watering or stabilization measures.

The management plan should also include communication with nearby residents. If the western side contains existing settlement, residents should know the construction schedule, complaint channels, and mitigation commitments. Environmental governance is more credible when baseline evidence is connected to transparent management actions. This is especially important for peri-urban housing, where new development often occurs near established communities with different expectations about dust, traffic, drainage, and landscape change.

3.15 Operational monitoring and future research

After construction, the site should be monitored to evaluate whether the residential layout improves or worsens microclimatic conditions (Setiawati et al., 2021). Monitoring can include temperature and humidity loggers in shaded and unshaded areas, simple wind measurements in ventilation corridors, surface-temperature observations on paving and roofs, and resident perception surveys on heat and comfort (Fong et al., 2023; Priya & Senthil, 2021). These data would allow planners to compare the operational estate with the baseline and adjust vegetation, shade, and maintenance strategies (Sobhaninia et al., 2025).

Future research could expand this paper by combining the baseline with computational fluid dynamics, ENVI-met simulation, building energy modelling, or high-resolution remote sensing of land surface temperature (Katal et al., 2022; Yin et al., 2022). Such methods would quantify the effect of different layouts and greening scenarios. However, even without complex modelling, the present baseline already provides practical evidence: the site is warm, humid, low-wind, and directionally exposed toward western receptors. These characteristics should shape the environmental management plan and the physical design of the development (Katal et al., 2022).

4. Conclusions

This study developed an integrated microclimate and wind-driven exposure baseline for the planned Sunville Residence area in Paccinongang, Somba Opu District, Gowa Regency. The analysis shows that the site is characterized by dominant east-to-west airflow, light air to light breeze conditions (Beaufort forces 1–2), warm tropical temperatures, moderate to high solar radiation, consistently high relative humidity, and stable atmospheric pressure. The dominant wind direction makes the western settlement area the most important receptor zone for dust and nuisance management, while the low wind-speed regime means that source control is more reliable than reliance on natural dispersion.

The temperature and radiation baselines indicate that heat mitigation should be embedded in site planning through shade trees, reflective and insulated materials, shaded pedestrian routes, ventilated building forms, and reduced dark impervious surfaces. The

humidity baseline indicates that moisture-resilient design, drainage around buildings, cross-ventilation, and careful landscape placement are necessary for long-term comfort and building durability. The air-pressure baseline shows a stable atmospheric setting, confirming that local exposure is more strongly controlled by wind, sources, receptors, and land-cover design than by monthly pressure variation.

The paper contributes an applied framework for translating local climate baseline data into climate-responsive residential planning. For the Sunville Residence project, the recommended approach combines western receptor protection, east-west ventilation corridors, green infrastructure, dust suppression, moisture control, and post-construction monitoring. For similar peri-urban developments in humid tropical regions, the study demonstrates that microclimate variables should be treated as planning inputs rather than descriptive appendices. Integrating these variables early can reduce environmental nuisance, improve outdoor comfort, and support more resilient residential landscapes.

Acknowledgement

The authors acknowledge the availability of the environmental baseline data used in this manuscript and the public meteorological data services that support climate-responsive planning. Any remaining interpretation, synthesis, and recommendations are the responsibility of the authors.

Author Contribution

Conceptualization, N.H. and Z.J.; Methodology, N.H.; Formal Analysis, S.H.; Data Curation, Z.J.; Writing - Original Draft Preparation, N.H.; Writing - Review & Editing, Z.J. and S.H.; Visualization, Z.J.; Supervision, N.H.; Project Administration, N.H.

Funding

This research received no external funding.

Ethical Review Board Statement

Not available. This study did not involve humans, animals, or clinical/public health intervention research.

Informed Consent Statement

Not available.

Data Availability Statement

The data supporting the findings of this study are derived from the project environmental baseline document and publicly available climate data sources cited in the manuscript. Additional raw project data may be subject to project-owner permission.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used generative artificial intelligence to assist in language structuring, academic organization, and formatting. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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