



**SITE REPORT  
NINH THUAN, VIETNAM**

**50 MW SOLAR PROJECT**

**26 MAY 2022**

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## Summary

- ❑ This report focuses on the site selection phase of a solar project in the given area of interest in the province of Ninh Thuan, Vietnam.
- ❑ Selection of suitable areas to build a Solar project requires a set of considerations that range from technical, economic, social and environmental factors.
- ❑ Potential sites for solar projects are identified using a combinational Multi-Criteria Evaluation (MCE) based GIS (Geographic Information System) approach.
- ❑ Key details of the study is outlined in the following sections:
  - ✓ **Section 1:** Giving a detailed overview of the Site location complimented with information pertaining to the nearby power generation projects, power evacuation possibilities, and natural gas network
  - ✓ **Section 2:** Portrays key Site-specific details for each layer considered in the study i.e., Land use, Surface roughness, earthquake, floods, cyclones, soil load-bearing capacity, slope, distance to road/transmission network, and exclusion zones.
  - ✓ **Section 3:** Gives individual scoring of each layer showing the variability of these individual layers across the area of interest.
  - ✓ **Section 4:** Outlines detailed assessments of solar irradiance datasets like GHI,DNI,DHI together with temperature, wind and rainfall data. This section also estimates the generation yields for selected types of solar modules, thereby giving an overview on the general suitability of solar PV generation at the proposed project site.

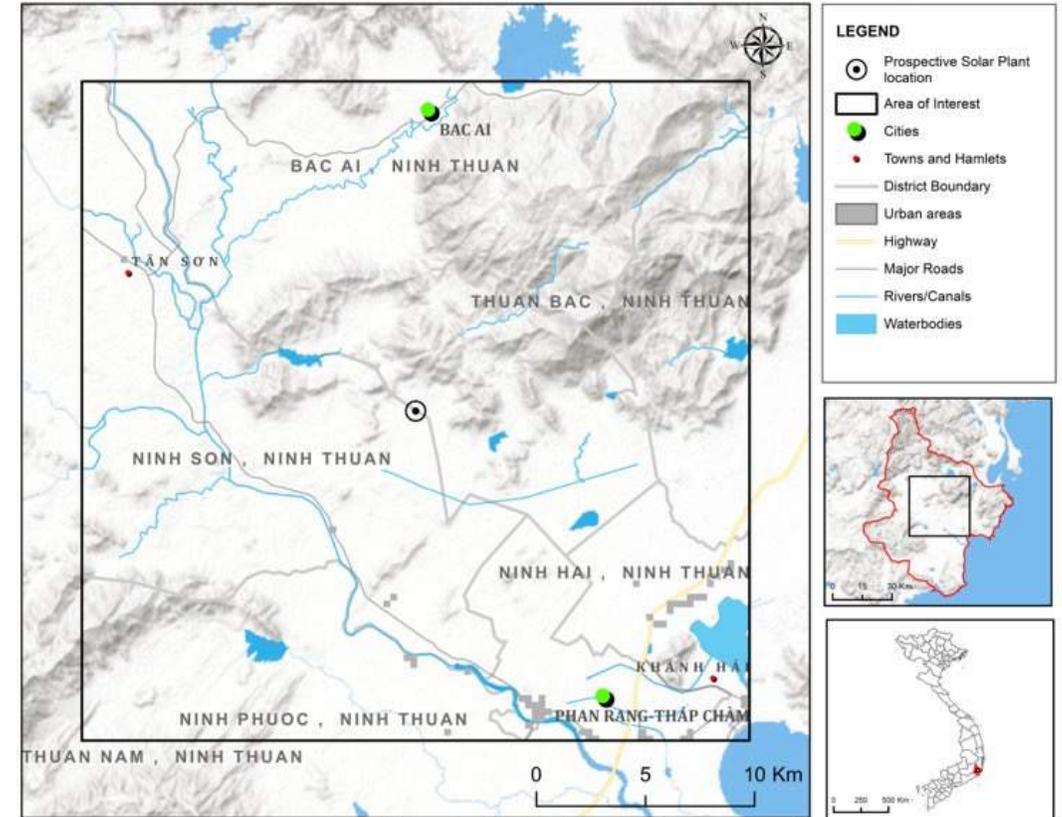


# Section 1: Site Introduction

# Site Profile

Particulars	Descriptions
Subdistrict	Bac Phong, Bao An, Dai Son, Do Vinh, Hai, Ho Hai, Hoa Son, Khanh Hai, Lam Son, Loi Hai, Luong Son, My Son, Nhon Son, Phu Ha, Phuoc Chien, Phuoc Chinh, Phuoc Dai, Phuoc Hau, Phuoc Hoa, Phuoc Khang, Phuoc My, Phuoc Son, Phuoc Tan, Phuoc Thai, Phuoc Thang, Phuoc Thanh, Phuoc Thuan, Phuoc Tien, Phuoc Trung, Phuoc Vinh, Quang Son, Tan Hai, Tan Son, Thanh Hai, Tri Hai, Van Hai, Xuan Hai
District	Bac Ai, Ninh Hai, Ninh Phuoc, Ninh Son, Phan Rang-Thap Cham, Thuan Bac
State	Ninh Thuan
Coordinates(Centroid)	11°43'0.694"N 108°53'57.682"E
Study Area(Sq.km)	900 sq.km
Nearest Railway	Ga Thap Cham Ninh Thuan
Nearest Airport	Phan Rang
Project Type/Capacity	Solar/50MW

**Power Generation Map – Nearby Infrastructure**



Source: Genesis Ray | Mapbox | ESRI Copyright protected by Genesis Ray © 2022

The study region lies within the districts of Vietnam; Bac Ai covering the northern part of the AOI, Phan Rang-Thap Cham and Ning Hai covering the Southeast, Ninh Phuoc covering the Southwest, Ninh Son towards the west and Thuan Bac towards the east, expanding across the sub-district of Phuoc Thai, Phuoc Vinh, Hoa Son, Phuoc Hoa, Phuoc Tan, Phuoc Thang, Phuoc Tien, Lam Son, Luong Son, Quang Son, Tan Son towards the west; Phuoc Dai, Phuoc Thanh, Bac Phong, Phuoc Khang, Ho Hai, Hai, Tri Hai, Tan Hai, Xuan Hai, Phuoc Hau, Phuoc Son, Phuoc Thuan, Bao An, Dai Son, Do Vinh, Phu Ha, Phuoc My, Thanh Hai, Van Hai, Bac Phong towards the east; Phuoc Chinh, Phuoc Trung, My Son, Nhon Son in the center.

## Nearby Power Generation Projects (1/3)

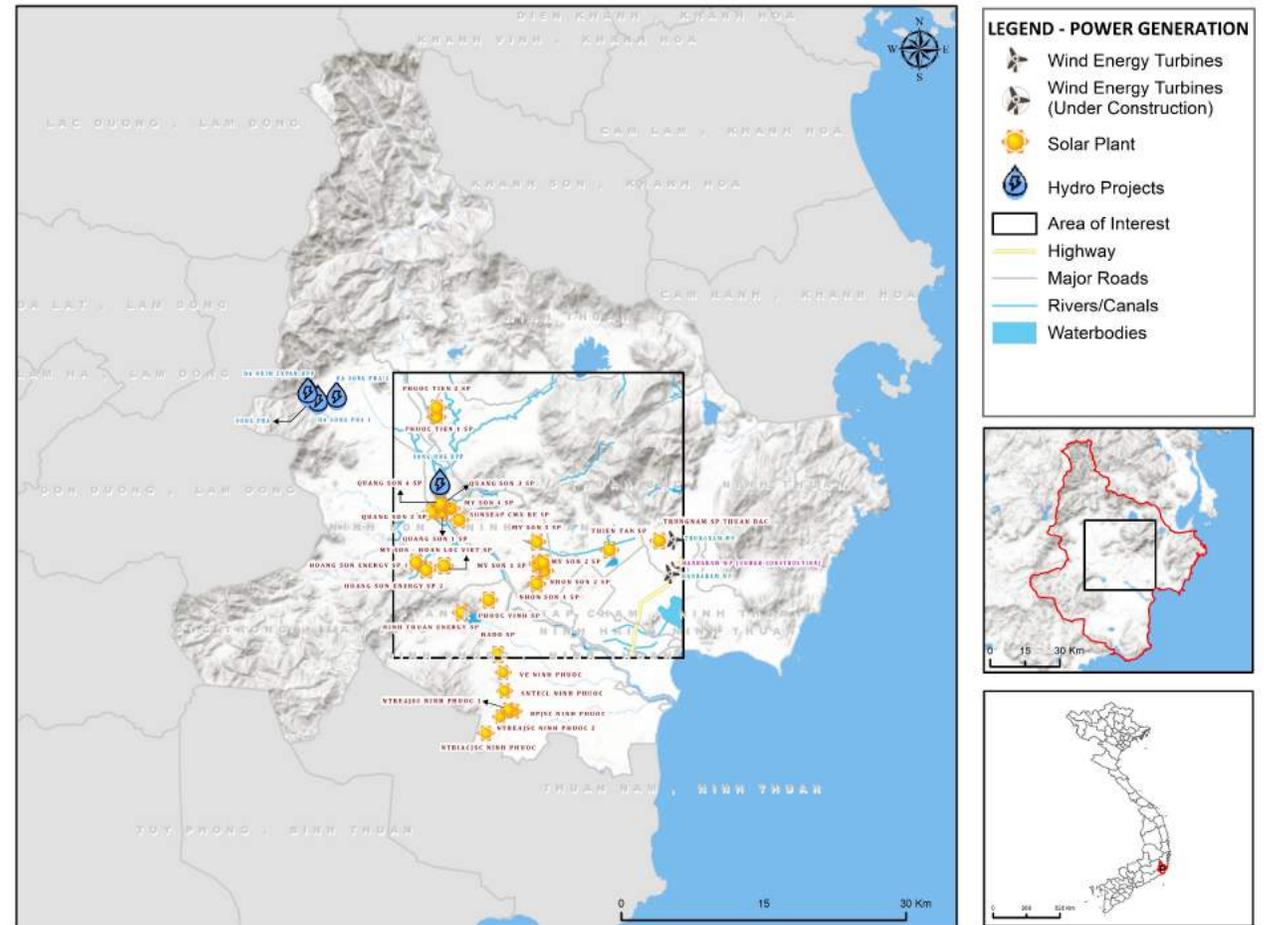
- The Area of Interest lies entirely in the Ninh Thuan province.
- Over 3.42 GW of power generation projects are completed in Ninh Thuan of which around 3.22 GW of projects are put into commercial operation.
- The total installed RE capacity across the state is over 2.92 GW.
- Ninh Thuan is also home to 9 major hydropower projects with an installed capacity of 299 MW.
- Within the Area of Interest, **~874 MW of RE installed capacity (698 MW - wind & 176 MW - solar)** is operational with certain projects owned by players like Trungam Group, Sunseap Cmx Re Solar, Hoang Son Energy etc.

*Note: RE includes on-grid solar and wind energy capacities only*

*Source: EVN, MOIT, Genesis Ray Energy Analysis*

*Statistics as on October 2021*

### Power Generation Map – Nearby Infrastructure



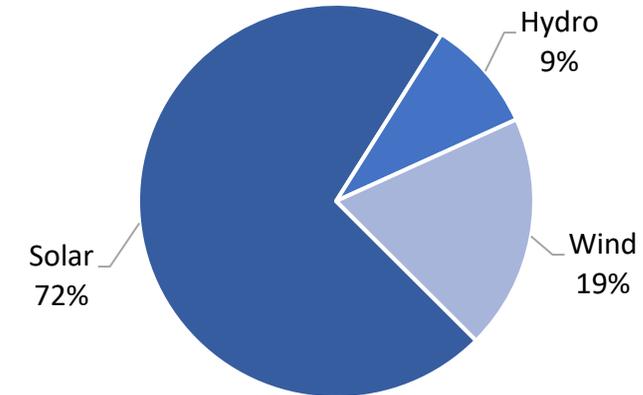
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## Nearby Power Generation Projects (2/3)

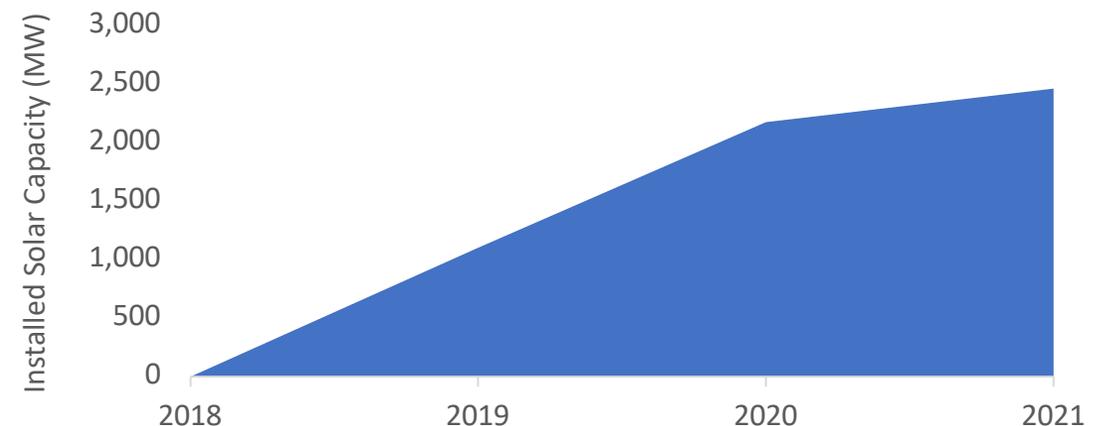
- Solar on-grid project development in the state started in 2018 and has seen rapid expansion since then.
- There are 35 completed solar projects in the state with a total capacity of 2457 MW, of which **2303 MW is operational**.
- The closest large scale solar project from the proposed location is a **62 MW project by Sunseap Cmx Re Solar Holdings Pte. Ltd**, which is around 7.5 km away, followed by a **50 MW project by Thien Tan Group** at around 8 km.
- These facts clearly indicate the area has high solar energy potential and many key players are scouting for ideal locations within the state for solar project development.
- As this is a fairly windy area, there are multiple wind turbines placed around the state, with a capacity of **over 622 MW operational** within the state.
- The largest wind project in Vietnam, a 151.95 MW project by Trungnam Group is approx. 12.5 km away from the proposed site.
- An 8.1 MW hydro power project by Song Ong Hydropower JSC is at a distance of around 11 km from the proposed site.
- There are no operational thermal (coal, gas, oil) and nuclear power generation projects in the study area.

*Note: Statistics as on October 2021*

**Share of Operational Capacity in Ninh Thuan (MW)**



**Year-wise trend of Installed Solar Capacity - Ninh Thuan**



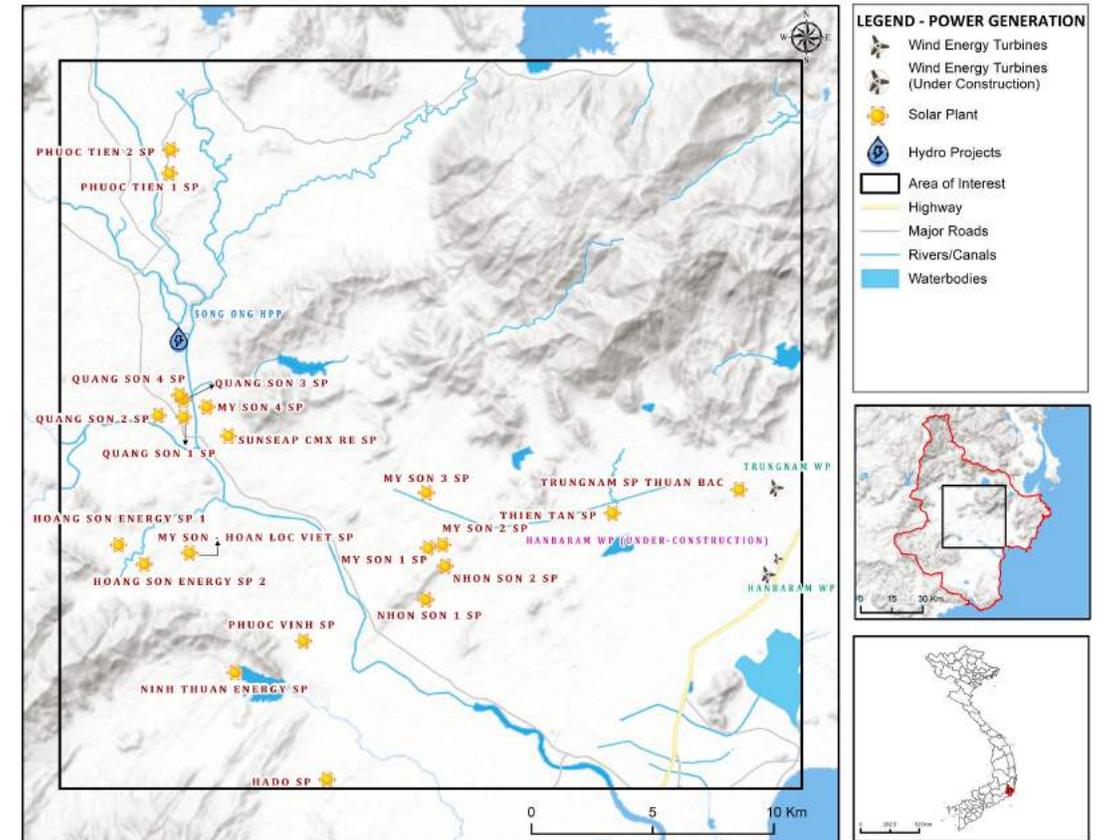
## Nearby Power Generation Projects (3/3)

List of projects with installed capacity ≥ 5 MW within the Area of Interest

S.No	Owner	Prime Mover	Total Plant Capacity (MW)	COD
1	Trungnam Solar Power JSC	Solar	204	2019
2	Sunseap Cmx Re Solar Holdings Pte. Ltd	Solar	168	2019
3	Trungnam Wind Power	Wind	151.95	2020
4	Hanbaram Wind Power JSC \$	Wind	93	-
5	Hoang Son Energy	Solar	62	2020
6	Thien Tan Group	Solar	50	2020
7	Hado Group	Solar	50	2020
8	My Son - Hoan Loc Viet Solar Power JSC	Solar	50	2019
9	Hoang Son Energy	Solar	50	2020
10	Ninh Thuan Energy Industry JSC	Solar	50	2020
11	Hanbaram Wind Power JSC	Wind	24	2021
12	Song Ong Hydropower JSC	Hydro	8.1	2009

\$ Under-construction project

Power Generation Map

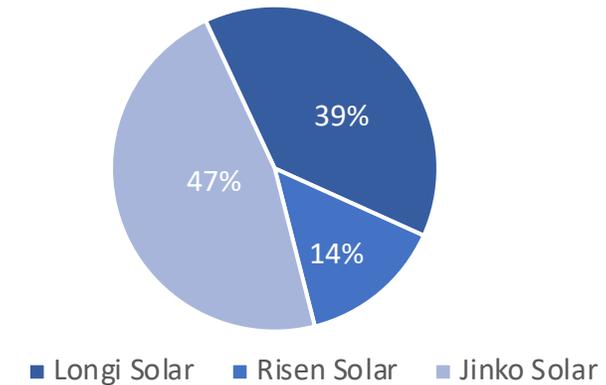


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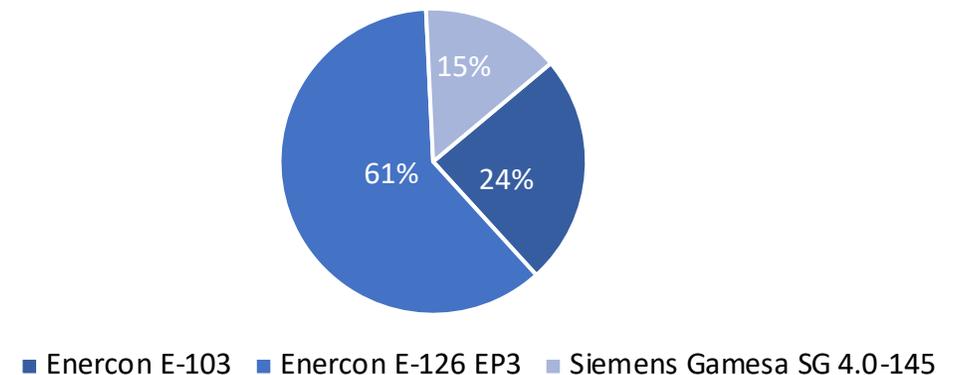
## RE Insights

- The largest solar project in Vietnam, the 450 MW Thuan Nam Solar Project by Trungham Group is at a distance of 28.5 km from the proposed site.
- There are 24 RE projects within the Area of Interest, with over 9 market players having more than 50 MW of installed capacity each.
- Trungham Group has the most share of RE projects within the Area of Interest with a capacity of ~356 MW, followed by Sunseap Cmx Re Solar Holdings Pte. Ltd with a capacity of 168 MW.
- The largest solar project within the Area of Interest, the 204 MW by Trungham Solar Power JSC uses over 7 lakh monocrystalline PERC panels on a 120-degree rotating rack system, which rotates and adjusts itself to receive maximum solar radiation throughout the day.
- There are 51 operational WTGs lying within the study area, with over 88% of them manufactured by Enercon.
- 24 MW of the proposed 117 MW wind project by Hanbaram Wind Power JSC is commissioned as of 31<sup>st</sup> October 2021. It is at a distance of 14 km from the proposed solar project site.

Share of module manufacturer in solar projects >60 MW within the Area of Interest



WTGs in operational projects within the Area of Interest

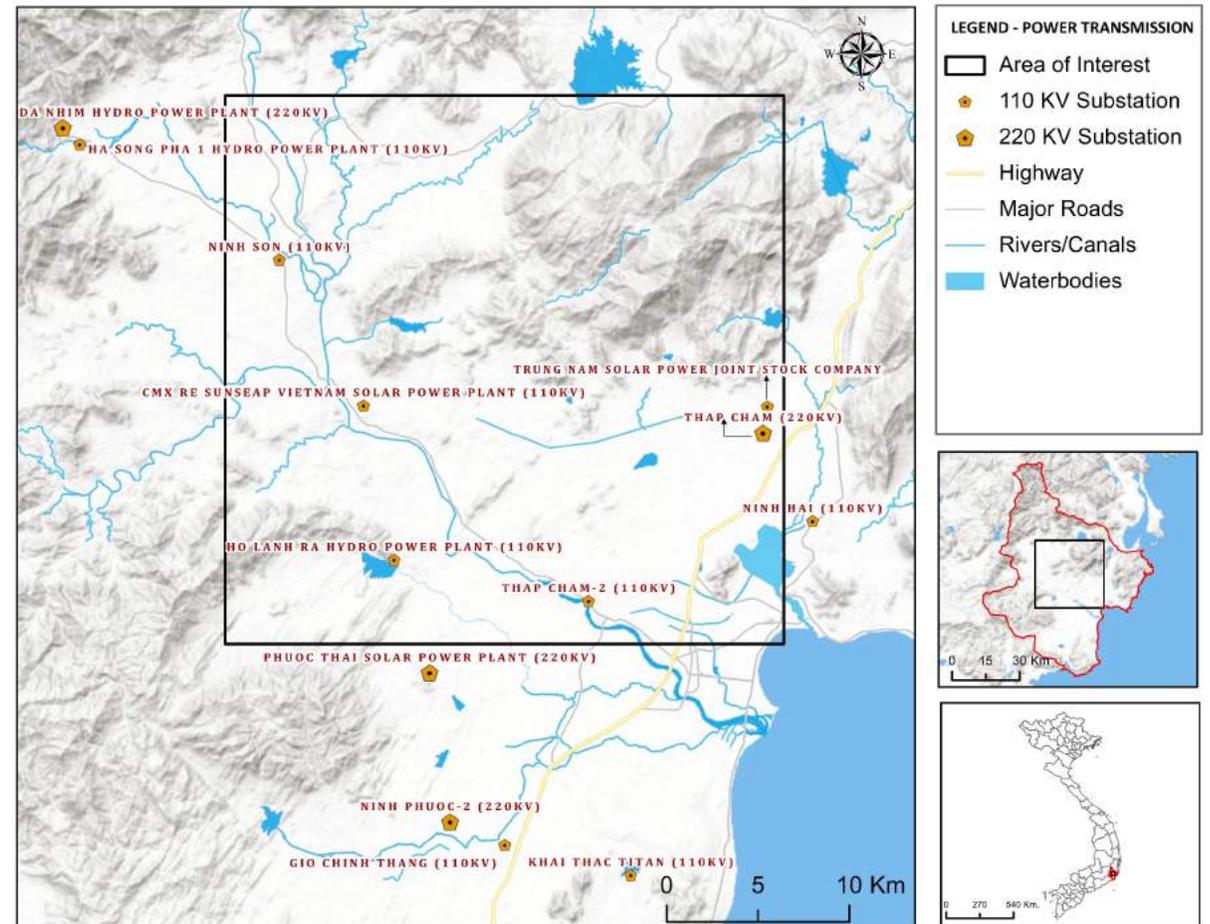


## Power Evacuation Possibilities (1/2)

### Substations (110KV and above)

- **Within the Area of Interest**, there are **6 operational substations** with total rated capacity of 305 MVA, identified in various districts of Nha Trang, Ninh Phuoc, Thuan Bac, Ninh Son and Thap Cham in Ninh Thuan & Khanh Hoa provinces. Out of which, there is one substation of 220kV voltage level (rated capacity of 125 MVA) & remaining 5 substations are of 110kV voltage levels (total rated capacity of 810 MVA).
- Moreover, outside the area of study, there are total 8 operational substations, out of which, 4 substations are of 220kV with total rated capacity of 1251 MVA (Da Nhim Hydro Power Plant, Nha Trang, Ninh Phuoc-2 & Phuoc Thai Solar Power Plant) and 4 substations of 110kV with total rated capacity of 125 MVA (Ninh Thai, Gio Chinh Thang, Khai Thac Titan & Ha Song Pha-1 Hydro Power Plant).
- There are **no under-construction substations** inside the given area of interest.
- In and around the Area of Interest, all the operational EHV substation are owned by Vietnam National Power Transmission Corporation (EVNNPT).

### Nearby Substations



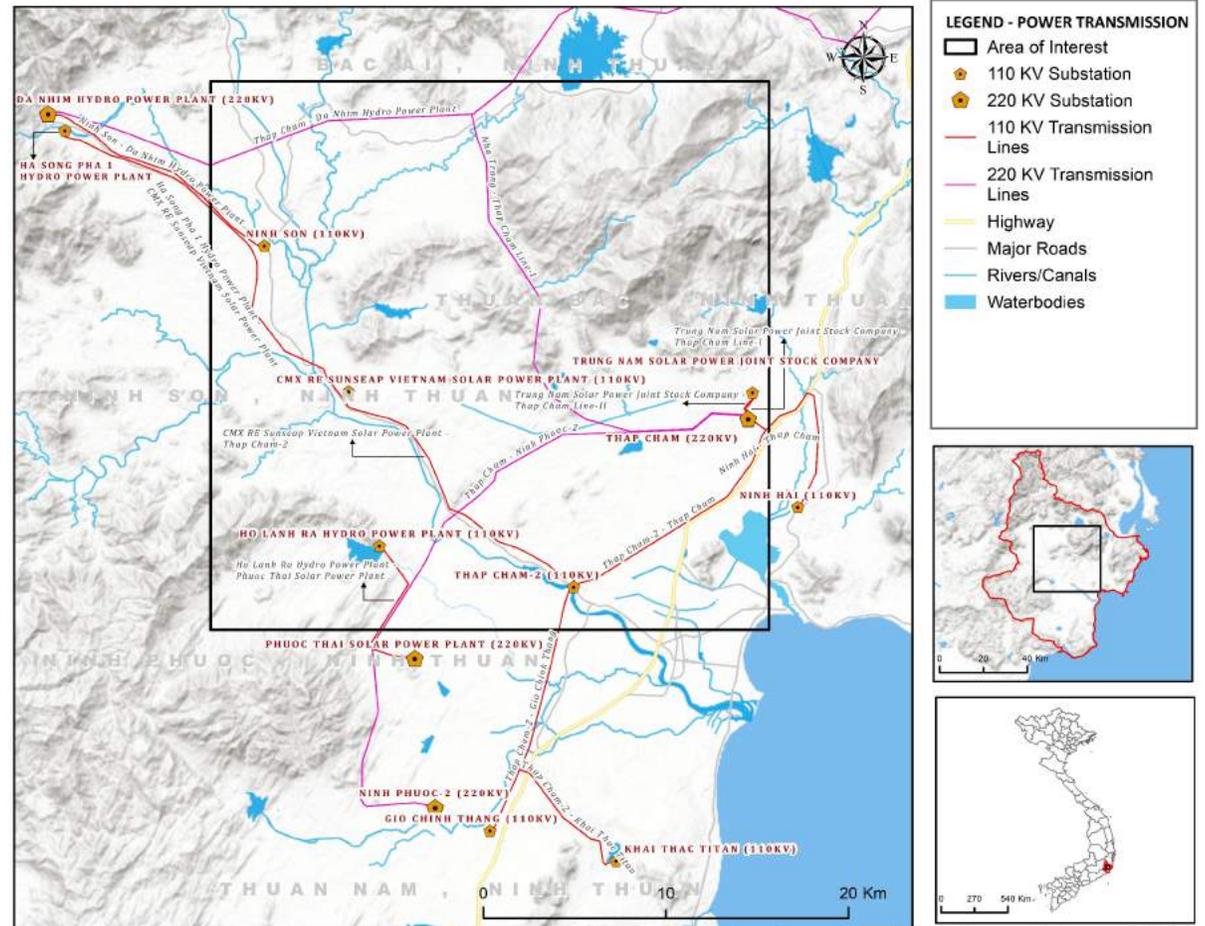
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## Power Evacuation Possibilities (2/2)

### Transmission Line

- There are **13 operational Extra High Voltage (EHV) transmission lines** with total line length of 455 ckm passing through the given Area of Interest.
- Out of the above operational lines, there are 3 lines of 220kV voltage level (295.75 ckm) and 10 lines of 110kV voltage level (159.29 ckm).
- There are no **under-construction lines** passing through the given area of interest.
- In and around the area of interest, all the operational lines are owned by Vietnam National Power Transmission Corporation (EVNNTPT).

Transmission Network Map



Source: Genesis Ray | Mapbox | ESRI Copyright protected by Genesis Ray © 2022

## Power Evacuation – Summary List of Assets

Sr. No.	Name of the Sub-station	Voltage Ratio (KV/KV)	Capacity (MVA)	Owner
1	Da Nhim Hydro Power Plant	220/110	126	EVNNPT
2	Nha Trang	220/110	500	EVNNPT
3	<b>Thap Cham</b>	220/110	125	EVNNPT
4	Ninh Phuoc-2	220/110	500	EVNNPT
5	Phuoc Thai Solar Power Plant	220/110	125	EVNNPT
6	<b>Ninh Son</b>	110/22	25	EVNNPT
7	Ninh Hai	110/22	50	EVNNPT
8	<b>Thap Cham-2</b>	110/22	80	EVNNPT
9	Gio Chinh Thang	110/22	25	EVNNPT
10	Khai Thac Titan	110/22	25	EVNNPT
11	Ha Song Pha 1 Hydro Power Plant	110/22	25	EVNNPT
12	<b>Trung Nam Solar Power Joint Stock Company</b>	110/22	25	EVNNPT
13	<b>CMX RE Sunseap Vietnam Solar Power Plant</b>	110/22	25	EVNNPT
14	<b>Ho Lanh Ra Hydro Power Plant</b>	110/22	25	EVNNPT

Sr. No.	Name of the Transmission Line	Voltage Level (KV)	Operator
1	<b>Thap Cham - Ninh Phuoc-2</b>	220	EVNNPT
2	<b>Nha Trang - Thap Cham Line-I</b>	220	EVNNPT
3	<b>Thap Cham - Da Nhim Hydro Power Plant</b>	220	EVNNPT
4	<b>Ninh Son - Da Nhim Hydro Power Plant</b>	110	EVNNPT
5	<b>Ninh Hai - Thap Cham</b>	110	EVNNPT
6	<b>Thap Cham-2 - Thap Cham</b>	110	EVNNPT
7	<b>Ha Song Pha 1 Hydro Power Plant - CMX RE Sunseap Vietnam Solar Power Plant</b>	110	EVNNPT
8	<b>Thap Cham-2 - Khai Thac Titan</b>	110	EVNNPT
9	<b>Thap Cham-2 - Gio Chinh Thang</b>	110	EVNNPT
10	<b>Trung Nam Solar Power Joint Stock Company - Thap Cham Line-I</b>	110	EVNNPT
11	<b>Trung Nam Solar Power Joint Stock Company - Thap Cham Line-II</b>	110	EVNNPT
12	<b>CMX RE Sunseap Vietnam Solar Power Plant - Thap Cham-2</b>	110	EVNNPT
13	<b>Ho Lanh Ra Hydro Power Plant - Phuoc Thai Solar Power Plant</b>	110	EVNNPT

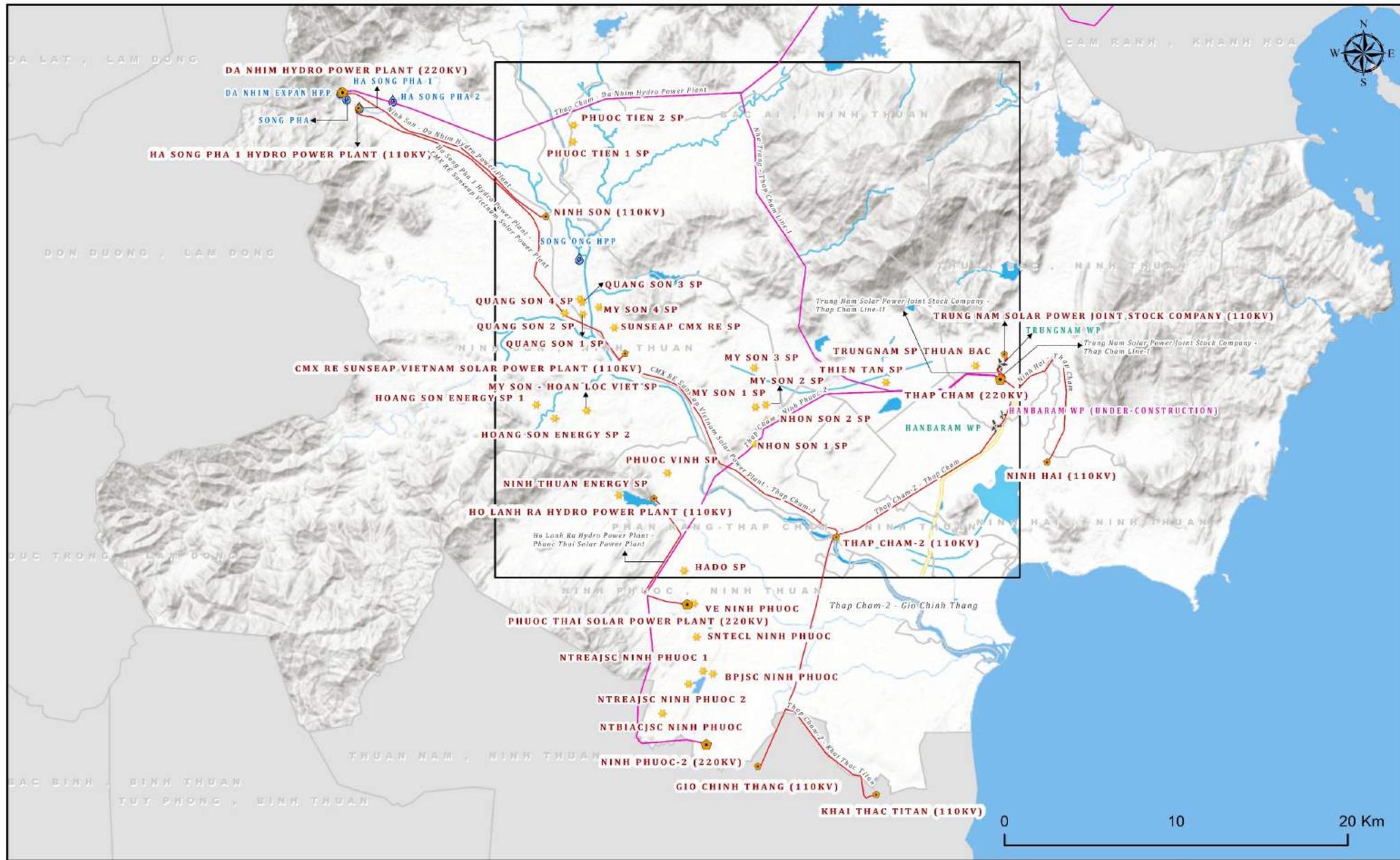
## Natural Gas Network

- There are no Natural Gas Network related assets in the study area.



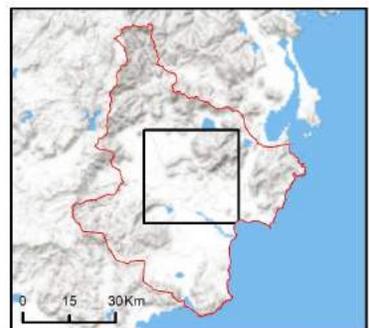
*\*This picture is for illustration purpose only*

# Energy Infrastructure Map (1/2)



**LEGEND - ENERGY INFRASTRUCTURE**

- Wind Energy Turbines
- Wind Energy Turbines (Under Construction)
- Solar Plant
- Hydro Projects
- 110 KV Substation
- 220 KV Substation
- 110 KV Transmission Lines
- 220 KV Transmission Lines
- Area of Interest
- Highway
- Major Roads
- Rivers/Canals
- Waterbodies







# Section 2: Site Specific Data Layers

## Site Suitability Layers

- Criteria “layers” are mainly related to technical factors as resource (strength and availability) or topographic site conditions (slope, elevation, soil bearing capacities) or economical feasibilities (distance to existing transport and transmission networks), and environmental factors as hazard conditioning (avoiding hazard susceptible locations).
- The continuous criteria for each of the layers are standardized to a common suitability numeric range from high to low suitability with respect to solar park siting, operations and maintenance, allowing spatial referencing of the region with respect to the general suitability ranking.
- By combining these standardized scored layers, individual site suitability maps are developed, classifying good, fair, low, and poor suitability regions within the area of interest.
- The importance of every layer along with their actual representation, exclusively for the highly promising sites are stated in the next sections.
- The method and the results of this phase can be individually used to support sustainable spatial solutions on their respective levels of project administration related to solar energy development projects only.

Suitability Value	Definition
<b>1</b>	Site with extremely severe limitations
<b>2</b>	Site with very severe limitations
<b>3</b>	Site with severe limitations
<b>4</b>	Site with moderately severe limitations
<b>5</b>	Site with minor severe limitations
<b>6</b>	Site with very moderate limitations
<b>7</b>	Site with moderate limitations
<b>8</b>	Site with minor limitations
<b>9</b>	Site with very minor limitations to use
<b>10</b>	Site with no limitations to use

## Site Suitability Layer: Land Use

- Land use provides information on the land cover, and the types of human activity involved in land use. Land cover assesses how much of a region is covered by forests, wetlands, impervious surfaces, agriculture, and other land and water types. Water types include wetlands or open water. Land use shows how people use these structures – whether for development, conservation, or mixed uses, facilitating the assessment of environmental impacts on, and potential or alternative uses of, land on the desired area of interest.
- The selected area of interest owing to the tropical savanna climatic conditions, has a mixture of different land use types, varying from cropland, herbaceous covers, mosaiced croplands, mosaic natural vegetation covers, tree covers, mosaiced tree and shrubland covers, shrublands, evergreen shrublands, grasslands and barren areas.
- The density of rivers in Ninh Thuan is relatively low, from 0.1 to 0.2 km per km<sup>2</sup>; rivers are often short and steep. The area of interest, has a handful of lakes and reservoirs, Ho Phuoc Trung and Ho Thanh Son in the Phuoc Trung region of the Bac Ai district, in the My Son region of the Ninh Son district, there is the Song Cho Mo, also the Ho Lanh Gia in the Phuoc Vinh region in the southern Ninh Phuoc district. There is also the presence of a major river, Song Cai Phan Rang and its tributaries within the area of interest. Traversing the area of interest diagonally from the north-western district of Phuoc Tan, Lam Son, Phuoc Tien, Luong Son, Tan Son and Quang Son, via the My Son district, towards the south-eastern districts of Phuoc Son, Bao An, Phuoc Thuan, Phuoc My to the southeast of the area of interest, progressing into the South China Sea.
- There are also a few urban centres restricted towards the north-western districts of Quang Son and Tan Son and heavily urbanized south-eastern districts of Ho Hai, Khanh Hai, Tan Hai, Xuan Hai, Phuoc Hai, Phuoc Son, Phuoc Thuan, Phuoc Vinh, Bao An, Dai Son, Do Vinh, Phuoc My and Thanh Hai.



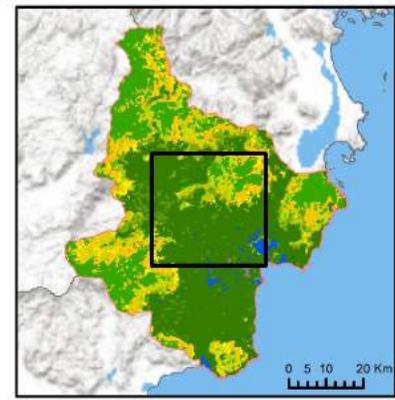
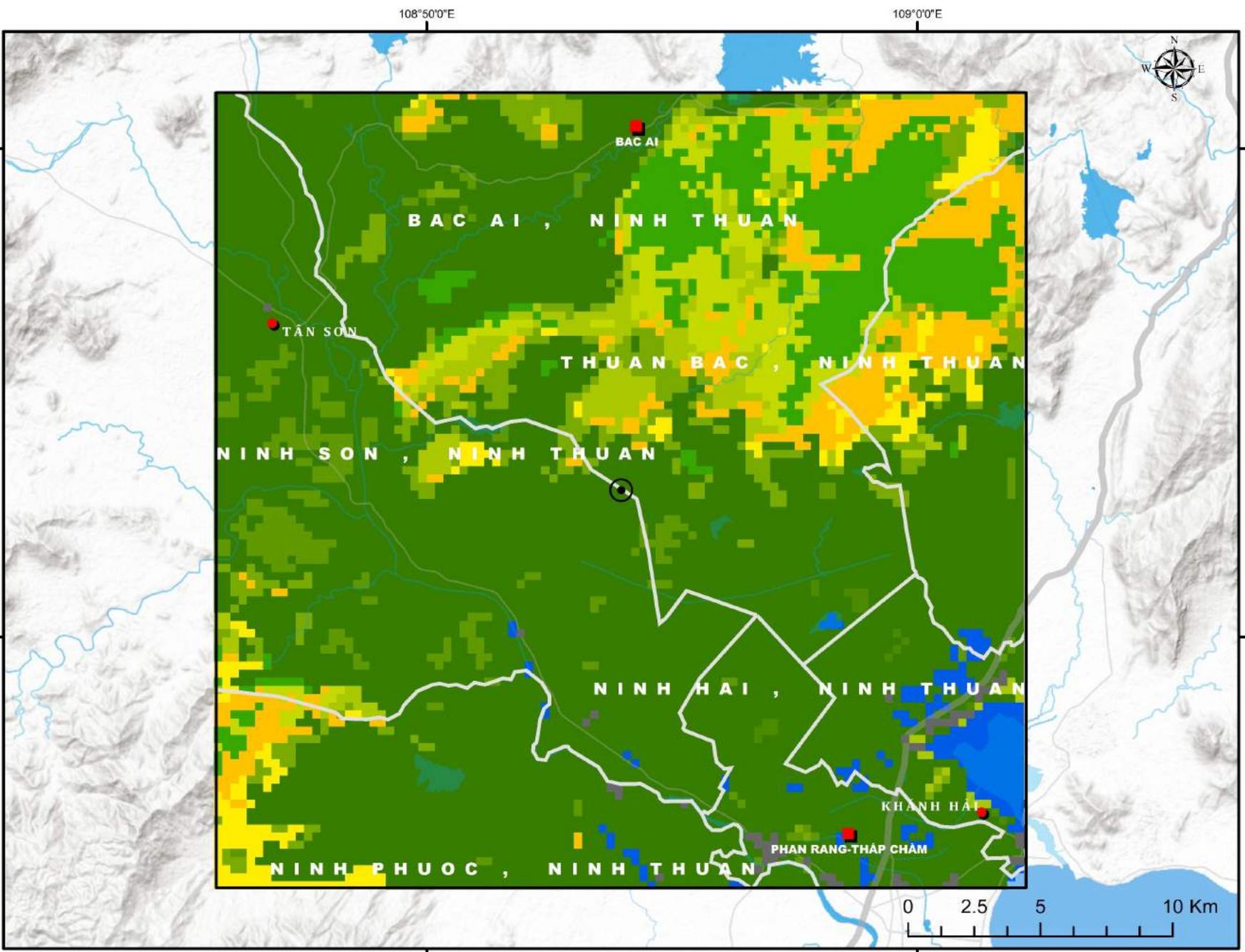
# Landuse

**Layer Description:**  
 Estimate providing information on the land cover, and the types of human activity involved in land use. Facilitating the assessment of environmental impacts on, and potential or alternative uses of the land.

**Source:** European Space Agency  
**Spatial Resolution:** 300 meters at the equator  
**Additional Information:** <http://maps.elie.ucl.ac.be/CCI/viewer/>

**LEGEND**

 Cropland	 Urban Areas
 Grassland	 Water bodies
 Herbaceous cover	 Cities
 Mosaic cropland (>50%) / natural vegetation (tree)	 Towns and Hamlets
 Mosaic natural vegetation (tree)	 District Boundary
 Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	 Area of Interest
 Shrubland	 Prospective Solar Plant location
 Shrubland evergreen	 Highway
 Tree cover	 Major Roads
	 Rivers/Canals
	 Waterbodies



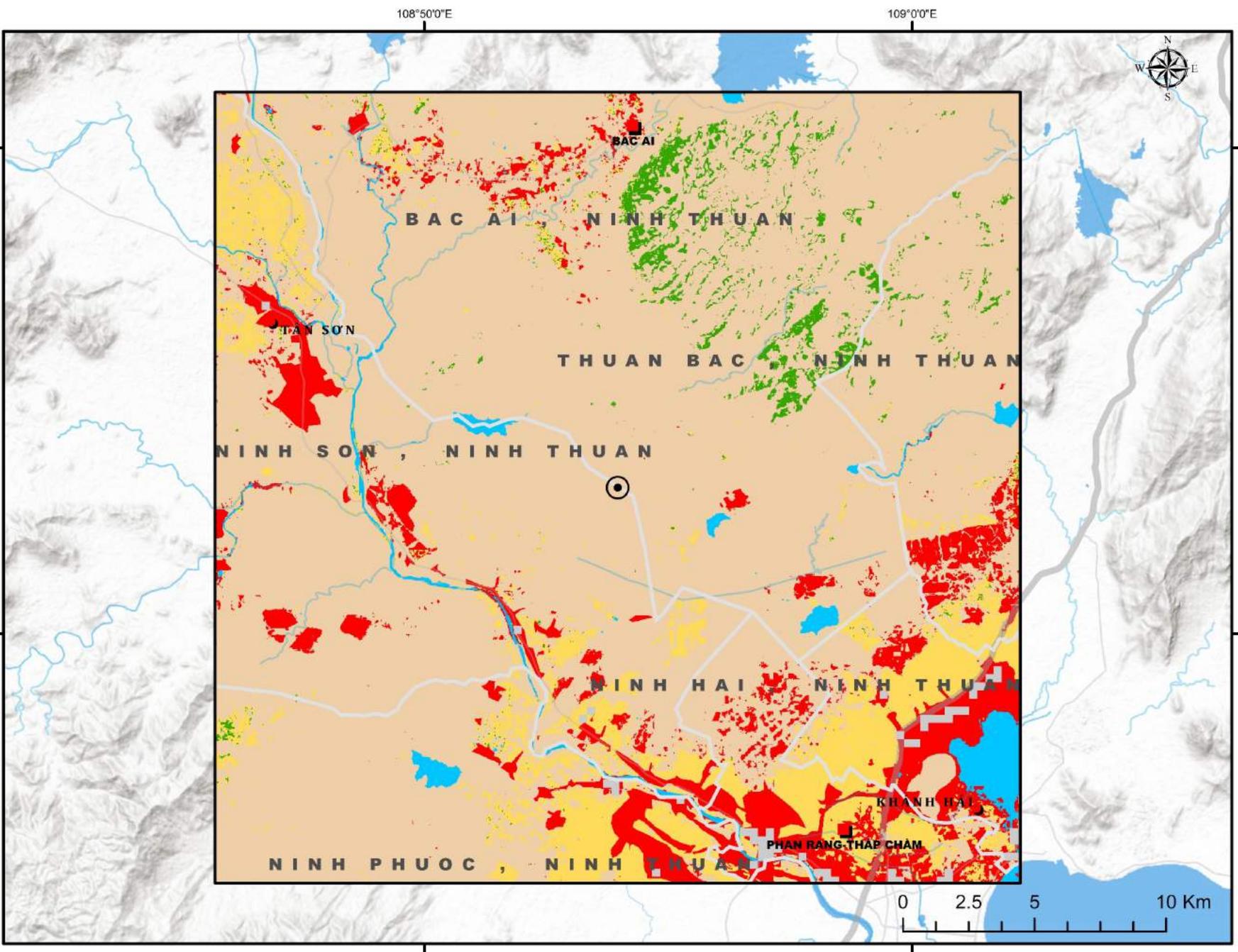
# Landuse

**Layer Description:**  
 Estimate providing information on the land cover, and the types of human activity involved in land use. Facilitating the assessment of environmental impacts on, and potential or alternative uses of the land.

**Source:** Genesis Ray Energy  
**Spatial Resolution:** 10 meters at the equator  
**Additional Information:** <https://www.genesisray.com/>

**LEGEND**

 Water	 Cities
 Forest	 Towns and Hamlets
 Cropland	 District Boundary
 Scrubland/Wasteland	 Urban areas
 Built-up	 Highway
 Prospective Solar Plant location	 Major Roads
 Area of Interest	 Rivers/Canals
	 Waterbodies



## Site Suitability Layer : Surface Roughness

- The surface roughness estimates the height above the surface at which wind speed goes to zero, with major obstacles causing excessive wind turbulence.
- The selected area of interest owing to the tropical savanna climatic conditions, has a mixture of different land use types, varying from cropland, herbaceous covers, mosaiced croplands, mosaic natural vegetation covers, tree covers, mosaiced tree and shrubland covers, shrublands, evergreen shrublands, grasslands and barren areas.
- The area of interest, has a handful of lakes and reservoirs, Ho Phuoc Trung and Ho Thanh Son in the Phuoc Trung region of the Bac Ai district, in the My Son region of the Ninh Son district, there is the Song Cho Mo, also the Ho Lanh Gia in the Phuoc Vinh region in the southern Ninh Phuoc district. There is also the presence of a major river, Song Cai Phan Rang and its tributaries within the area of interest. Traversing the area of interest diagonally from the north-western district of Phuoc Tan, Lam Son, Phuoc Tien, Luong Son, Tan Son and Quang Son, via the My Son district, towards the south-eastern districts of Phuoc Son, Bao An, Phuoc Thuan, Phuoc My to the southeast of the area of interest, progressing into the South China Sea.
- There are also a few urban centres restricted towards the north-western districts of Quang Son and Tan Son and heavily urbanized south-eastern districts of Ho Hai, Khanh Hai, Tan Hai, Xuan Hai, Phuoc Hai, Phuoc Son, Phuoc Thuan, Phuoc Vinh, Bao An, Dai Son, Do Vinh, Phuoc My and Thanh Hai.
- Each land-use type has a specific roughness factor, providing friction to the wind speed above, and within the selected area of interest the surface roughness varies between land use types between flatter surfaces like waterbodies with a surface roughness factor of 0 to terraneous and shrubby surfaces with a surface roughness factor of 1.5.



*For illustration purposes only*

## Surface Roughness

### Layer Description:

Estimate of the height above the surface at which wind speed goes to zero if the turbulent layer extends completely to the ground.

Source: Genesis Ray Energy

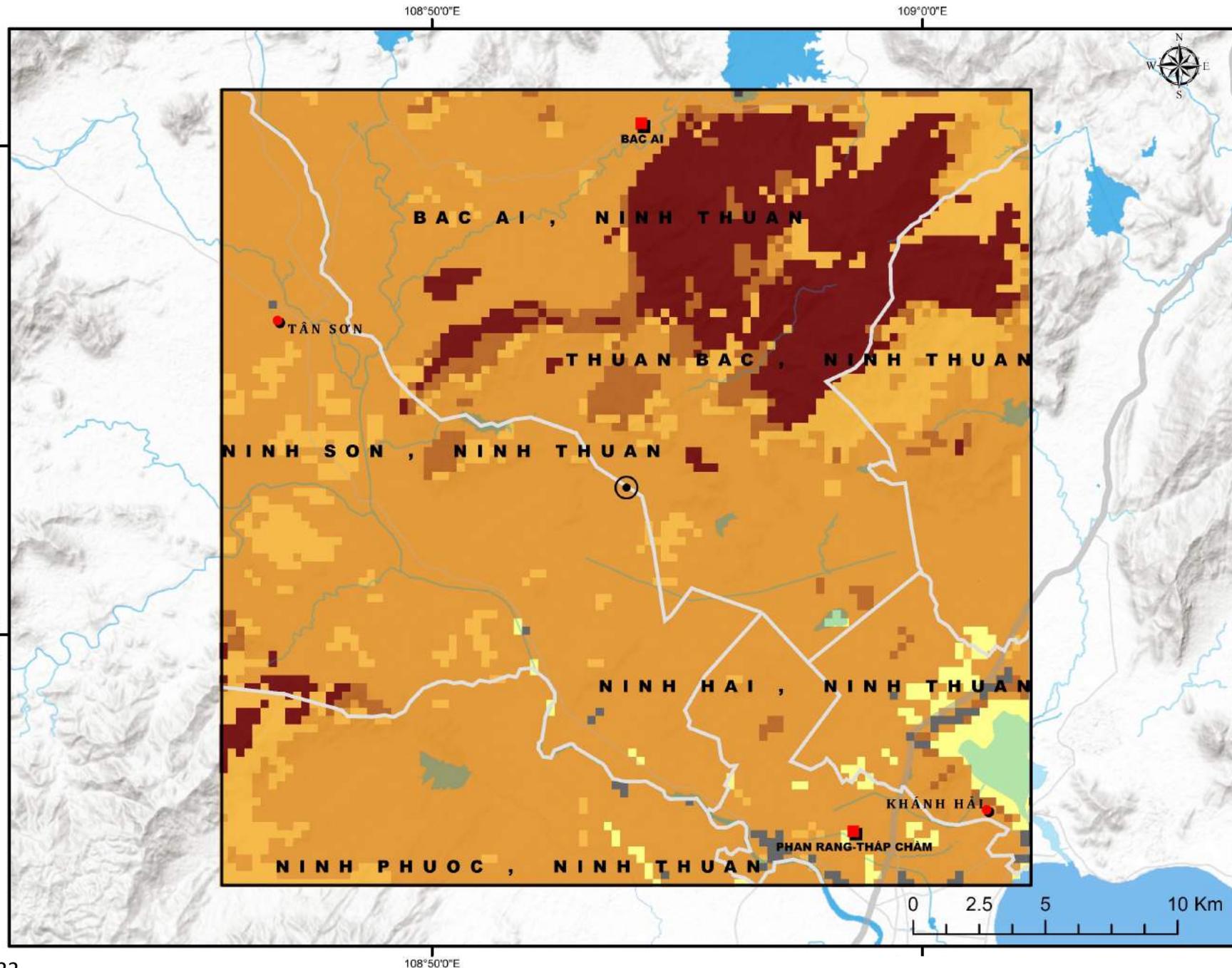
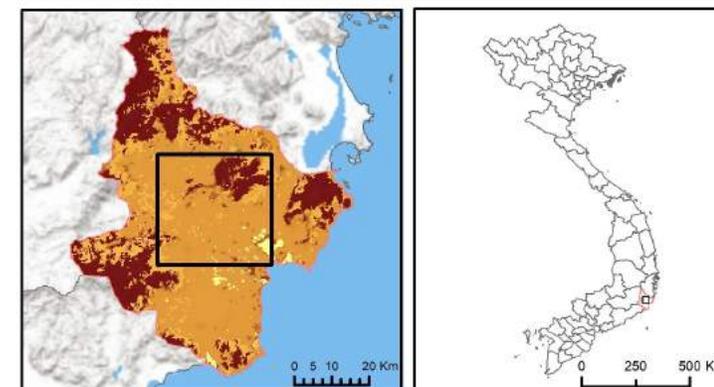
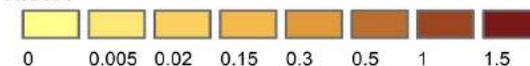
Spatial Resolution: 300 meters at the equator

Additional Information: <https://www.genesisray.com/>

### LEGEND

- |  |   |
|--|---|
|  Cities                           |  Settlements   |
|  Towns and Hamlets                |  Highway       |
|  Prospective Solar Plant location |  Major Roads   |
|  District Boundary                |  Rivers/Canals |
|  Area of Interest                 |  Waterbodies   |

### Surface Roughness factor



## Site Suitability Layer: Proximity to Road Network

- Distance to road networks provide an estimate on the distance of the nearest road network i.e., national highways/ major roadways in and around the desired area of interest.
- The land suitability for supporting transport planning is relatively higher as compared to the land suitability not supporting the same.
- To minimize the construction and maintenance costs, it is necessary that the distance between the proposed location within the area of interest and road network should be as less as possible.
- The area of interest is traversed with national highway QL27 from the north-western district of Tan Son, towards Quang Son, My Son towards the south-eastern districts of Nhon Son and Do Vinh of the area of interest.
- The national highway QL27B towards the north-western district of Tan Son, also extends across east to west, through all the northern districts of the area of interest, Phuoc Tien, Phuoc Tang, Phuoc Dai and Phuoc Thanh.
- The area of interest is also traversed from the eastern district of Bac Phong, by national highway QL1A towards the south-eastern districts of Tan Hai, Ho Hai and Thanh Hai.
- Any point in the selected area of interest falls within a range of 0.09 to 14.16 kilometers from the nearest national highway/ major road network.



*For illustration purposes only*

## Proximity to Road Network

**Layer Description:**  
 Estimate providing information on the distance of the nearest road network i.e., national highways/ major roadways.

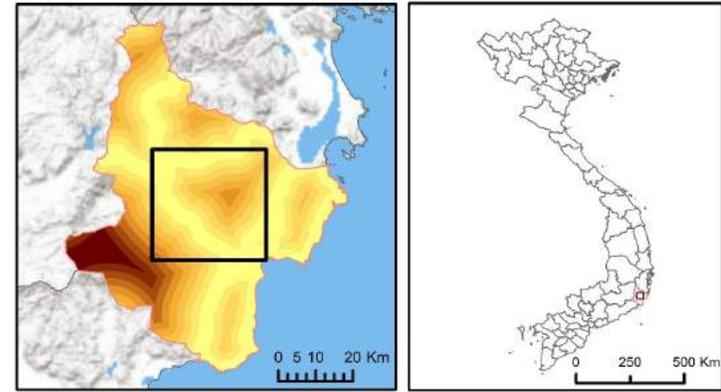
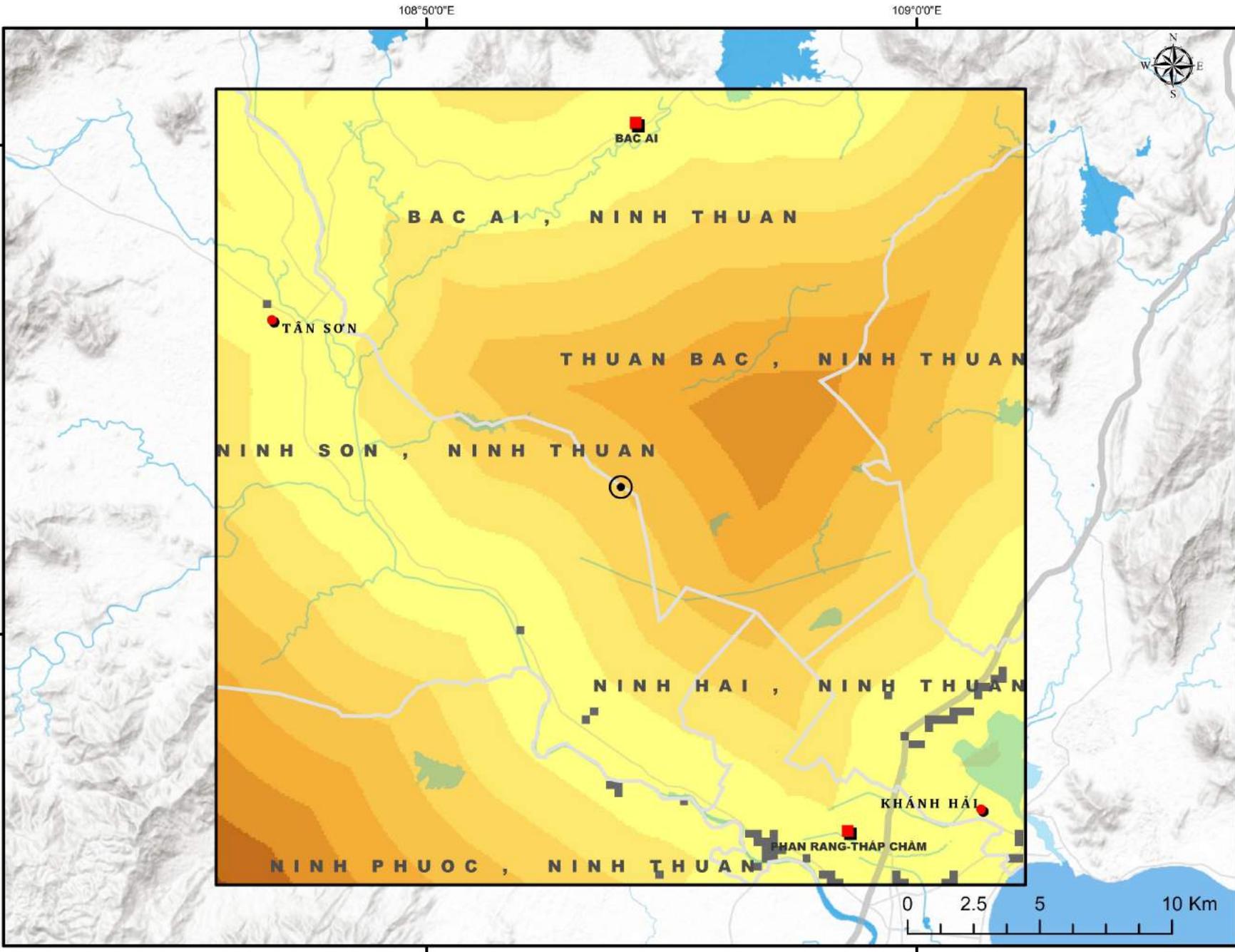
**Source:** GEOFABRIK- Open Street Map + Genesis Ray Energy  
**Spatial Resolution:** N.A.  
**Additional Information:**  
<https://download.geofabrik.de/asia/vietnam.html>

**LEGEND**

Cities	Settlements
Towns and Hamlets	Highway
Prospective Solar Plant location	Major Roads
District Boundary	Rivers/Canals
Area of Interest	Waterbodies

**Proximity to Road Network kilometers**

< 2	2 - 4	4 - 6	6 - 8	8 - 10	10 - 12	12 - 14	14 - 16	16 - 18	> 18

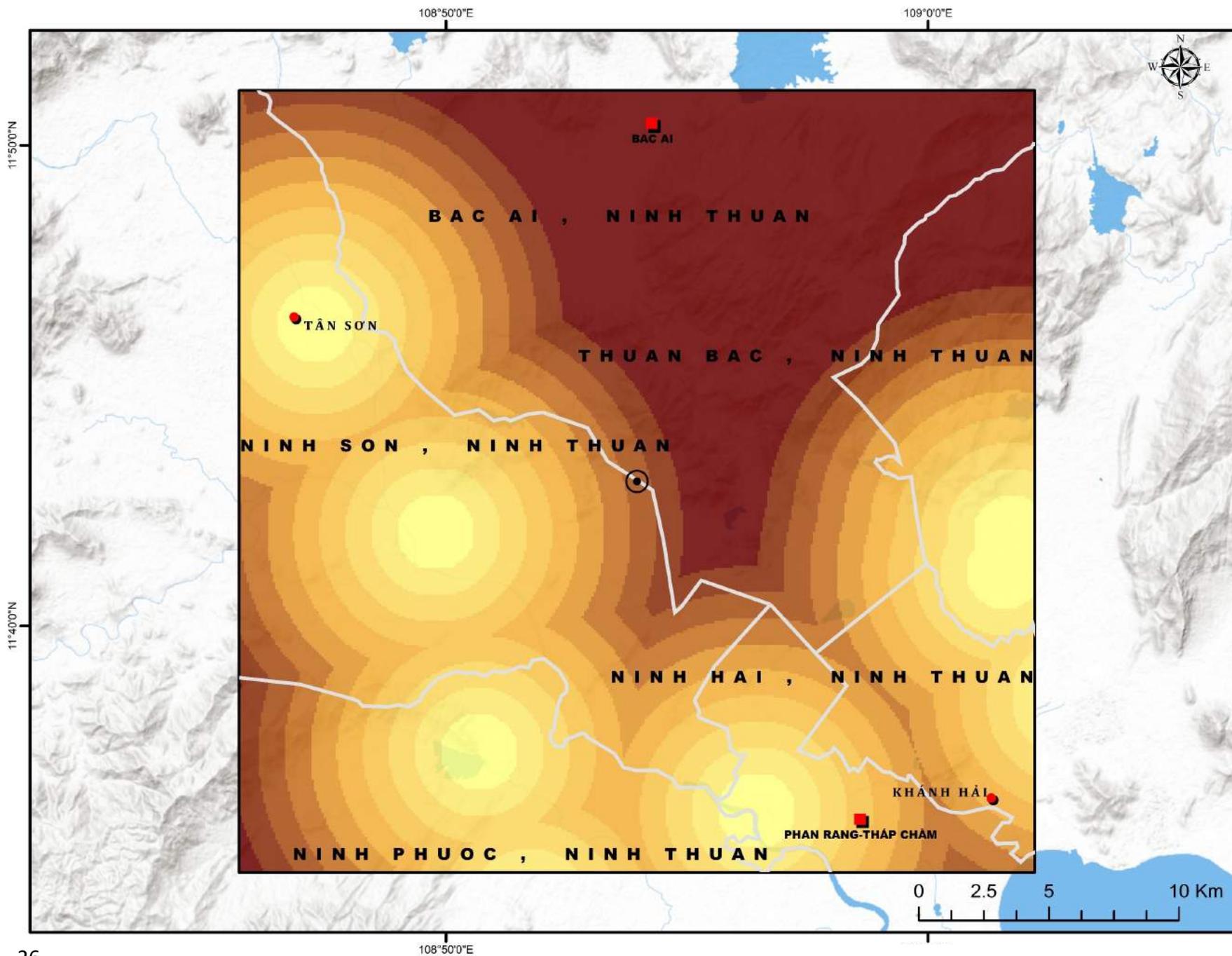


## Site Suitability Layer: Proximity to Transmission Network

- Distance to transmission network provides the estimate of the distance of all the nearest substations in and around the desired area of interest.
- The land suitability supporting transmission well connected with substations is relatively higher as compared to the land suitability not supporting the same.
- To minimize the construction and maintenance costs, it is necessary that the distance between the proposed location within the area of interest and transmission substations should be as less as possible.
- There are various numbers of operational substations at 110KV and 220KV voltage levels in and around the area of interest. Although, there are no under-construction substations.
- The operational substations include **9 x 110 KV** substations: Ninh Hai (110KV), Thap Cham-2 (110KV), Ninh Son (110KV), Khai Thac Titan (110KV), Gio Chinh Thang (110KV), Ha Song Pha 1 Hydro Power Plant (110KV), Trung Nam Solar Power Joint Stock Company (110KV), CMX RE Sunseap Vietnam Solar Power Plant (110KV), and Ho Lanh Ra Hydro Power Plant (110KV), and, **5 x 220KV** substations: Nha Trang (220KV), Thap Cham (220KV), Da Nhim Hydro Power Plant (220KV), Ninh Phuoc-2 (220KV), and Phuoc Thai Solar Power Plant (220KV).
- Any point located in the selected area of interest falls within a range of 0 to 18.98 kilometers from the nearest **110KV** or **220KV** substation.
- This analysis doesn't consider the power evacuation availability in the substation.



*For illustration purposes only*



## Proximity to Transmission Network

**Layer Description:**  
 Estimate providing information on the distance of the nearest substation.

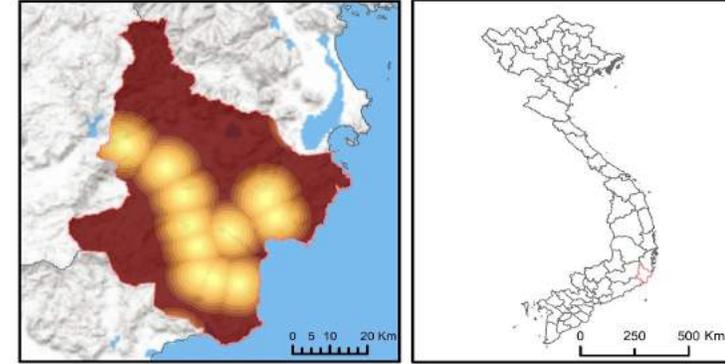
**Source:** GEOFABRIK- Open Street Map + Genesis Ray Energy  
**Spatial Resolution:** N.A.  
**Additional Information:**  
<https://download.geofabrik.de/asia/vietnam.html>

**LEGEND**

 Cities	 Settlements
 Towns and Hamlets	 Highway
 Prospective Solar Plant location	 Major Roads
 District Boundary	 Rivers/Canals
 Area of Interest	 Waterbodies

**Proximity to Transmission Network kilometers**

									
< 1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	> 9

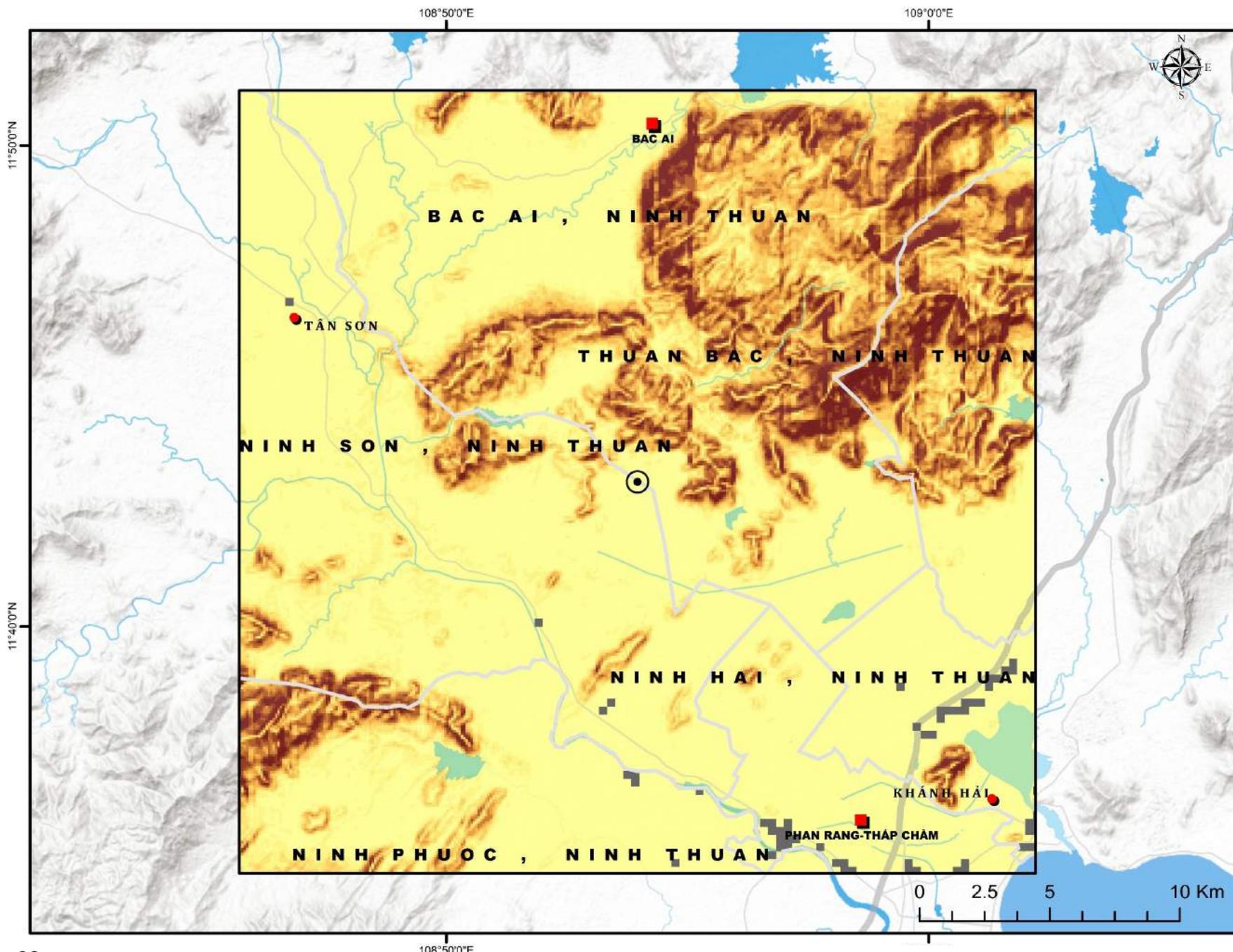


## Site Suitability Layer: Elevation (Slope)

- Slope is the estimate of the topographic gradient or incline of the land and is calculated for every 100 feet of horizontal distance.
- The accessibility for installation and maintenance of panels are hindered by steep slope of a terrain.
- Averagely, the allowed maximum slope thresholds, range from 10% to 30% for solar energy development projects.
- Predominantly the area of interest is relatively a flat surface, although traversed by terraneous ranges towards the north-eastern districts of Phuoc Dai, Phuoc Thanh, Phuoc Chien, Phuoc Khang and Phuoc Trung and the south-western districts of Phuoc Thai and My Son, within the area of interest.
- Within the desired area of interest, the slope varies between 0.0 degrees to 45.76 degrees.



*For illustration purposes only*



## Slope

**Layer Description:**  
 Estimate of the topographic gradient or incline of the land for every 100 feet of horizontal distance.

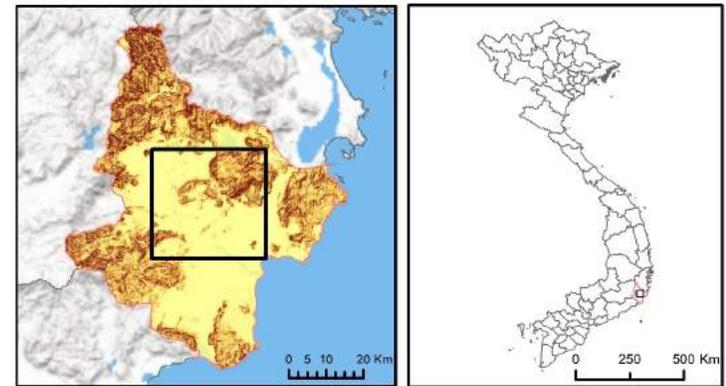
**Source:** USGS Shuttle Radar Topography Mission (SRTM)  
**Spatial Resolution:** 90 meters at the equator  
**Additional Information:** <https://earthexplorer.usgs.gov/>

**LEGEND**

Cities	Settlements
Towns and Hamlets	Highway
Prospective Solar Plant location	Major Roads
District Boundary	Rivers/Canals
Area of Interest	Waterbodies

**Slope degrees**

< 3	3 - 6	6 - 9	9 - 12	12 - 15	15 - 18	18 - 21	21 - 24	24 - 27 > 27



## Site Suitability Layer: Soil Bearing Capacity

- The soil bearing capacity factor estimates the capacity of the soil to support the loads applied to the ground, calculated as the maximum average contact pressure between the foundation and the soil which should not produce shear failure in the desired area of interest.
- Alluvial soils account for about one-fourth of the land in the south of Vietnam, being the most dominant kind in the area of interest. Alluvial soils are also concentrated in the Mekong delta region of Vietnam, as are peat and muck soils. Gray podzolic soils are found in parts of the central highlands and in old terraces along the Mekong. While regurs (rich black loams) and lateritic soils occur in both the central highlands and the terrace zone, along the coast of central Vietnam, regosols (soft, undeveloped soils) and noncalci brown soils are found.
- The corresponding information on their respective soil bearing capacities, enable the choice of foundations for solar installations in the area of interest, ranging from direct drive foundation posts for higher soil bearing capacity soils, to helical posts, earth screws or concrete ballast for weaker and granular soil with lower soil bearing capacities.
- The soils within the area of interest, predominantly have greater soil bearing capacities of around  $115\text{kN/m}^2$ , with patches of soil with even greater soil bearing capacities, of up to  $120\text{kN/m}^2$  towards the south-eastern districts of Ho Hai, Phuoc Hau, Phuoc Son, Phuoc Thuan, Phuoc My, Bao An, Do Vinh, Thanh Hai, as compared to anywhere else within the area of interest.
- The soil bearing capacities range from 115 to  $120\text{kN/m}^2$  within the desired area of interest.



*For illustration purposes only*

## Soil Bearing Capacity

### Layer Description:

The soil bearing capacity factor estimates the capacity of the soil to support the loads applied to the ground, calculated as the maximum average contact pressure between the foundation and the soil which should not produce shear failure.

**Source:** World Soil Information + Genesis Ray Energy

**Spatial Resolution:** 250 meters at the equator

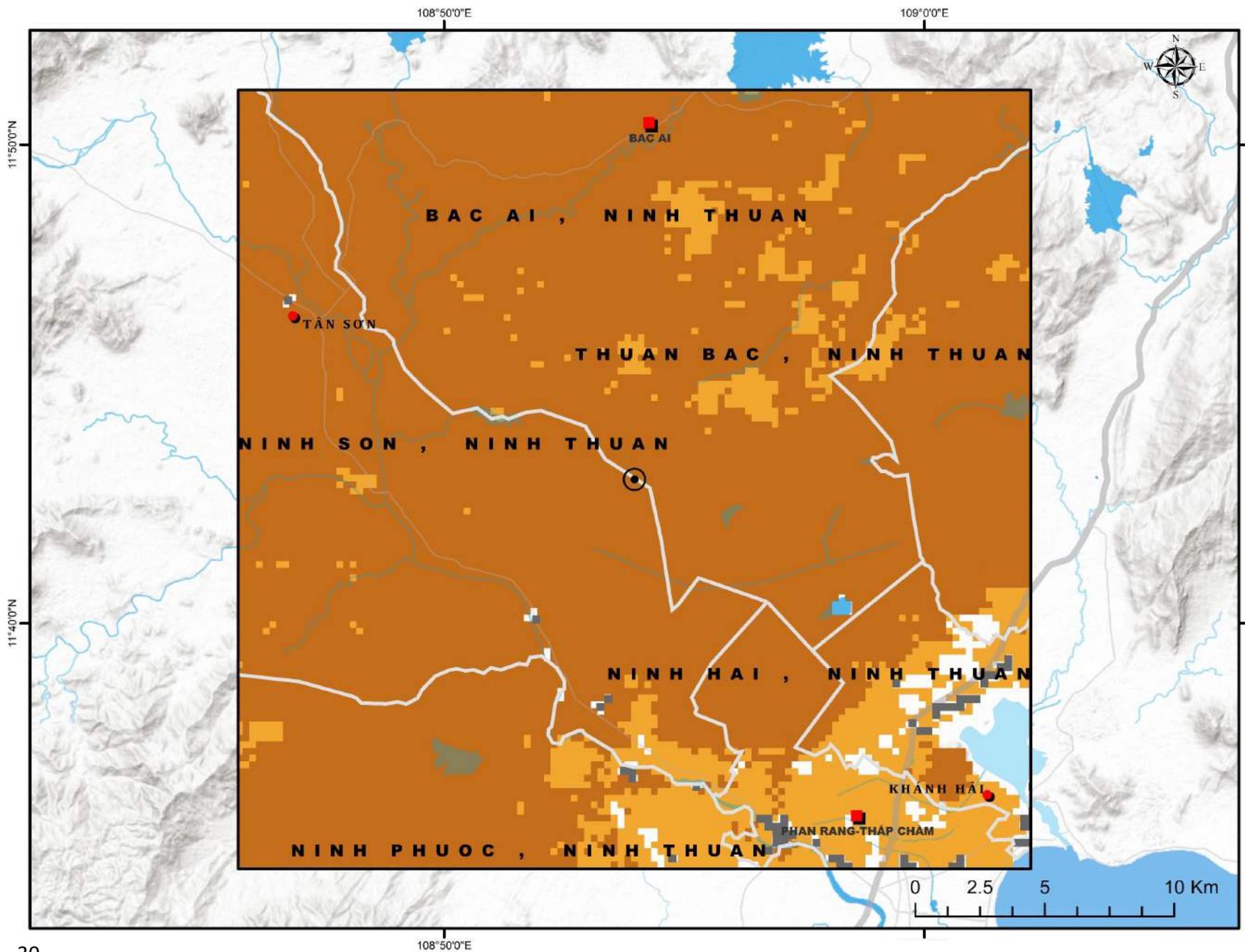
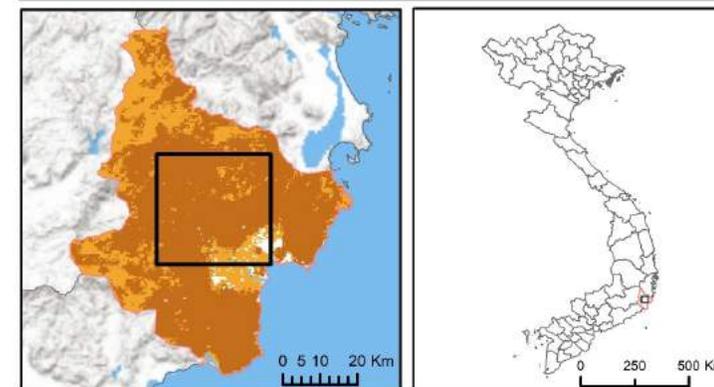
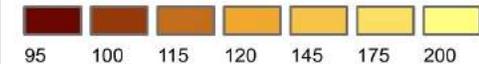
**Additional Information:** <https://www.isric.org/explore/soilgrids>

### LEGEND

- |  |   |
|--|---|
|  Cities                           |  Settlements   |
|  Towns and Hamlets                |  Highway       |
|  Prospective Solar Plant location |  Major Roads   |
|  District Boundary                |  Rivers/Canals |
|  Area of Interest                 |  Waterbodies   |

### Soil Bearing Capacity

kN/m<sup>2</sup>



## Site Suitability Layer: Natural Disasters - Cyclones

- The cyclonic risk provides the estimates of the number of events that occurred, when system of winds rotated about a centre of low atmospheric pressure, advancing to speeds of about 30 to 50 kilometres an hour, and often brought heavy rain along within the desired area of interest.
- Vietnam is a southeast Asian country and is the easternmost country of mainland Southeast Asia. It borders the South China Sea, hence, seeing the increased likeliness of tropical cyclones. Tropical cyclones in this area are part of the Northwest Pacific basin, and therefore, storms here are considered as *typhoons*.
- The area of interest within the Ninh Thuan province, being one of the most arid provinces with the lowest rainfall in Vietnam, experiences frequent and prolonged droughts. Ninh Thuan is less affected by tropical cyclones and tropical depression, just around one event per year, that sometimes can cause heavy rain and drive floods with harmful impacts on crop production and livelihoods. However, rain from such events also contribute significantly to the water budget for this savanna region.
- But, building solar power plants, avoiding even these rare cyclone prone areas add some form of insurance against potential cyclonic disasters, supporting the development of an insurance system for the solar PV power plant operators, against cyclonic activities, although of low to medium severity, which can be potentially used for the evaluation of the risk type and the magnitude, opting for equivalent insurance schemes, providing swift recovery from any damage, that might be caused by the disaster event and thus reduce the risks faced by solar power operators.
- The selected area of interest, located in the south-central coast of Vietnam, showed none such historical events (since 1970) and therefore has and overall cyclonic susceptibility of 0 events/year.



*For illustration purposes only*

## Natural Disasters - Cyclones

### Layer Description:

The cyclonic risk provides the estimates of the number of events that occurred, when system of winds rotated about a center of low atmospheric pressure, advancing to speeds of about 30 to 50 km an hour, and often brought heavy rain along.

**Source:** United Nations Environment Programme : Global Risk Data Platform

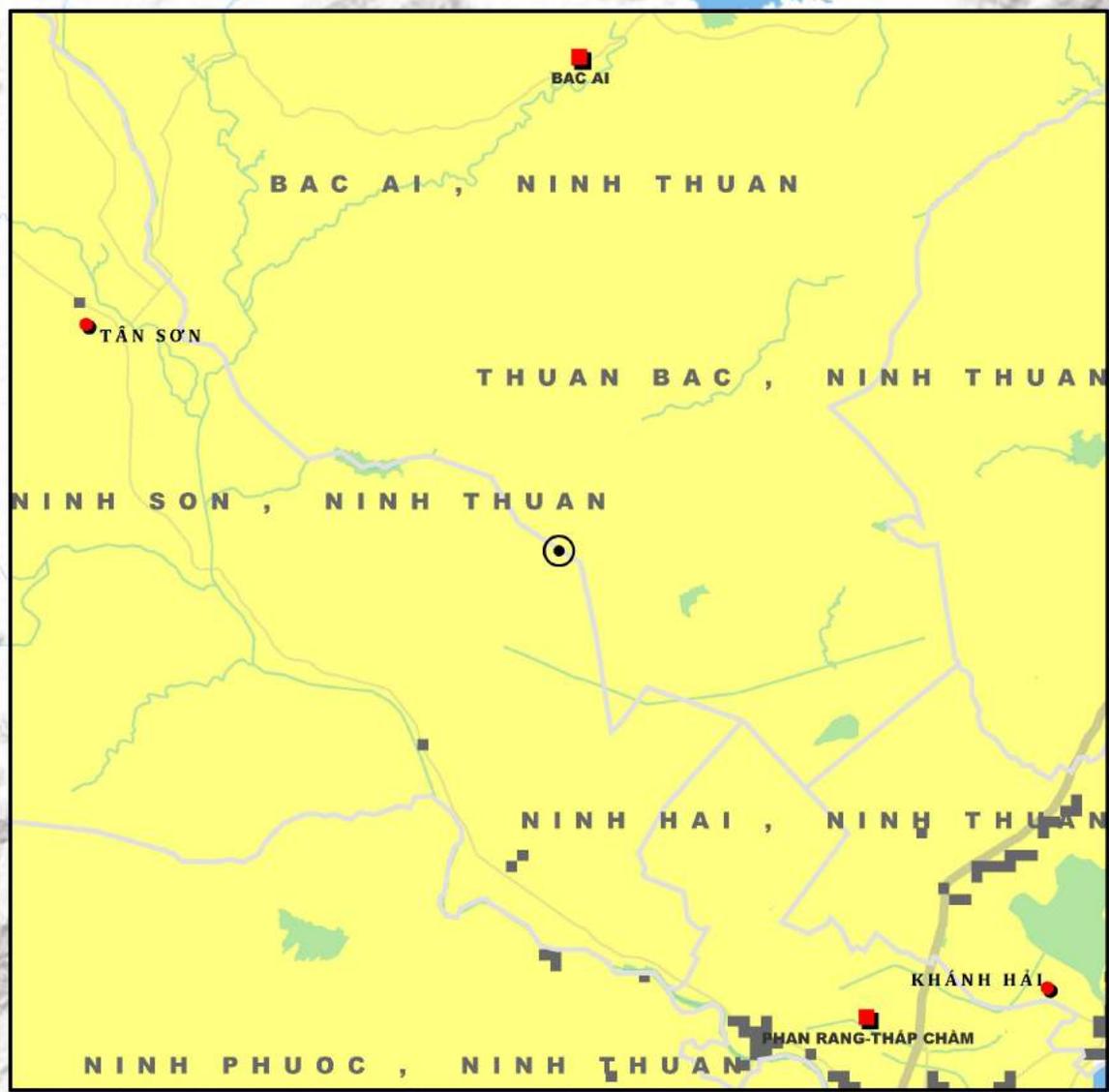
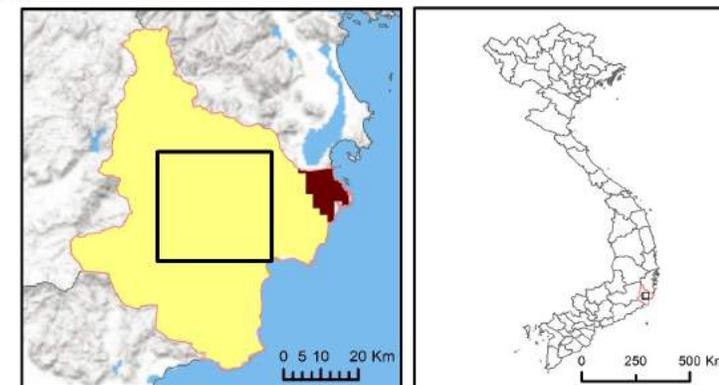
**Spatial Resolution:** 1 kilometer at the equator

**Additional Information:** <https://preview.grid.unep.ch/>

### LEGEND

- |                                  |               |
|----------------------------------|---------------|
| Cities                           | Settlements   |
| Towns and Hamlets                | Highway       |
| Prospective Solar Plant location | Major Roads   |
| District Boundary                | Rivers/Canals |
| Area of Interest                 | Waterbodies   |

### Cyclone events/year



## Site Suitability Layer: Natural Disasters - Earthquake

- The earthquake risk provides estimate of the severity of earthquakes based on the seismicity, or seismic activity, frequency, type, and size of earthquakes experienced over a period at the desired area of interest.
- Recent research reveals a high seismicity level in the off-shore areas as well as high tsunami hazard from the East Vietnam Sea that can affect the South-Central Vietnam (N. H. Phuong, [2001](#), [2011](#); N. H. Phuong et al., [2012](#), [2014](#)). Therefore, a seismic hazard assessment is necessary for the Southern Central Vietnam in the sense that it may provide the important and quantitative information for natural disaster emergency response and risk management in the region.
- This information will also assist the building of solar power plants, avoiding seismic prone areas add some form of insurance against potential disasters, supporting the development of an insurance system for the solar PV power plant operators, against seismic activities and their severity, which can be potentially used for the evaluation of the risk type and the magnitude, opting for equivalent insurance schemes, providing swift recovery from the damage caused by the disaster event and thus reduce the risks faced by solar power operators.
- The selected area of interest is prone to low-risk seismic activities, prone to tectonic movements, ranging between 0.18 - 0.24 on the Richter Scale.



*For illustration purposes only*

## Natural Disasters - Earthquake

### Layer Description:

Estimate of the severity of earthquakes based on the seismicity, or seismic activity, frequency, type, and size of earthquakes experienced over a period.

**Source:** GFZ German Research Centre for Geosciences

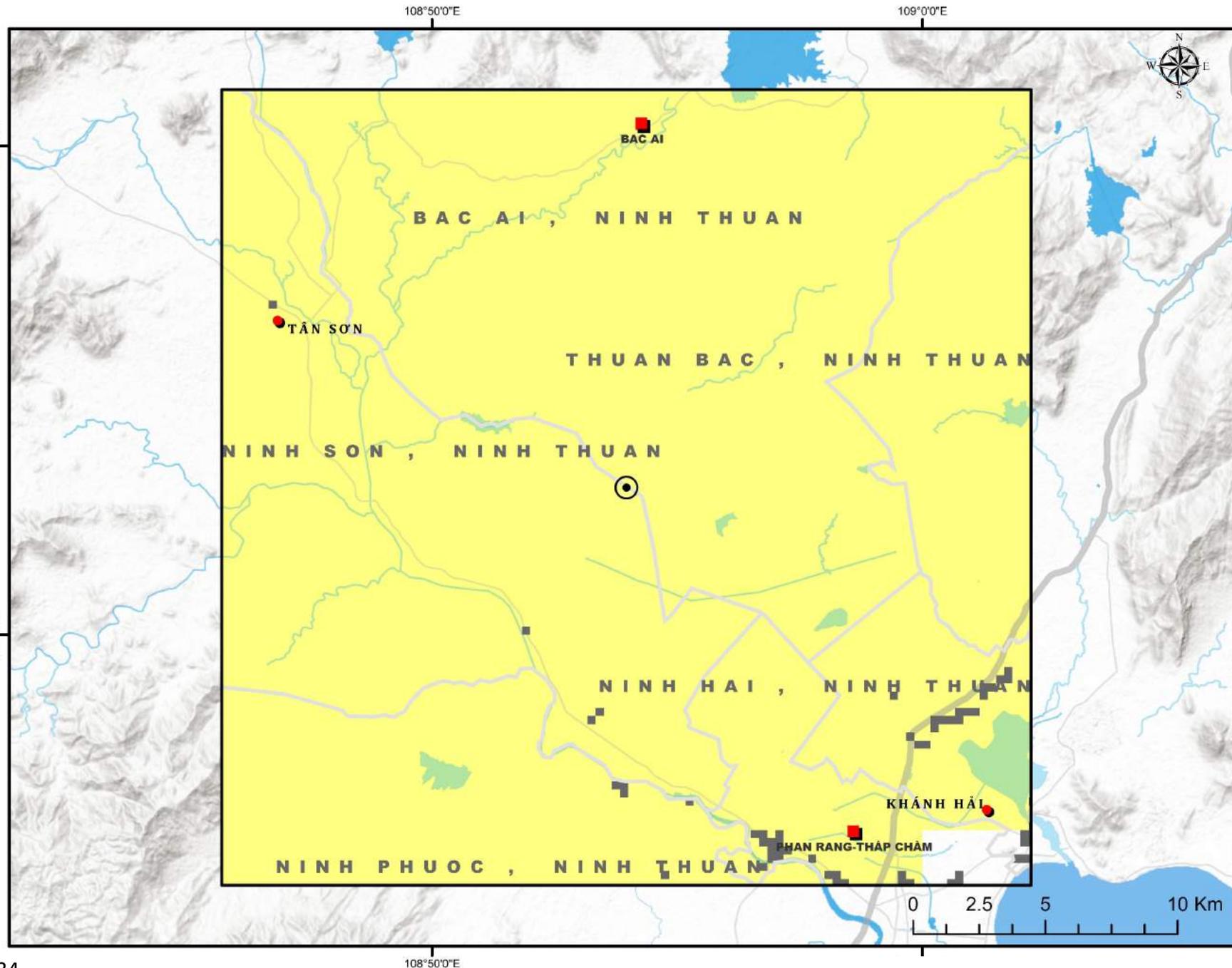
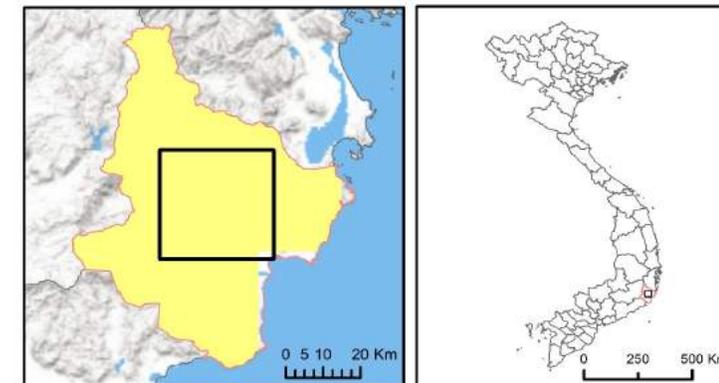
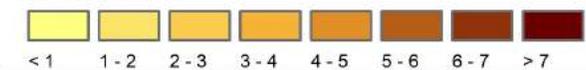
**Spatial Resolution:** 10 kilometers at the equator

**Additional Information:** <https://www.gfz-potsdam.de/>

### LEGEND

- |                                  |               |
|----------------------------------|---------------|
| Cities                           | Settlements   |
| Towns and Hamlets                | Highway       |
| Prospective Solar Plant location | Major Roads   |
| District Boundary                | Rivers/Canals |
| Area of Interest                 | Waterbodies   |

### Earthquake Richter Scale



## Site Suitability Layer: Natural Disasters - Floods

- The flood risk provides an estimate of the annual percentage of occurrence of incidents that inundated the landmass otherwise normally dry, either after heavy rainfall or after rivers or lakes overflow its banks at the desired area of interest.
- Building solar power plants, avoiding the flood prone and flood susceptible areas add some form of insurance against potential flooding disasters, supporting the development of an insurance system for the solar PV power plant operators, against flooding activities and their severity, which can be potentially used for the evaluation of the risk type and the magnitude, opting for equivalent insurance schemes, providing swift recovery from the damage caused by the disaster event and thus reduce the risks faced by solar power operators.
- Ninh Thuan a province in a tropical monsoon climate area; there is a tropical savanna climate in Phan Rang with the features of drought, hot weather, much wind, and rapid evaporation. Ninh Thuan is one of the provinces most affected by drought in Vietnam, and this is also a region at risk of desertification and severe land resource degradation, with quite severe hydro-meteorological conditions, the average rainfall for many years in Ninh Thuan is all achieved about 750 mm per year, with very high hours of sunshine of about 2700 - 2800 hours per year, making it a heavy dry area. The density of rivers in Ninh Thuan is relatively low, from 0.1 to 0.2 km per km<sup>2</sup>; rivers are often short and steep, causing many severe droughts in the region, resulting in significant damage to the agricultural sector and socio-economic activities.
- The selected area of interest showed occurrence of flooding ranging between 0 to 0.27% of days annually, especially along the low-lying regions and the coastal lagoon Dam Nai. In October 2020, many low-lying localities in Ninh Thuan province were flooded, due to heavy rains for many hours accompanied by numerous lake flooding incidents, particularly in areas adjacent to the area of interest. According to the IPCC (2013), as there is high confidence that extremes in sea level will increase with mean sea level rise, and precipitation days will increase, along with the number of extreme rainfall events. The present hazard level may increase in the future because of climate change, therefore projects in especially low-lying areas, should be designed to be robust, because floods might cause major threats, affecting people, socio-economic activities and ecosystem services.



*For illustration purposes only*

## Natural Disasters - Floods

**Layer Description:**  
 Estimate of the annual percentage of occurrence of incidents that inundates landmass otherwise normally dry, either after heavy rainfall or after rivers or lakes overflows its banks.

**Source:** NASA Global Flood Mapping (NASA) + Genesis Ray Energy

**Spatial Resolution:** 250 meters at the equator

**Additional Information:**  
<https://floodmap.modaps.eosdis.nasa.gov/index.php>

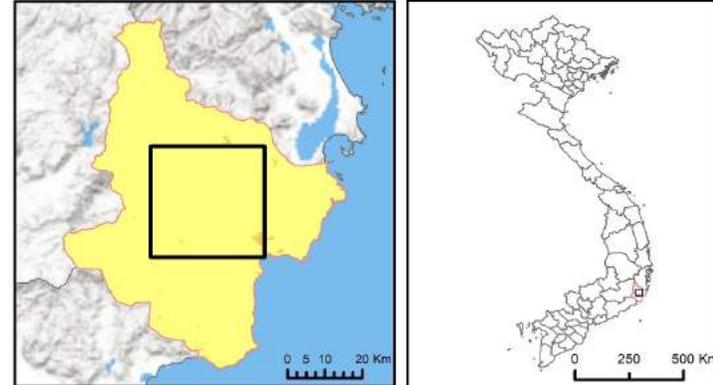


**LEGEND**

Cities	Settlements
Towns and Hamlets	Highway
Prospective Solar Plant location	Major Roads
District Boundary	Rivers/Canals
Area of Interest	Waterbodies

**Flood percentage**

0	0-0.1	0.1-0.6	0.6-2	2-5	5-10	10-30	> 30



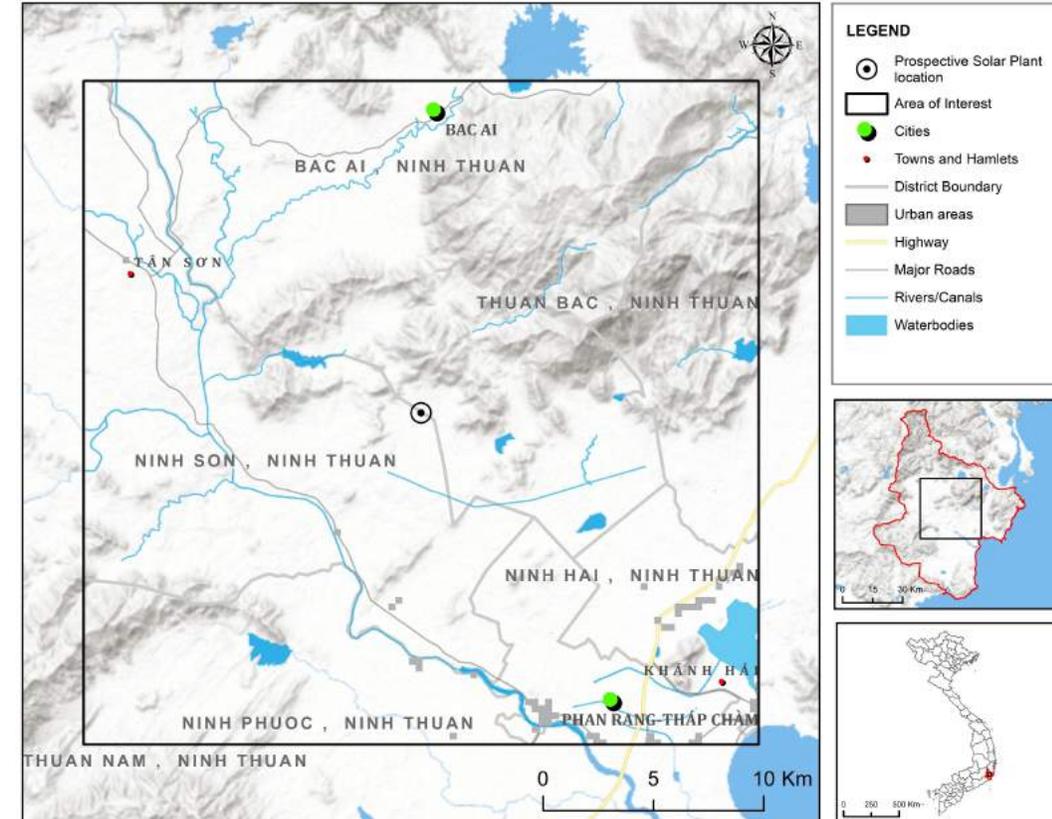


# Section 3: Site Scoring

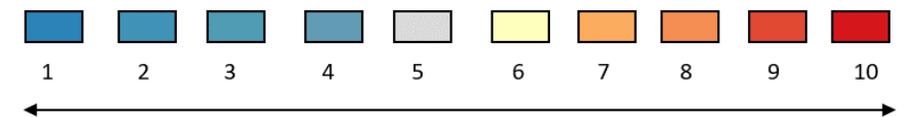
## Prospective Location (Mid-point) : 11°43'0.694"N 108°53'57.682"E

SITE SUITABILITY CALCULATOR	SCORED VALUE	ACTUAL VALUE	SUSTAINABILITY NOTES
Land Use	9	Cropland	The selected coordinates belong to the land use type of Cropland.
Surface Roughness	9	Factor of 0.300	The selected coordinates have a surface roughness of 0.300 factor.
Slope	10	2.21°	The selected coordinates have a slope of 2.21°.
Distance to Road Network	8	6.11 kilometers	The selected coordinates are located at 6.11 kilometers from the nearest national highway/ major road network.
Distance to Transmission Network	4	7.44 kilometers	The selected coordinates are located at 7.44 kilometers from the nearest >=66kV substation.
Natural Disasters: Floods	10	0.00 %	The selected coordinates are flooded for 0.00 % of the days annually.
Natural Disasters: Cyclone	10	0 events/year	The selected coordinates have predictive 0 cyclonic events/year.
Natural Disasters: Earthquakes	10	0.22 on Richter Scale	The selected coordinates are prone to seismic activities of up to 0.22 on the Richter Scale.
Soil Bearing Capacity	10	115 kN/m2	The selected coordinates have a soil bearing capacity of 115 kN/m2.

## Location Map



Source: Genesis Ray | Mapbox | ESRI Copyright protected by Genesis Ray © 2022



Low Suitability

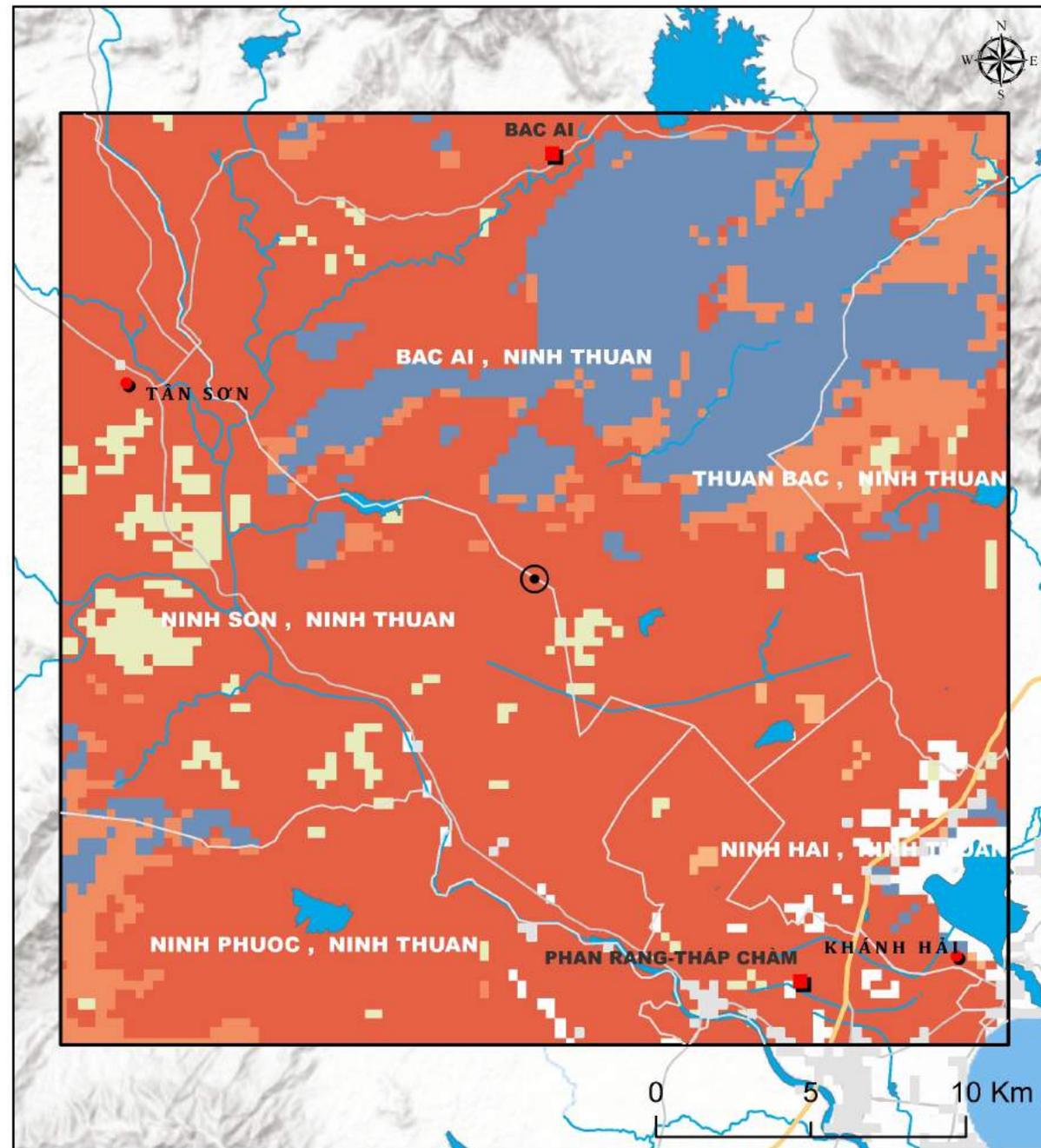
High Suitability

The continuous criteria for each of the layers are standardized to a common suitability numeric range from high (10) to low (1) suitability

## Site Suitability Layer: Land Use

The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to solar park siting, operations, and maintenance, (Table.) allowing spatial referencing of the region with respect to only land use-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections.

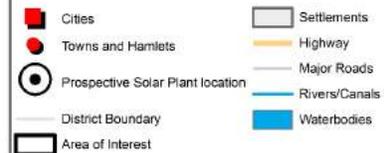
Land Use (factor)	
Scored Value	Definition
10	Bare areas, Consolidated bare areas, Unconsolidated bare areas
9	Mosaic cropland (>50%) / natural vegetation (tree)
8	Shrubland, Shrubland evergreen, Shrubland deciduous
7	Grassland
6	-
5	Herbaceous cover, Mosaic herbaceous cover (>50%) / tree and shrub (<50%), Sparse vegetation (tree, Shrub or herbaceous cover)
4	-
3	-
2	Tree or shrub cover, Mosaic natural vegetation, Mosaic tree and shrub (>50%) / herbaceous cover (<50%)
1	Bare areas, Consolidated bare areas, Unconsolidated bare areas



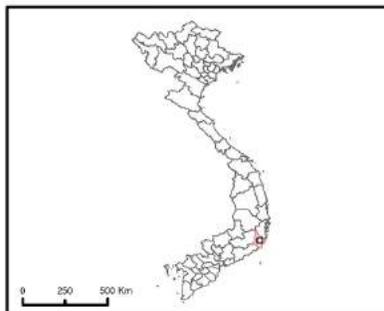
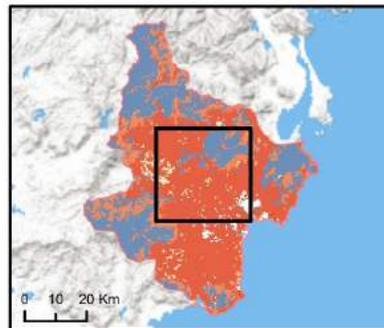
## Landuse (Scored)

Source: European Space Agency  
 Spatial Resolution:  
 300 meters at the equator  
 Additional Information:  
<http://maps.elie.ucl.ac.be/CCI/viewer/>

### LEGEND



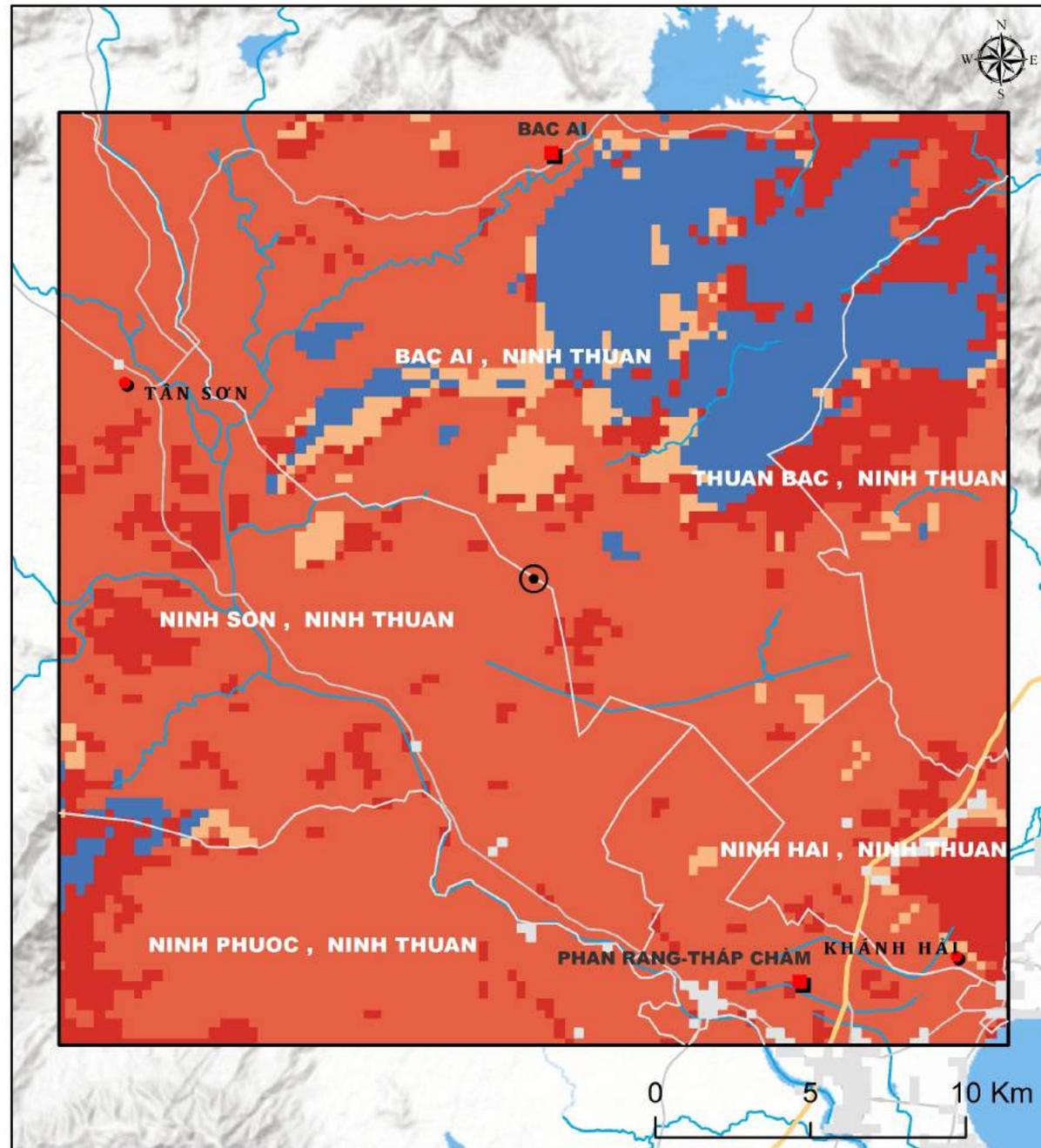
### Landuse (Scored)



## Site Suitability Layer: Surface Roughness

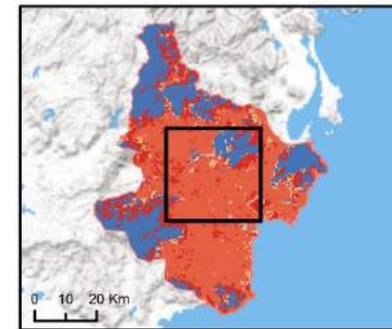
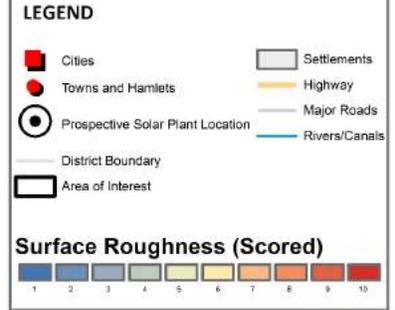
The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to solar park siting, operations, and maintenance, (Table.) allowing spatial referencing of the region with respect to only surface roughness-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections.

Surface Roughness (factor)	
Scored value	Raw Value
10	0-0.15
9	0.15-0.3
8	0.3-0.45
7	0.45-0.6
6	0.6-0.75
5	0.75-0.9
4	0.9-1.05
3	1.05-1.2
2	1.2-1.35
1	1.35-1.5



## Surface Roughness (Scored)

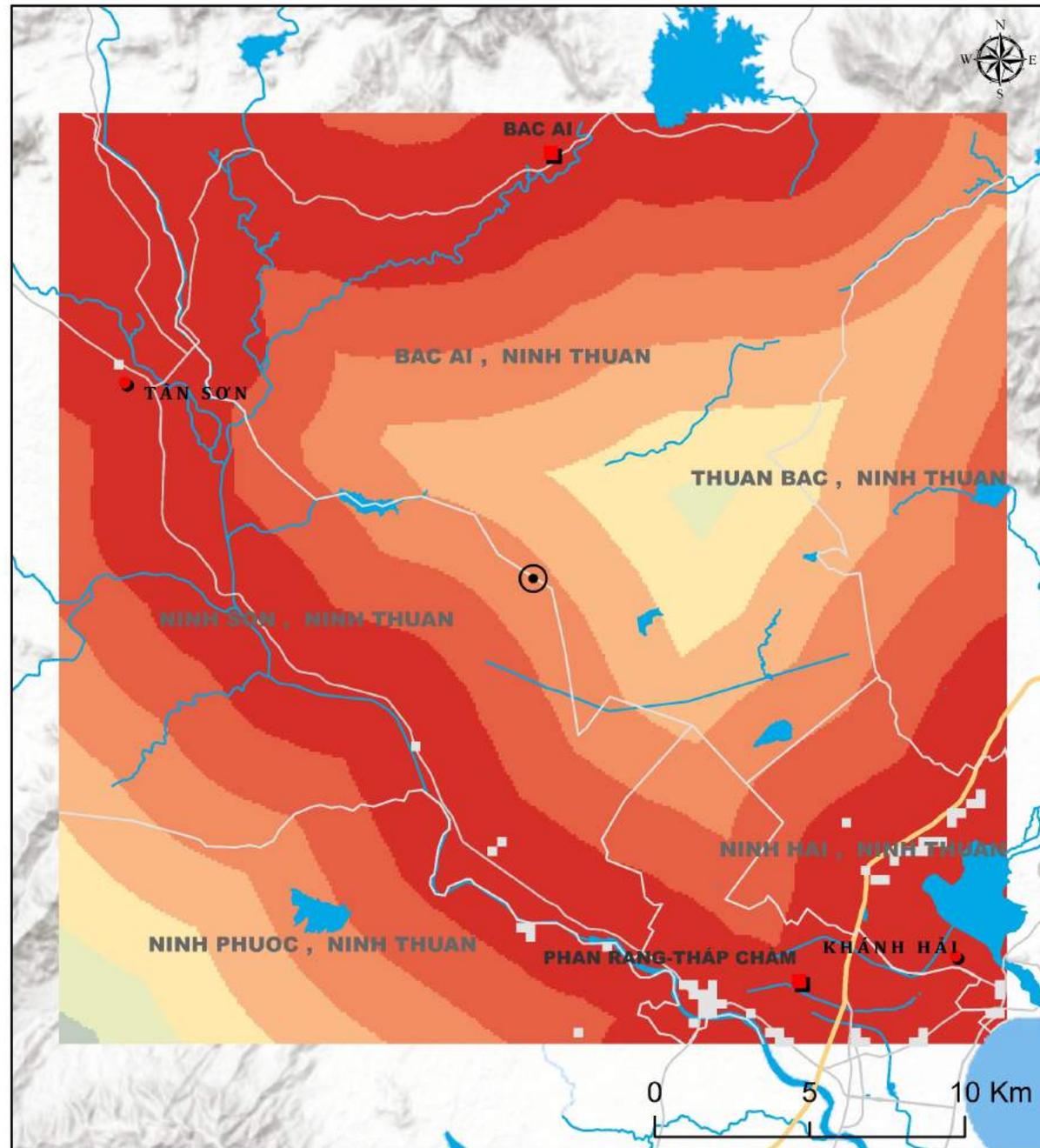
Source: Genesis Ray Energy  
 Spatial Resolution:  
 300 meters at the equator  
 Additional information:  
<https://www.genesisray.com/>



## Site Suitability Layer: Proximity to Road Network

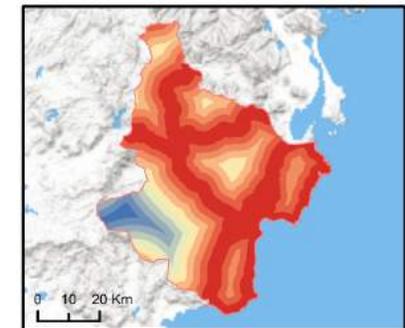
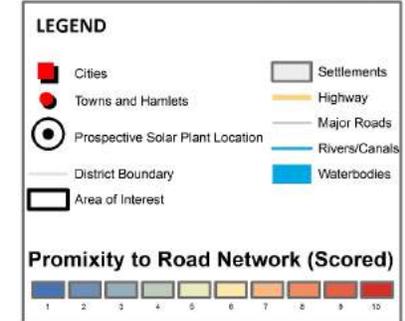
The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to solar park siting, operations, and maintenance, (Table.) allowing spatial referencing of the region with respect to only distance to road network-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections.

Proximity to Road Network (factor)	
Scored value	Raw Value
10	<2000 meters
9	4000 meters
8	6000 meters
7	8000 meters
6	10000 meters
5	12000 meters
4	14000 meters
3	16000 meters
2	18000 meters
1	>20000 meters



## Proximity to Road Network (Scored)

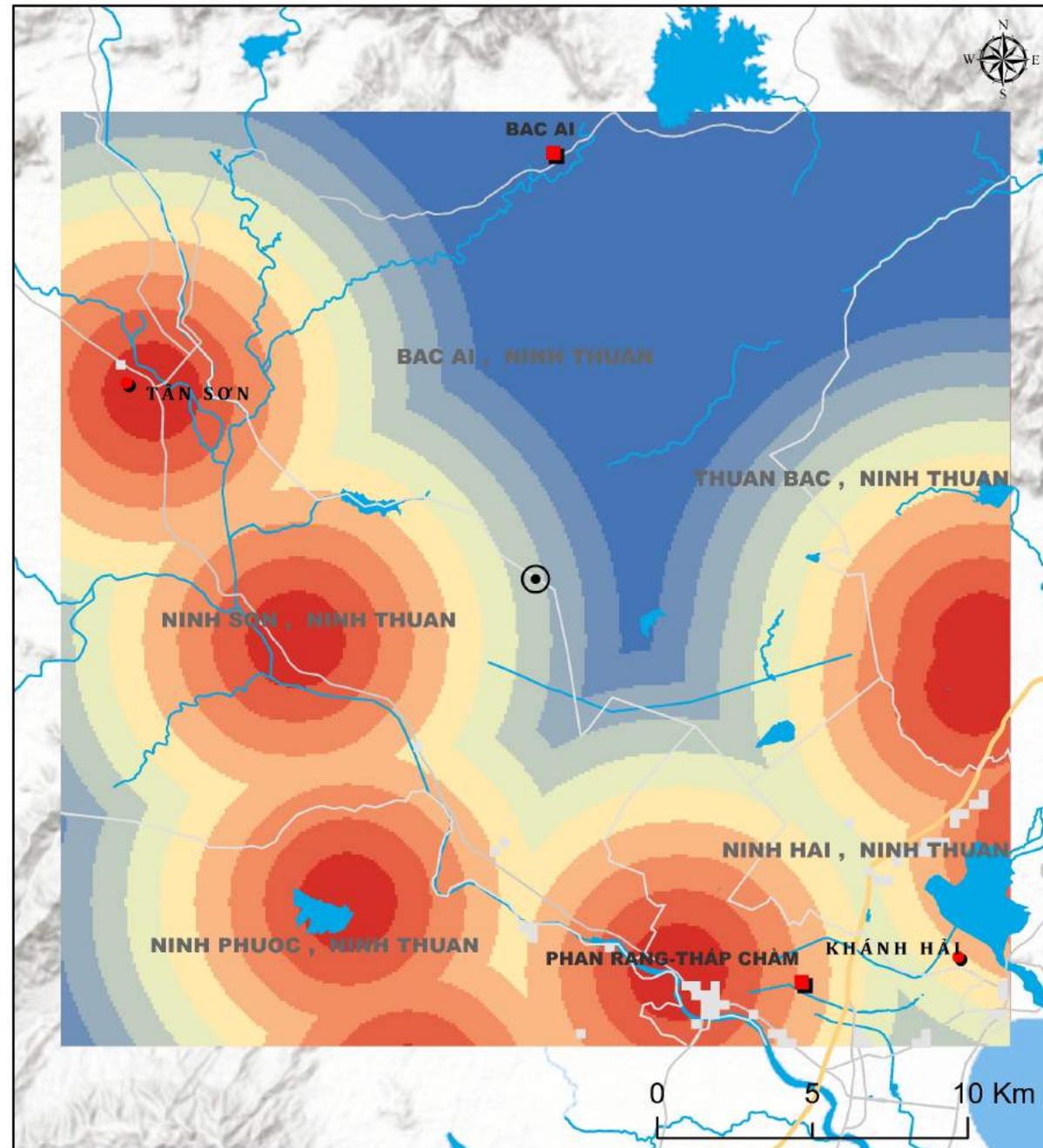
Source: GEOFABRIK- Open Street Map + Genesis Ray Energy  
 Spatial Resolution: N.A.  
 Additional Information:  
<https://download.geofabrik.de/asia/vietnam.html>



## Site Suitability Layer: Proximity to Transmission Network

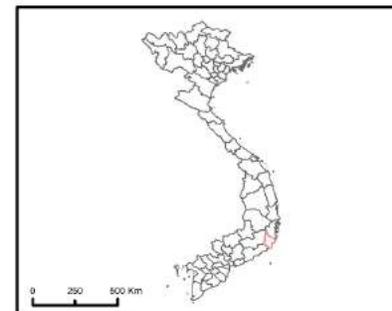
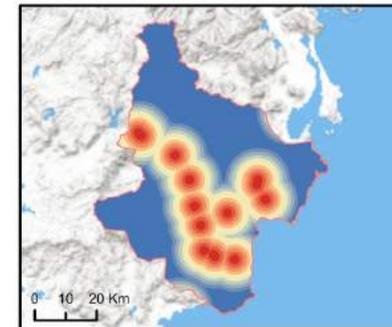
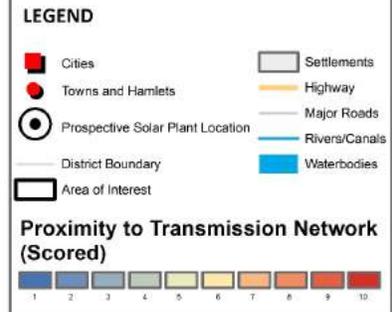
The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to solar park siting, operations and maintenance, (Table.) allowing spatial referencing of the region with respect to only distance from transmission network-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections.

Proximity to Transmission Network (factor)	
Scored value	Raw Value
10	<1000 meters
9	2000 meters
8	3000 meters
7	4000 meters
6	5000 meters
5	6000 meters
4	7000 meters
3	8000 meters
2	9000 meters
1	>10000 meters



## Proximity to Transmission Network (Scored)

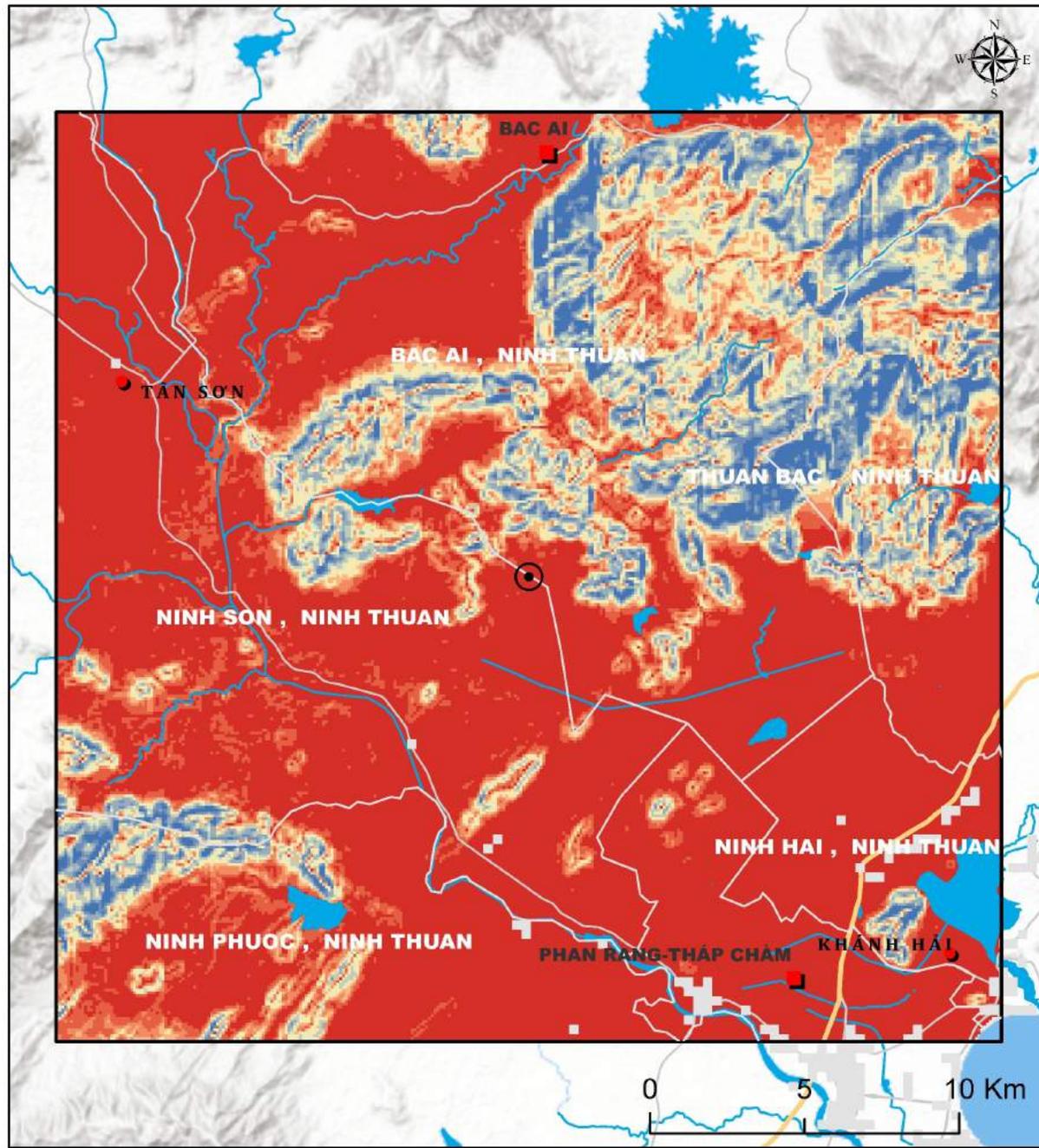
Source: GEOFABRIK - Open Street Map  
 + Genesis Ray Energy  
 Spatial Resolution: N.A.  
 Additional Information:  
<https://download.geofabrik.de/asia/vietnam.html>



## Site Suitability Layer: Elevation (Slope)

The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to solar park siting, operations and maintenance, (Table.) allowing spatial referencing of the region with respect to only slope-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections

Slope (degrees)	
Scored value	Raw Value
10	0-3
9	3-6
8	6-9
7	9-12
6	12-15
5	15-18
4	18-21
3	21-24
2	24-27
1	>27



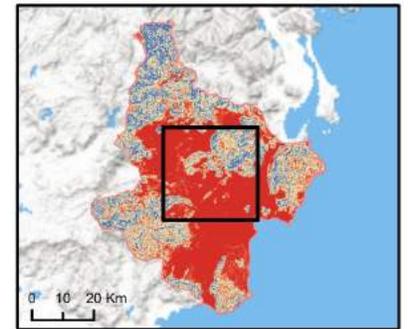
## Slope (Scored)

Source: USGS Shuttle Radar Topography Mission (SRTM)  
 Spatial Resolution: 90 meters at the equator  
 Additional Information: <https://earthexplorer.usgs.gov/>

**LEGEND**

- Cities
- Towns and Hamlets
- Prospective Solar Plant location
- District Boundary
- Area of Interest
- Settlements
- Highway
- Major Roads
- Rivers/Canals
- Waterbodies

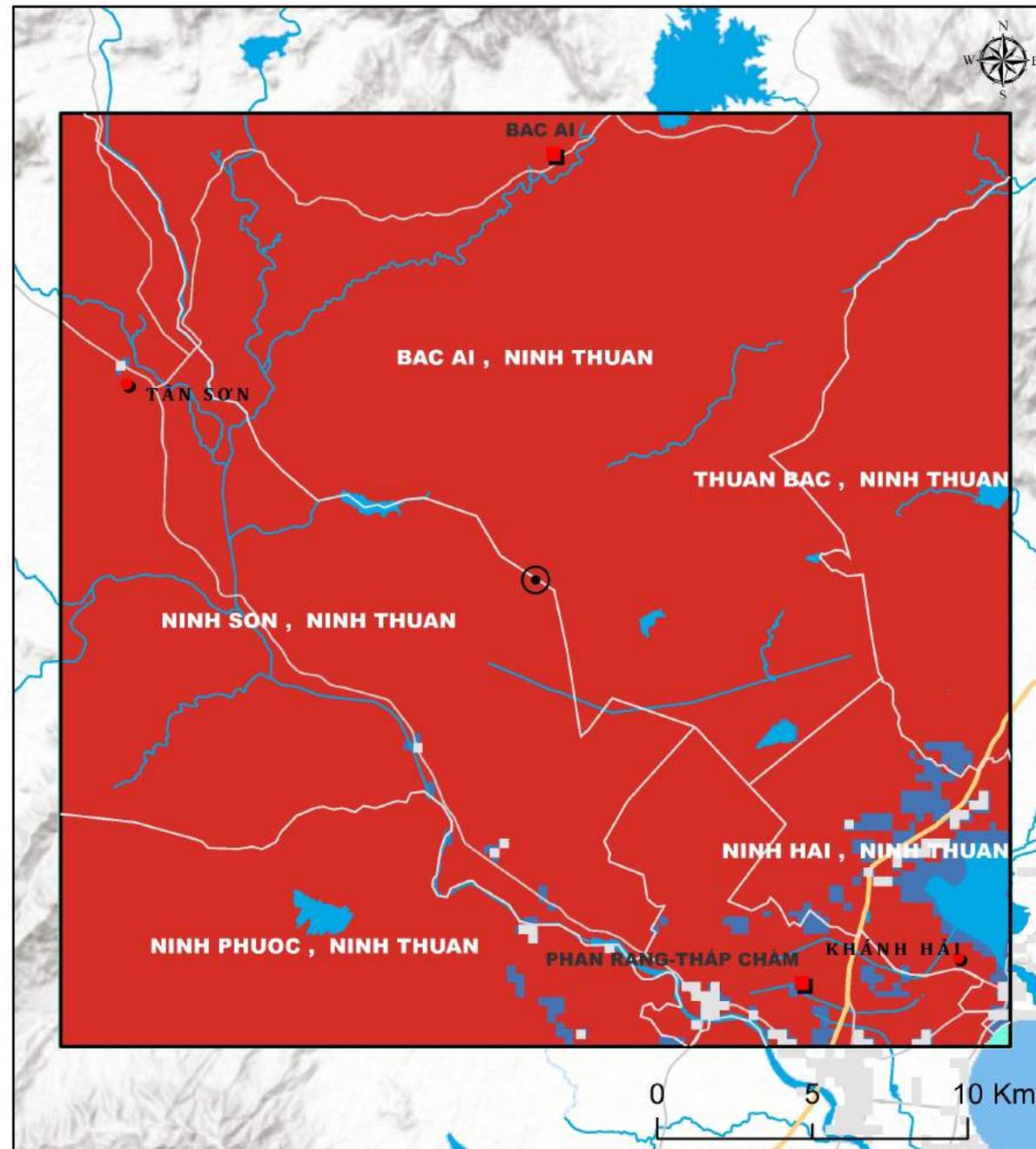
**Slope (Scored)**



## Site Suitability Layer: Soil Bearing Capacity

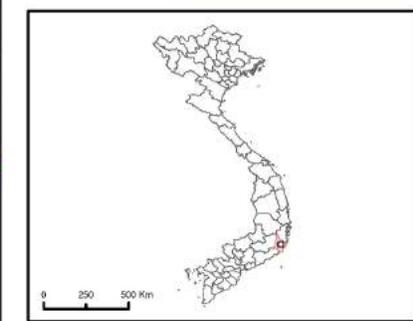
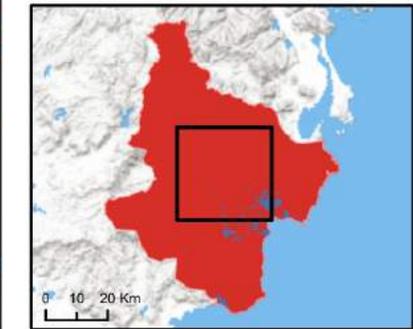
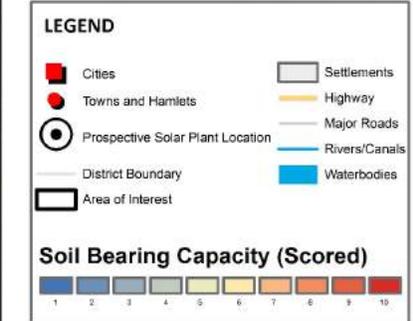
The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to solar park siting, operations and maintenance, (Table.) allowing spatial referencing of the region with respect to only soil bearing capacity-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections

Soil Bearing Capacity- (kN/m <sup>2</sup> ) (factor)	
Scored value	Raw Value
10	100-200
9	-
8	-
7	-
6	-
5	-
4	95
3	-
2	-
1	NO DATA



## Soil Bearing Capacity (Scored)

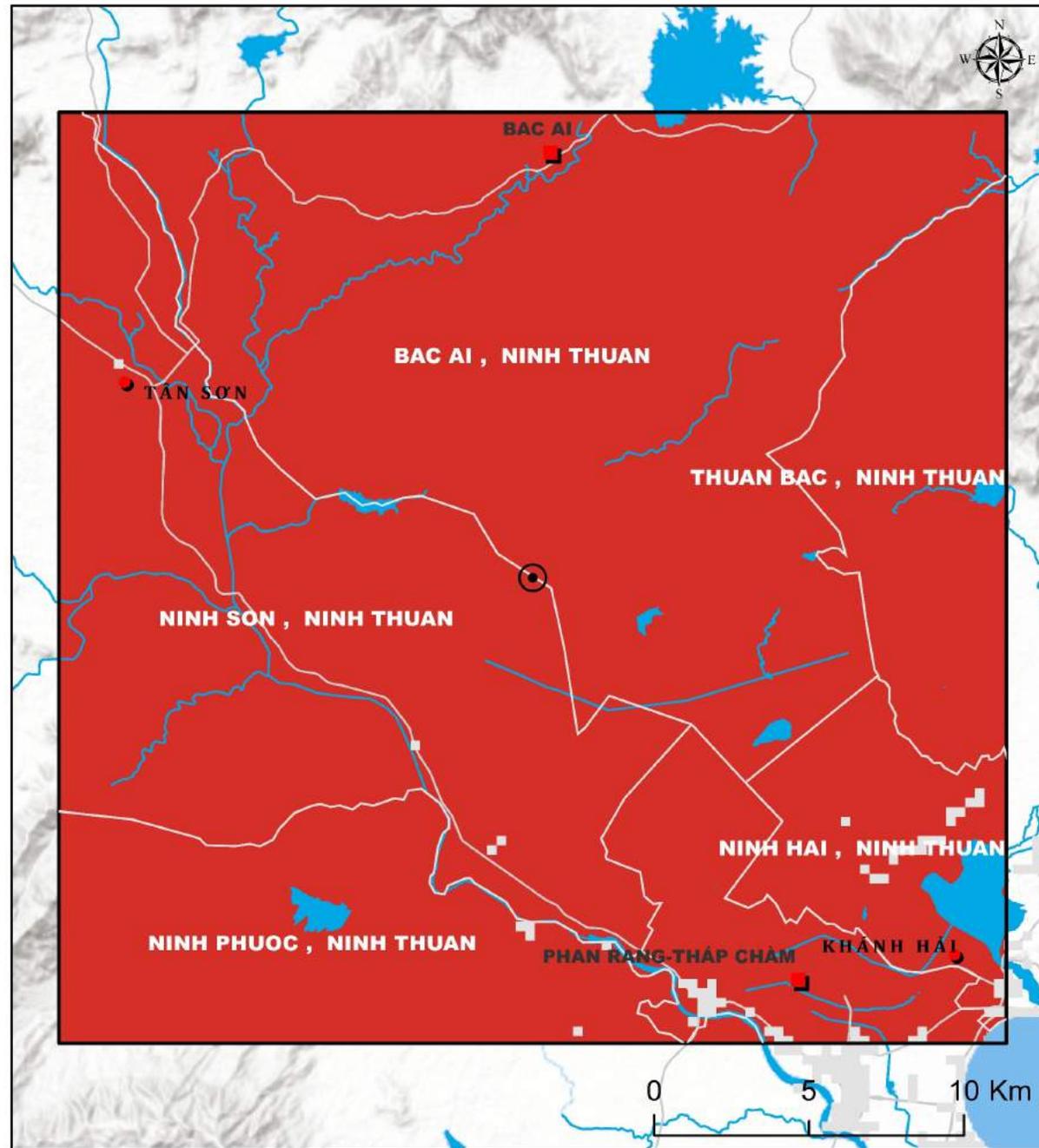
Source: World Soil Information + Genesis Ray Energy  
 Spatial Resolution: 250 meters at the equator  
 Additional information: <https://www.isric.org/explore/soilgrids>



## Site Suitability Layer: Natural Disasters - Cyclones

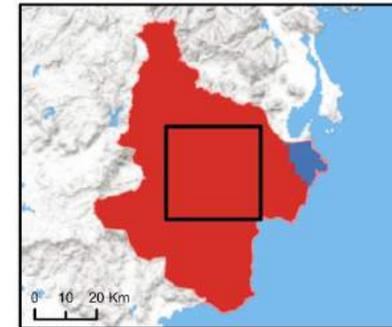
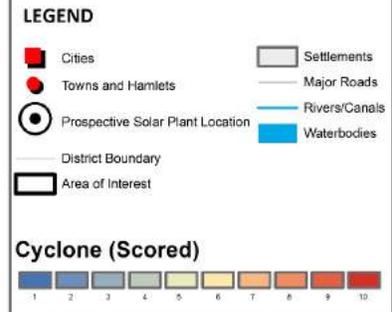
The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to Solar park siting, operations, and maintenance, (Table.) allowing spatial referencing of the region with respect to only cyclonic activity-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections

Cyclones - (meters/second) (factor)	
Scored value	Raw Value
10	No events
9	-
8	-
7	-
6	-
5	-
4	-
3	-
2	-
1	More than 0.25 events



## Cyclone (Scored)

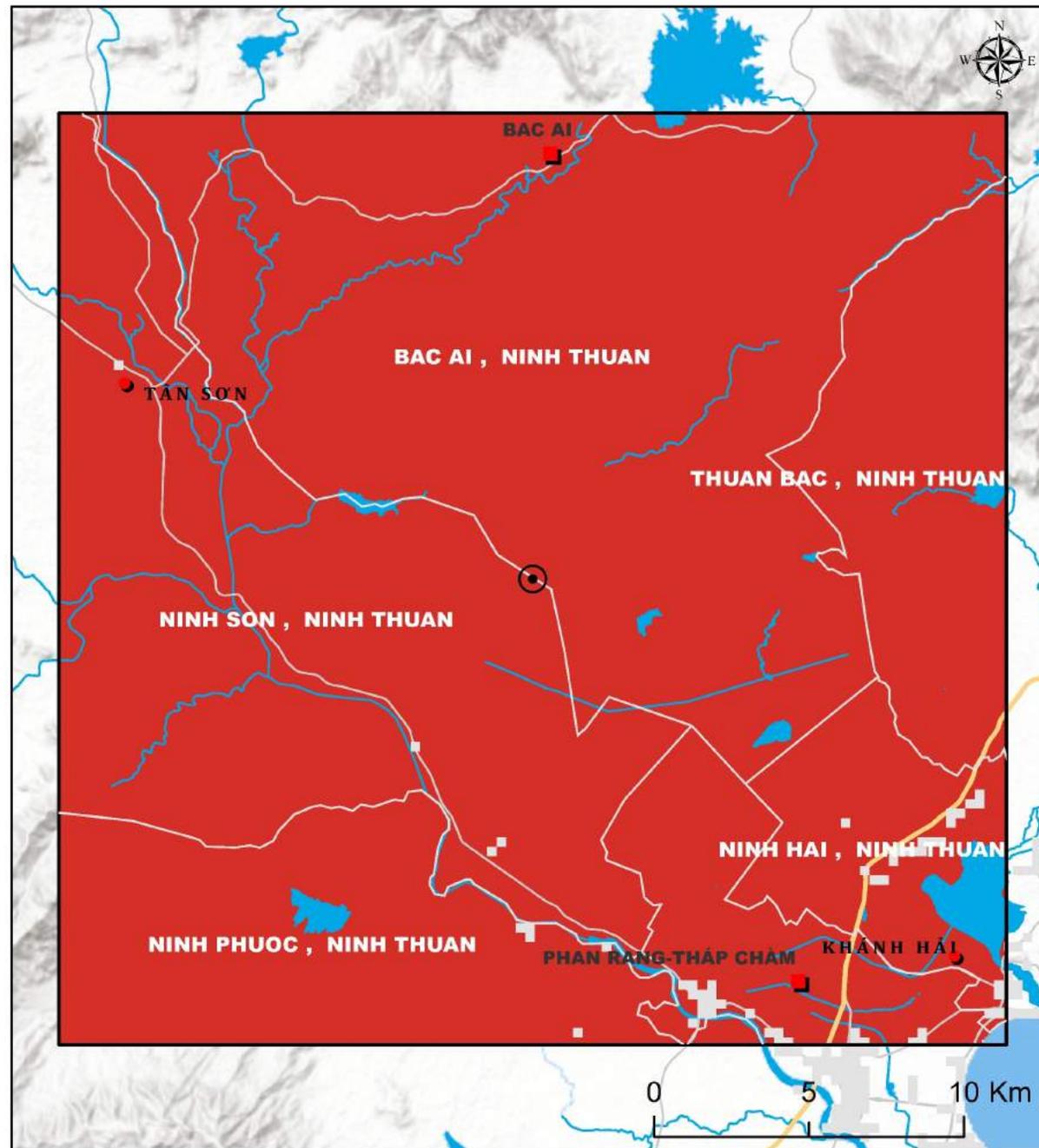
Source: United Nations Environment Programme :  
 Global Risk Data Platform  
 Spatial Resolution: 90 meters  
 Additional information:  
<https://preview.grid.unep.ch/>



## Site Suitability Layer: Natural Disasters - Earthquakes

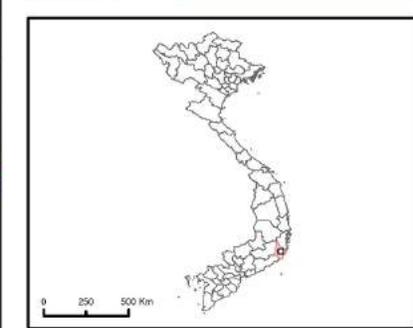
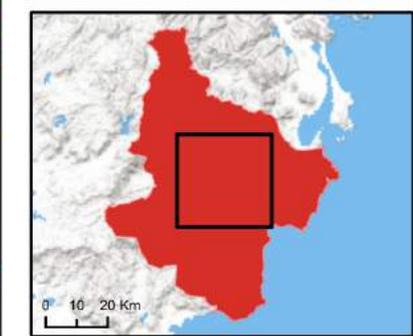
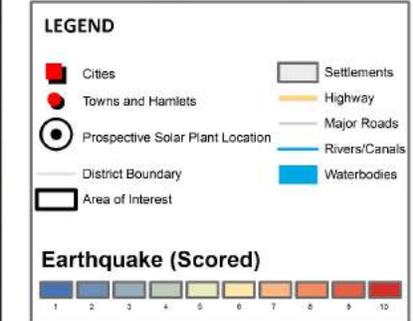
The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to Solar park siting, operations, and maintenance, (Table.) allowing spatial referencing of the region with respect to only seismic activity-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections.

Earthquake - (Richter scale) (factor)	
Scored value	Raw Value
10	<2.0
9	2.0-2.9
8	3.0-3.9
7	4.0-4.9
6	5.0-5.9
5	6.0-6.9
4	7.0-7.9
3	8.0-8.9
2	9.0-9.9
1	>10.0



## Earthquake (Scored)

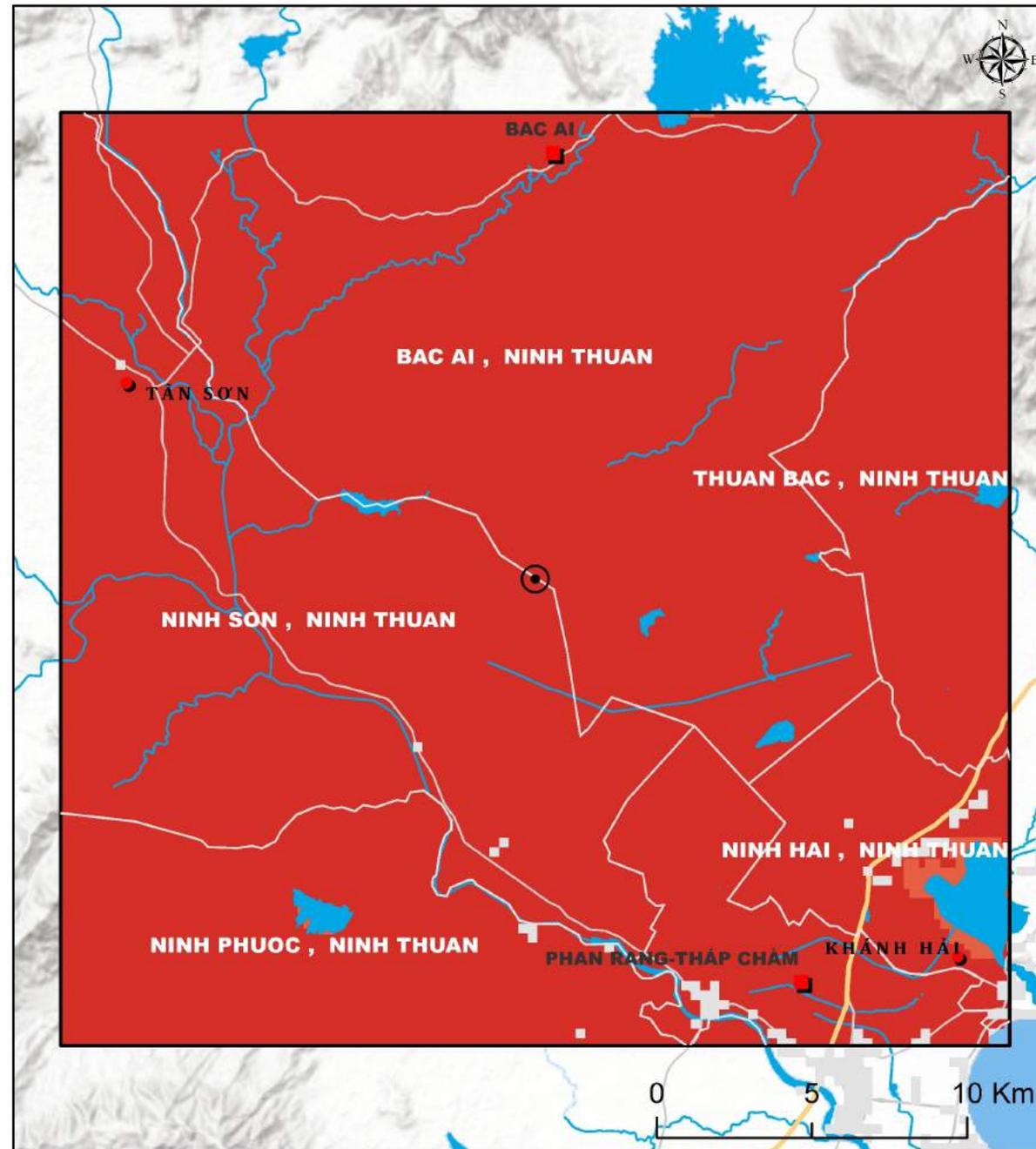
Source: GFZ German Research Centre for Geosciences  
 Spatial Resolution: 10 kilometers at the equator  
 Additional information: <https://www.gfz-potsdam.de/>



## Site Suitability Layer: Natural Disasters - Floods

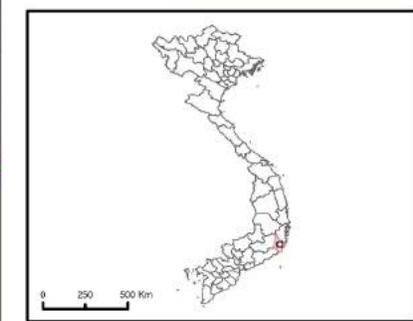
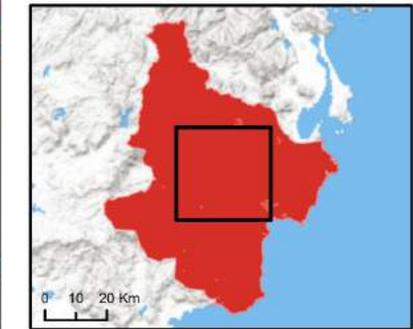
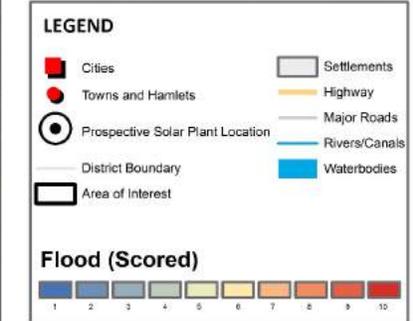
The continuous range is standardized to the common suitability numeric range from high (10) to low suitability (1) with respect to Solar park siting, operations, and maintenance, (Table.) allowing spatial referencing of the region with respect to only flooding susceptibility-based suitability ranking. Forming the basis of selection of a few highly promising sites, with their scored representations, also stated in the next sections.

Flooding - (% of days) (factor)	
Scored value	Raw Value
10	0
9	0-0.3
8	0.3-0.6
7	0.6-1
6	1-2
5	2-3
4	3-5
3	5-10
2	10-30
1	30-100



## Flood (Scored)

Source: NASA Global Flood Mapping (NASA) + Genesis Ray  
 Spatial Resolution: 250 meters at the equator  
 Additional information: <https://floodmap.modaps.eosdis.nasa.gov>



## Exclusion Zones

Type	Exclusion Zone	Description Details
<b>Road Network</b> (Exemption buffer width: 150 meters)	Exists	Nearest road: Asian Highway 1, QL 27
<b>Railway Network</b> (Exemption buffer width: 150 meters)	Exists	Nearest railway station: Ga Thap Cham Ninh Thuan
<b>Transmission Network</b> (Exemption buffer width: 150 meters)	Exists	Ha Song Pha 1 Hydro Power Plant - CMX RE Sunseap Vietnam Solar Power Plant (110KV), CMX RE Sunseap Vietnam Solar Power Plant - Thap Cham-2 (110KV), Thap Cham - Ninh Phuoc-2 (220KV), Thap Cham - Da Nhim Hydro Power Plant (220KV), Nha Trang - Thap Cham Line-I (220KV)
<b>Military Restrictions</b> (Exemption: extent out-of-bounds under military jurisdiction and special security measures prevent unauthorized construction)	Exists	San bay Thanh Son
<b>Airspace in &amp; around civil aerodromes</b> (Exemption: Turbine height restrictions depending upon permissible elevation of construction, with respect to the elevation of the airport and flight landing/ take-off strip)	Exists	Phan Rang
<b>Protected areas and heritage sites</b> (Exemption: extent recognized, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values.)	Does not exist	Not Applicable
<b>Waterways and waterbodies</b> (Exemption: only extent)	Exists	Song Dinh, Suoi A Le, Suoi O Cam

\* all exclusion zones are within the project Box (see map in next slide)

## EXCLUSION ZONE

**Layer Description:**  
 Highlighting areas unsuitable for renewable energy development purposes. e.g. protected, restricted, airspace or aerodomes, etc.

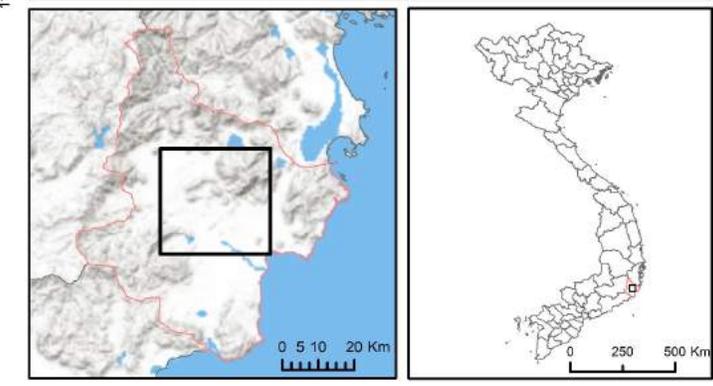
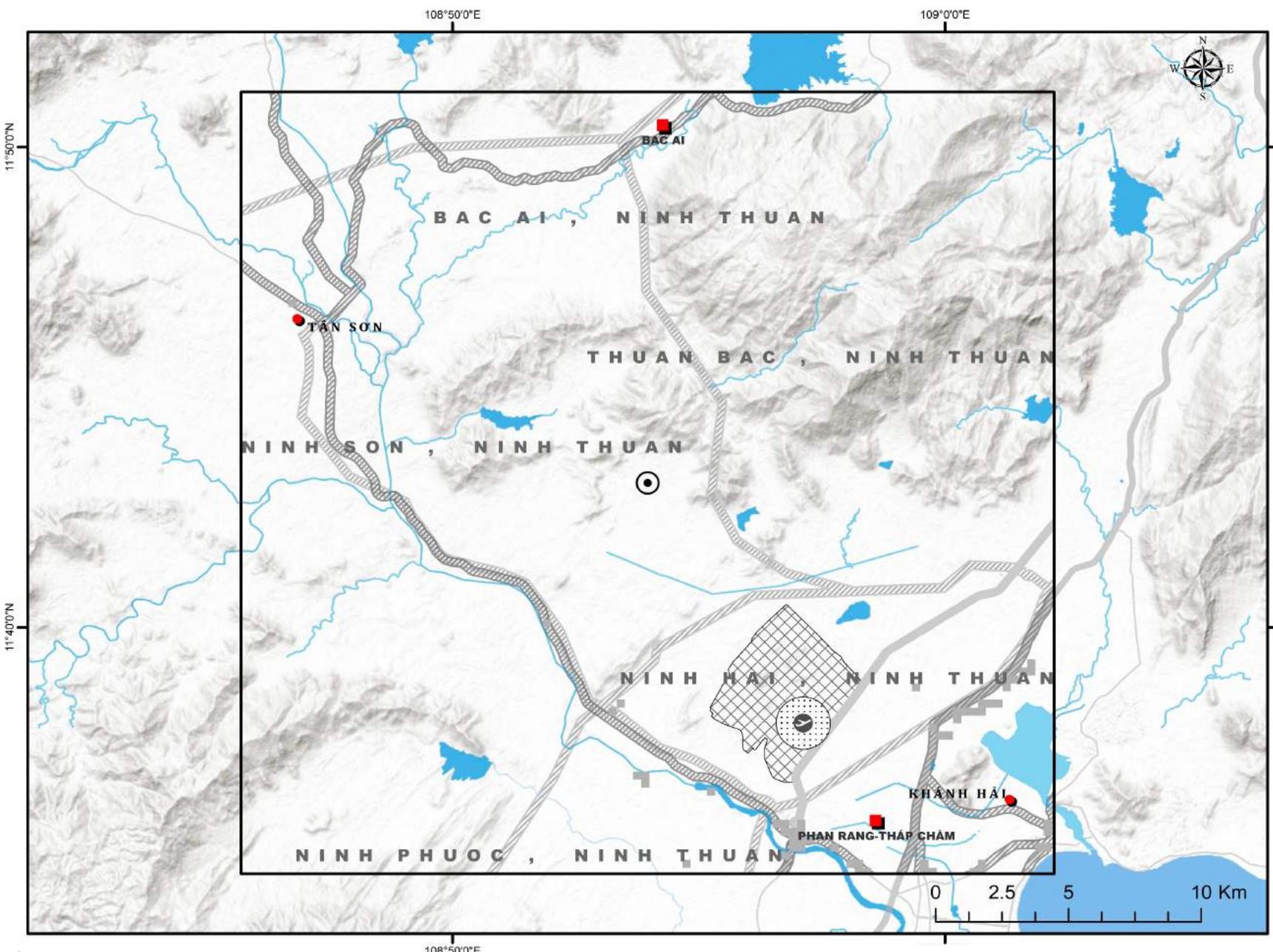
**Source:** GEOFABRIK- Open Street Map  
**Spatial Resolution:** N.A  
**Additional information:** <https://download.geofabrik.de/asia/vietnam.html>

**LEGEND**

Cities	Settlements
Towns and Hamlets	Highway
Prospective Solar Plant location	Major Roads
District Boundary	Rivers/Canals
Area of Interest	Waterbodies

**Exclusion Zones**

Military Areas	Exclusion Zone -Railway
Exclusion Zone -Road	Exclusion Zone - Transmission Line





# Section 4: Solar Irradiation and Yield Estimation Analysis

# Solar Resource Map



## SOLAR RESOURCE MAP

### Layer Description:

Global Horizontal Irradiation/Irradiance (GHI) is the sum of direct and diffuse radiation received on a horizontal plane. GHI is a reference radiation for the comparison of climatic zones.

**Source:** Genesis Ray Energy

**Spatial Resolution:** 25 Km at the equator

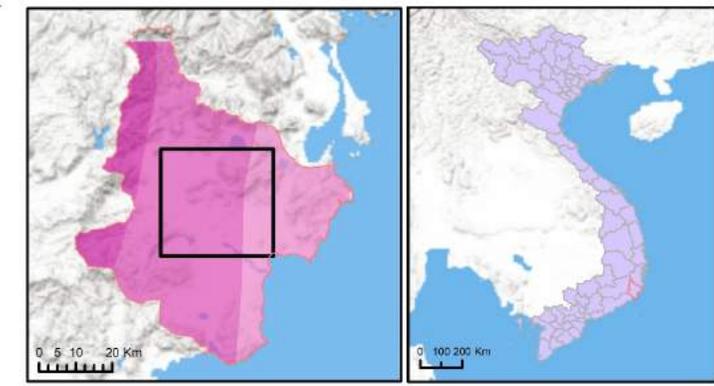
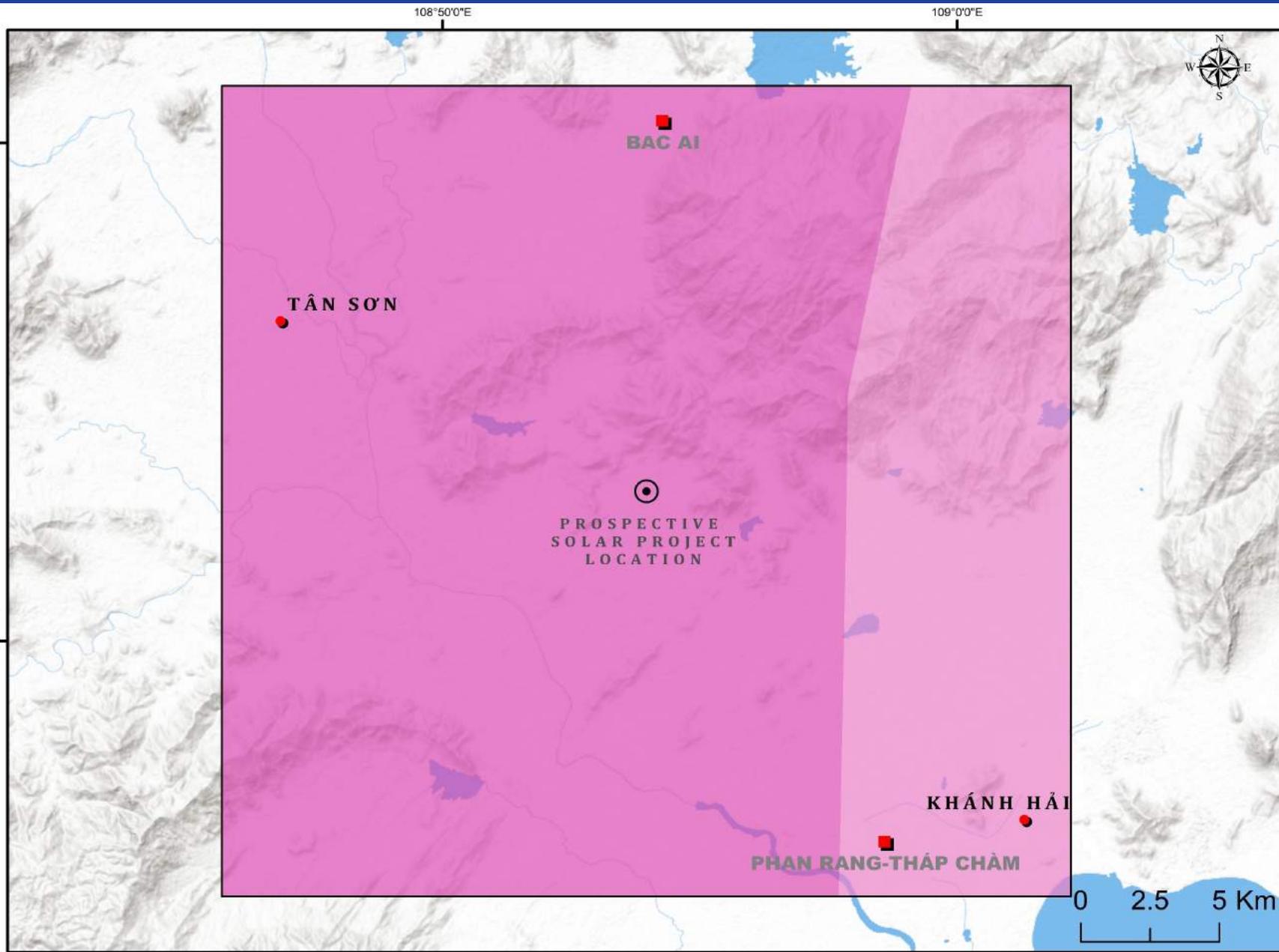
**Additional Information:**

[www.genesisray.com](http://www.genesisray.com)

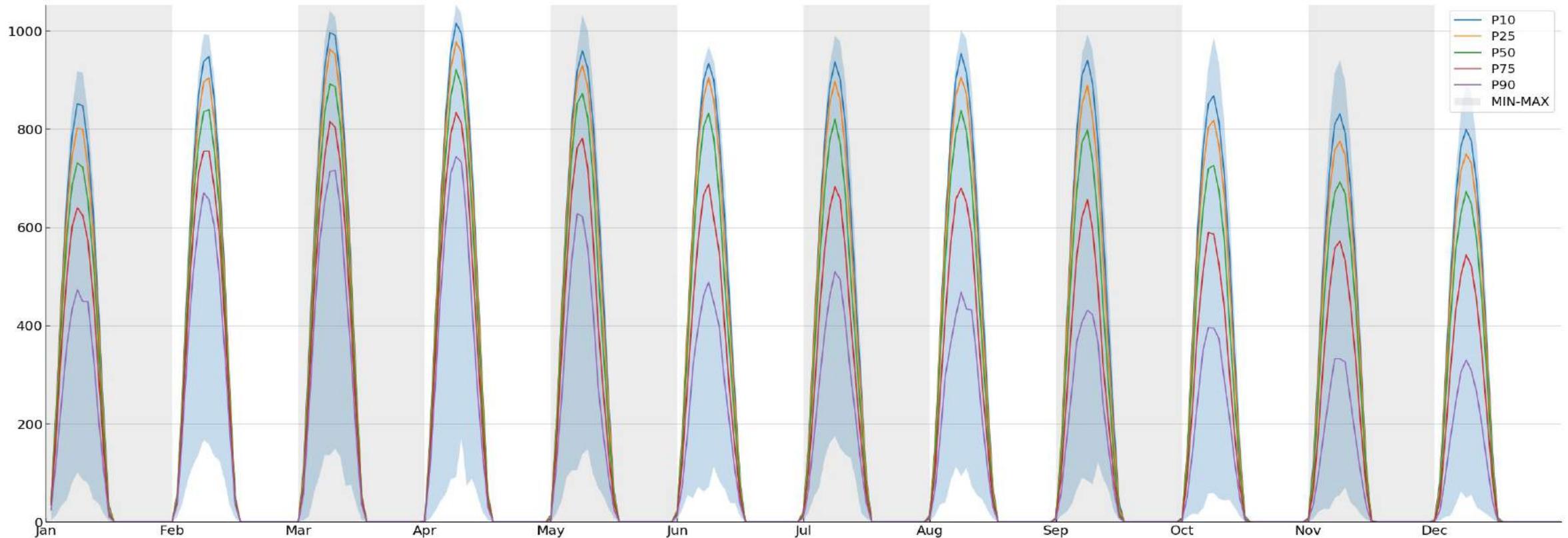
### LEGEND

- Area of Interest
- Prospective Solar Plant location
- villages
- Towns and Hamlets
- District Boundary
- Major Roads
- Highway
- Rivers/Canals
- Waterbodies

### Global Horizontal Irradiance (GHI) kW/m2/day

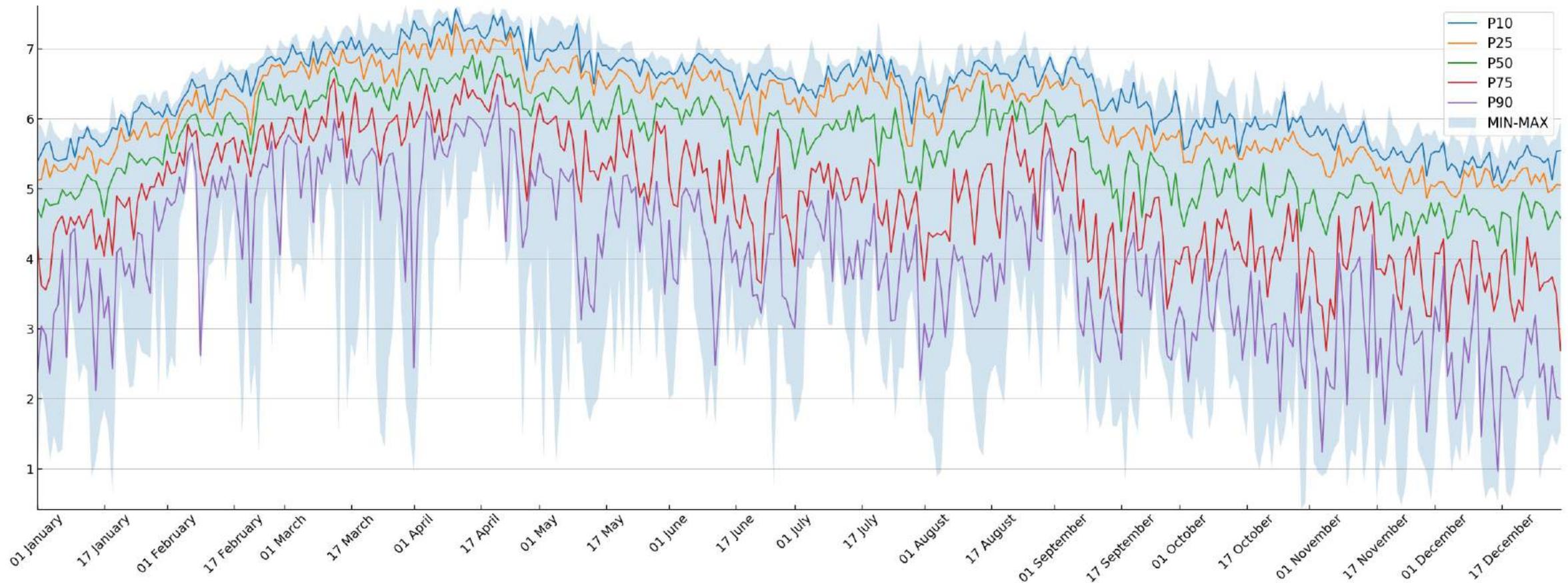


## Data Inputs - Global Horizontal Irradiation (GHI): Typical Daily Profile across Months (watts/m<sup>2</sup>/hour)



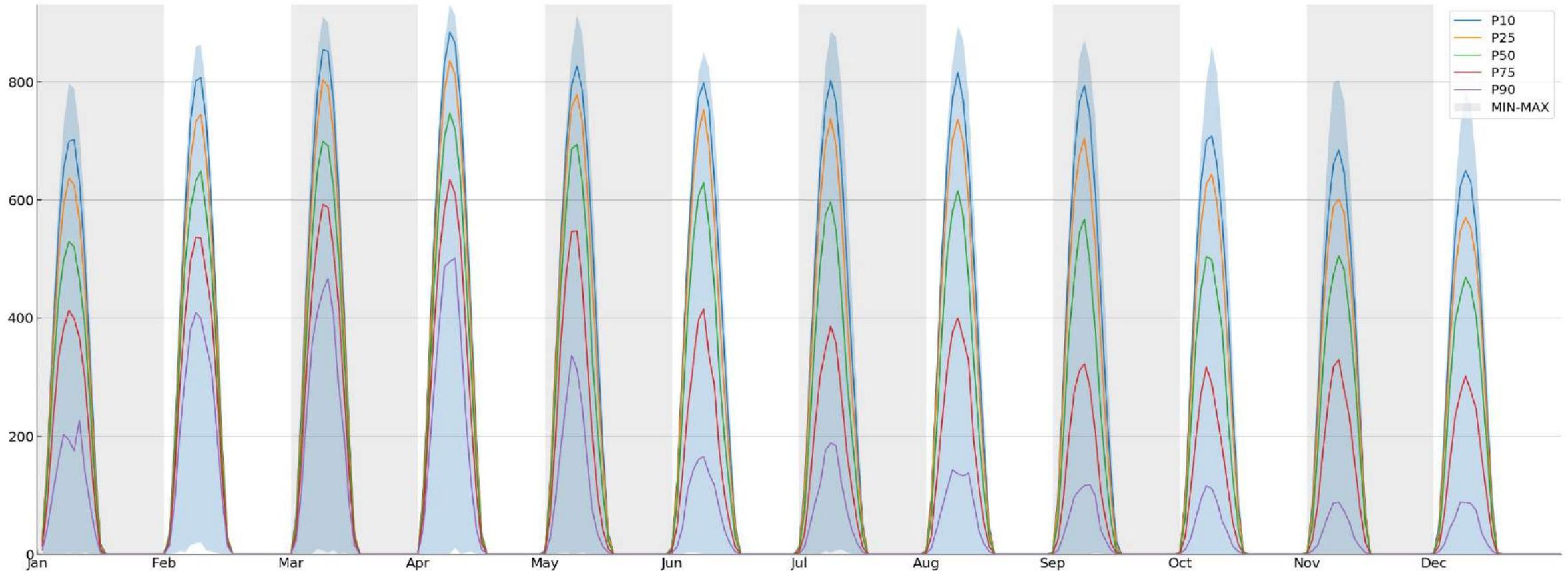
- **Typical daily profiles (24 hours)** from January to December are calculated using 20 years of hourly GHI data from 2001 to 2020.
- A drop in the irradiance values from May onwards is due to the start of the monsoon season. During this time, most parts of the country experience an extensive cloud cover and rainfall, which is also evident from the typical annual profile of precipitation.
- The maximum GHI values can be seen during March and April, which is around 1041 and 1052 watts/m<sup>2</sup>/hour, respectively, and the maximum value of GHI exceeds 7 kW/m<sup>2</sup>/day per day these months.
- A gradual increase in GHI values can be seen from January onwards, before reaching its peak in April.

## Data Inputs - Global Horizontal Irradiation (GHI): Typical Meteorological Year (kW/m<sup>2</sup>/day)



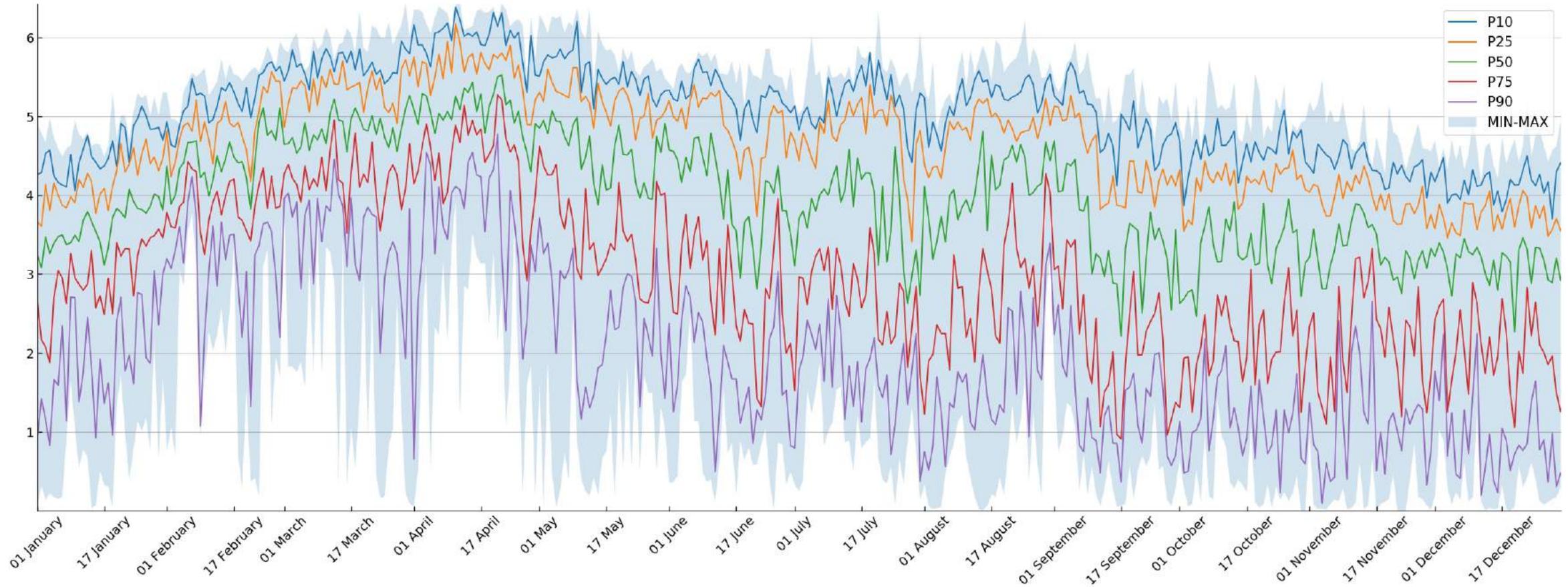
- **Typical Meteorological Year (TMY)** profile on hourly basis (8760 hours) is calculated using 20 years of hourly GHI data from 2001 to 2020.

## Data Inputs – Direct Normal Irradiance (DNI): Typical Daily Profile across Months (watts/m<sup>2</sup>/hour)

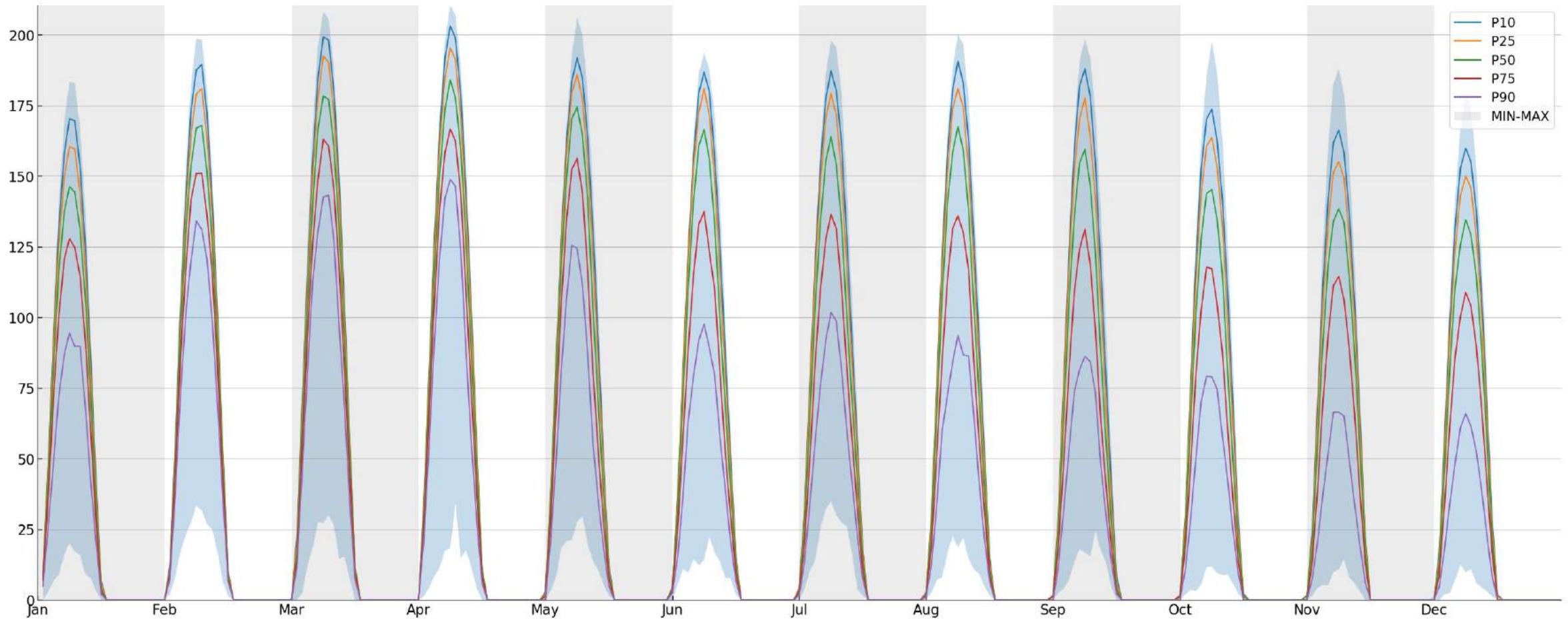


- DNI is also known as Direct solar Radiation at the Surface.
- DNI values are in-sync with the GHI values and show an identical pattern with a similar drop rate, having slightly lower minimum and maximum values.
- The maximum DNI values can be seen during the month of March and April, which are around 909 and 930 watts/m<sup>2</sup>/hour, respectively. Per day the maximum reach of DNI values exceeds 6 kW/m<sup>2</sup>/day during the months of March and April.

## Data Inputs – Direct Normal Irradiance (DNI): Typical Meteorological Year (kW/m<sup>2</sup>/day)

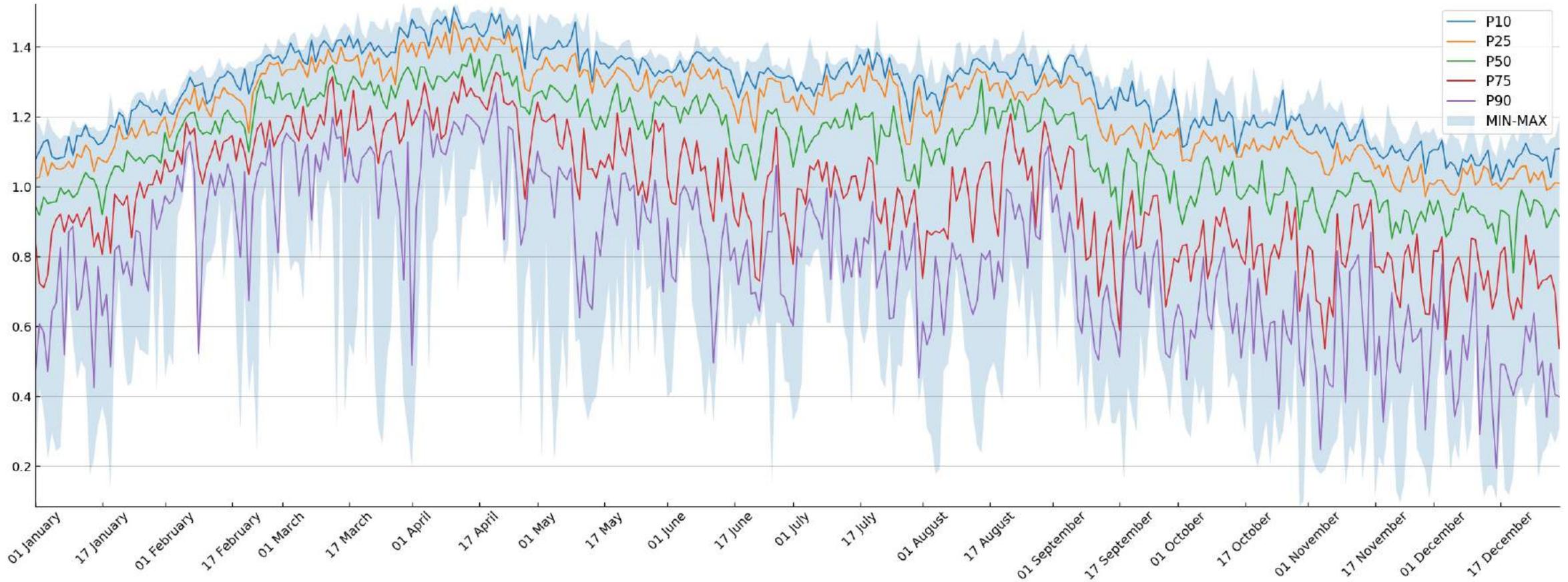


## Data Inputs – Diffused Horizontal Irradiance (DHI): Typical Daily Profile across Months (watts/m<sup>2</sup>/hour)

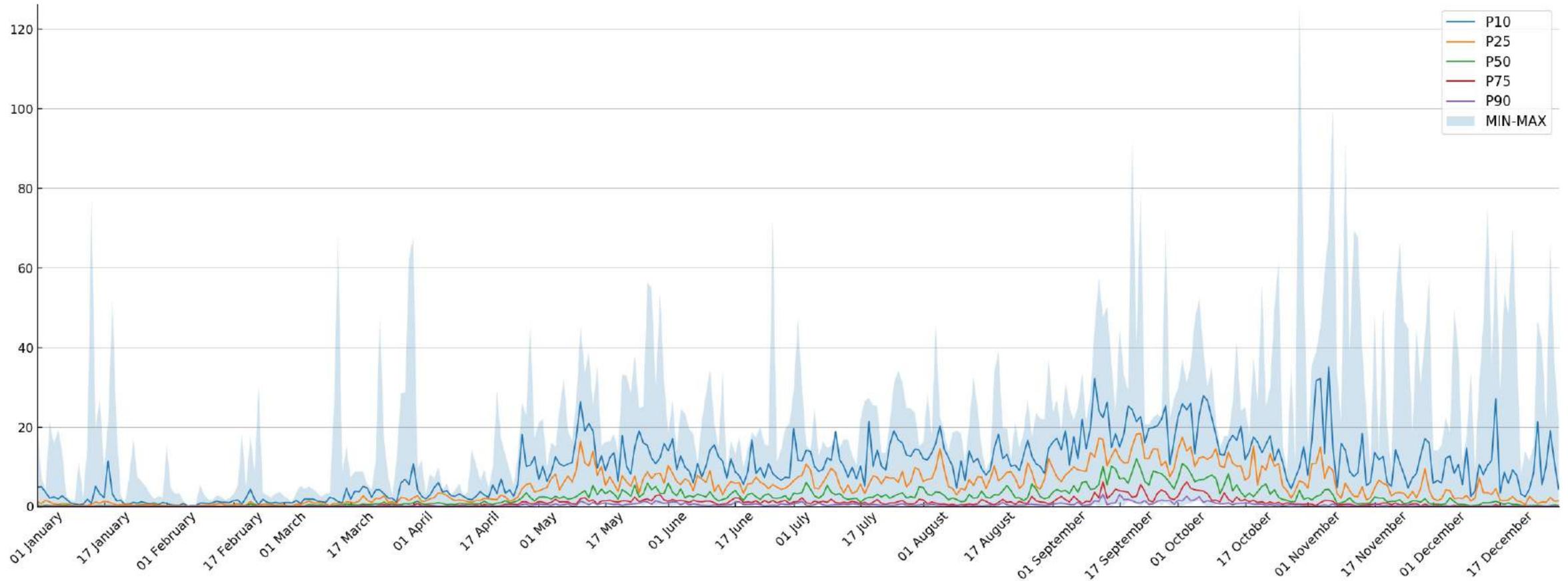


- DHI values are also in-sync with the GHI values and shows similar pattern with much higher drop rate, lower minimum, and maximum values.
- The maximum DHI values can be seen during the month of April, which is around 210 watts/m<sup>2</sup>/hour, and per day the maximum value of DHI exceeds 1.4 kW/m<sup>2</sup>/day during the months of April and May.

## Data Inputs – Diffused Horizontal Irradiance (DHI): Typical Meteorological Year (kW/m<sup>2</sup>/day)



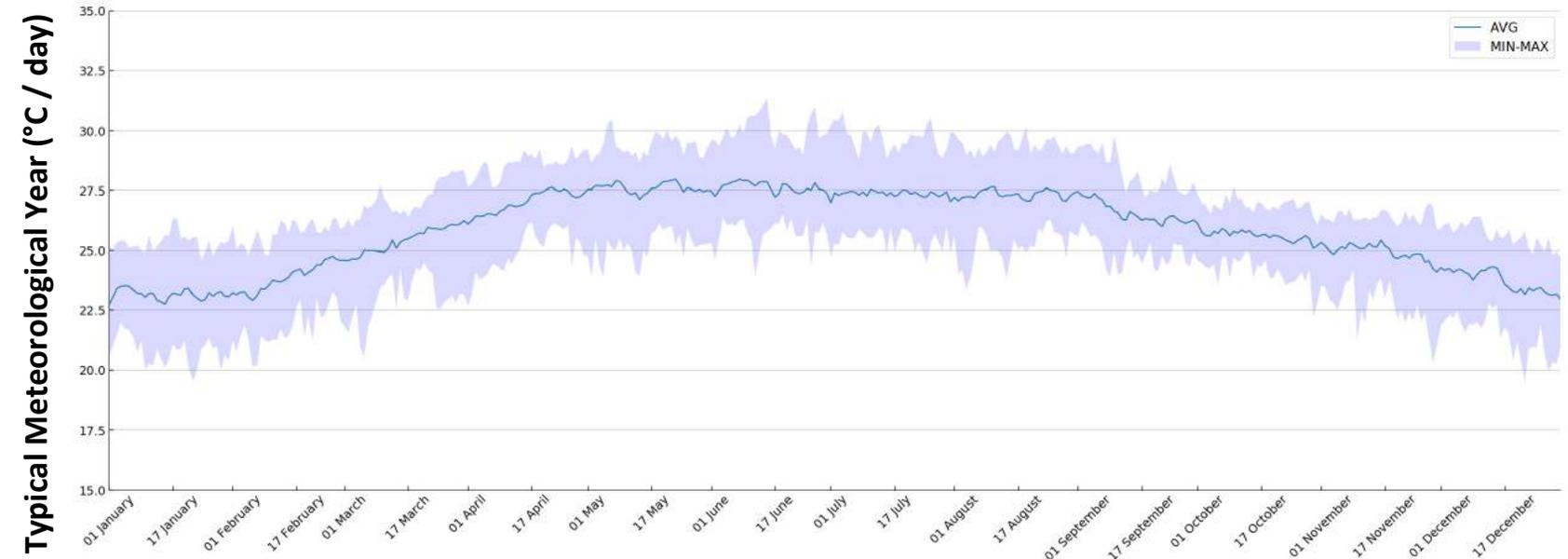
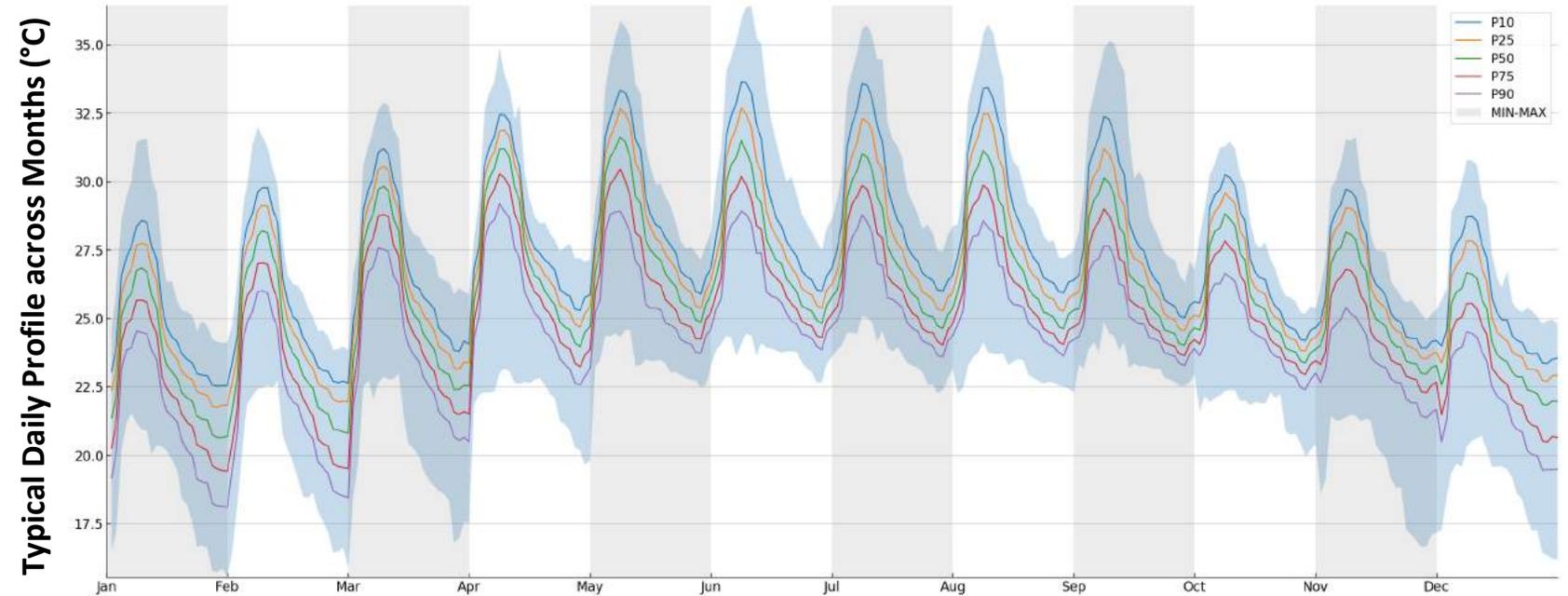
## Data Inputs – Precipitation: Typical Meteorological Year (mm/day)



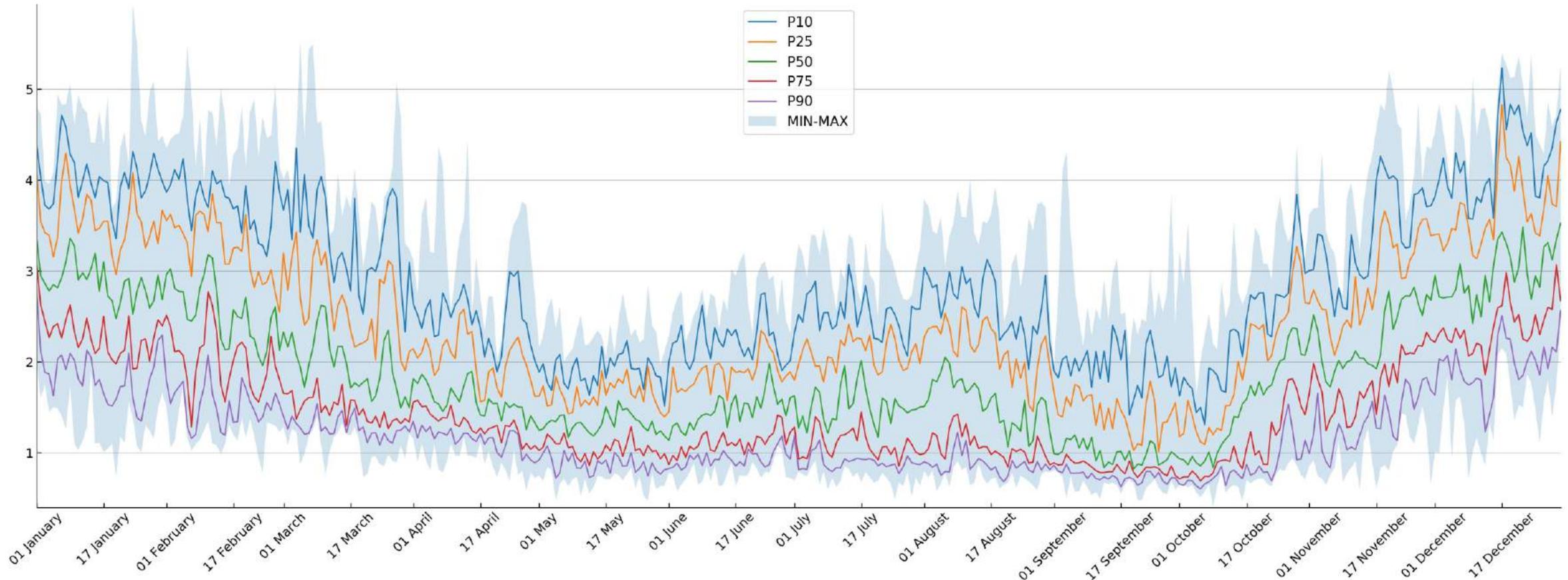
- DHI values are also in-sync with the GHI values and shows similar pattern with much higher drop rate, lower minimum, and maximum values.
- The maximum DHI values can be seen during the month of April, which is around 210 watts/m<sup>2</sup>/hour, and per day the maximum value of DHI exceeds 1.4 kW/m<sup>2</sup>/day during the months of April and May.

## Temperature

- The temperature gradually increases from January onwards up to June and then starts decreasing.
- Maximum temperature is around 36°C in the month of June.
- $T_{MIN}$  and  $T_{MAX}$  profiles show a maximum spread of approximately 6.7°C in the month of June and a minimum of around 1.8°C in the month of October. On average, the spread is about 3.9°C throughout the year.
- The average temperature varies between 22.7°C to 28.1°C, approximately, in a year.
- $T_{MIN}$  and  $T_{MAX}$  vary between 19.5°C to 26.5°C and 24.6°C to 31.3°C, respectively.

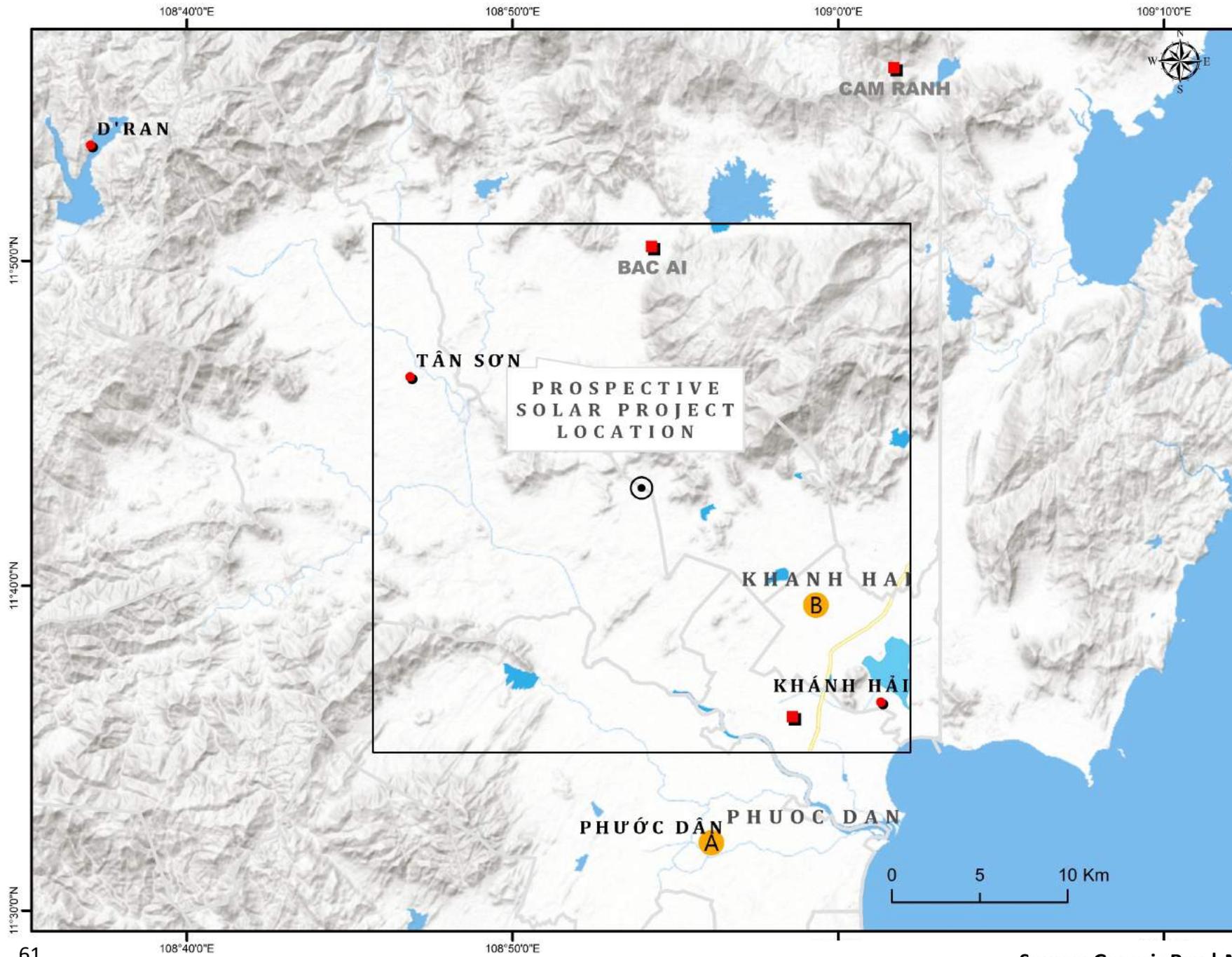


## Data Inputs – Wind Speed (m/s)



- Wind speed gradually decreases from January to April, and from then onwards, it starts increasing with the arrival of monsoon season with a slight dip in the September-October months.
- In general, the average wind speed varies from 0.8 m/s - 3.5 m/s throughout the year.

**Based on the multiple inputs considered in the area of interest, the site is deemed suitable for the solar plant, however, it is likely to generate slightly less during the rainy season.**



## Data Validation Locations

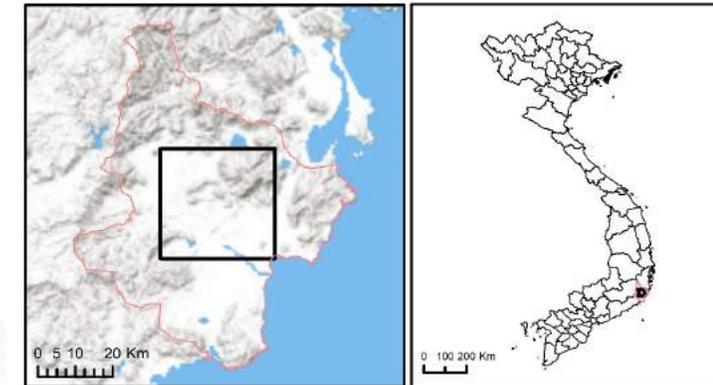
**Layer Description:**

Point A and Point B are representation points for the Diurnal profiles for Phuoc Dan and Khanh Hai.

**Source:** Genesis Ray Energy  
**Spatial Resolution:** 25 Km at the equator  
**Additional Information:**  
[www.genesisray.com](http://www.genesisray.com)

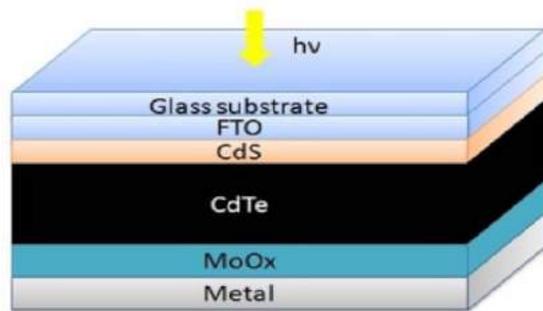
**Legend**

	Prospective Solar Plant location		District Boundary
	Area of Interest		Settlements
	Towns and Hamlets		Major Roads
			Waterbodies



## Energy Yield Estimation Assumptions 1/2

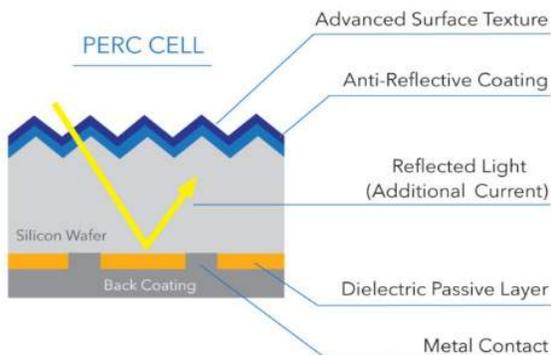
- To determine generation profile for 50MWp solar plant Genesis Ray Energy has considered 2 photovoltaic technologies.
- The solar plant is considered as fixed ground-mount.
- Local solar time and incident radiation on module is determined.
- The power generated is calculated as a function of temperature to determine DC power. Finally, the DC power is converted to AC power considering utility scale losses.
- Monthly and annual generation values and annual CUF of the solar plant at the proposed site is calculated.



**Thin Film CdTe:** Technology that is based on the use of cadmium telluride, a thin semiconductor layer designed to absorb and convert sunlight into electricity. Cadmium telluride PV is the only thin film technology with lower costs than conventional solar cells made of crystalline silicon in multi-kilowatt systems. This is due to consumption of less material and energy in the fabrication processes.

PV based on CdTe represent the largest segment of commercial thin-film module production worldwide. CdTe PV has the smallest carbon footprint. CdTe is one the most prominent technology to be installed in hot and humid climatic zones.

**Manufacturer:**  
First Solar,  
**Model:**  
FS-4122A-3  
**Power :**  
122.5Wp  
**Efficiency:**  
17.00%



**Monocrystalline PERC:** PERC technology boosts efficiency through the addition of a layer to the back of a traditional solar cell. Objective of PERC being to get the most of electrons out of the solar cells. Its architecture essentially enables to improve light capture near the rear surface and to optimize electrons capture thus having better efficiency as compared to traditional silicon wafer modules.

PERC solar cells typically perform better than traditional panels in both low-light conditions and high temperatures. Solar markets around the world are markedly shifting to mono PERC, and Vietnam is expected to follow suit.

**Manufacturer:**  
Waaree ,  
**Model:**  
WSMP - 350  
**Power :**  
350Wp  
**Efficiency:**  
18.07%

## Energy Yield Estimation Assumptions 2/2

- Genesis Ray has considered **DC losses** and **irradiation losses** while calculating the monthly and annual generation values of the solar plant at the proposed site.
- Table here represents a typical example of how different losses considered can impact the overall power generation, Here, Total irradiance of 1000 W/m<sup>2</sup> and temperature of 30°C is assumed as a reference
- To determine the generation profile of the solar plant, Genesis Ray Energy has considered an **ABB central inverter (PVS800-MWS-1000kW-20)** with an efficiency of **97.80%**.
- **AC conversion efficiency** is taken as **96%**.
- Genesis Ray has analyzed the bias-corrected ERA5 data to generate resource profiles for the location of interest. We use a time period of 20 years from 2001-to 2020 at a 1-hour temporal resolution to estimate the entire weather governed resource profiles for weather parameters.

Parameters	Values (W/m <sup>2</sup> )	Efficiency %	Remarks
Total Irradiance (It)	<b>1000</b>	100	Total irradiance of 1000 W/m <sup>2</sup> at temperature of 30°C is assumed
Converted Irradiance	<b>950</b>	95%	5% of total irradiation losses is considered.
Power Produced by Mono PERC cell	<b>171.67</b>	18.07%	Solar cell efficiency of a standard Mono PERC technology is used to calculate power produced from the converted irradiance(18.07%).
Actual Energy with Temp variation	<b>152.726</b>	-11.03%	Losses due to difference in module wrt standard temperature (25°C) is used to calculate the actual power produced from the Mono PERC cell. Difference in temperature = standard temp. – module temp. Temperature coefficient = Difference in temp. * temp. coefficient Pmax (Mono)*
DC energy	<b>145.8534</b>	95.50%	Various types of DC losses are considered to find the DC energy from the Actual Energy produced (4.5%)
AC energy	<b>142.6446</b>	97.8%	DC Energy is converted to AC energy using the inverter efficiency
Actual AC Power after losses	<b>136.94</b>	96.00%	Actual AC Power after various losses is calculated

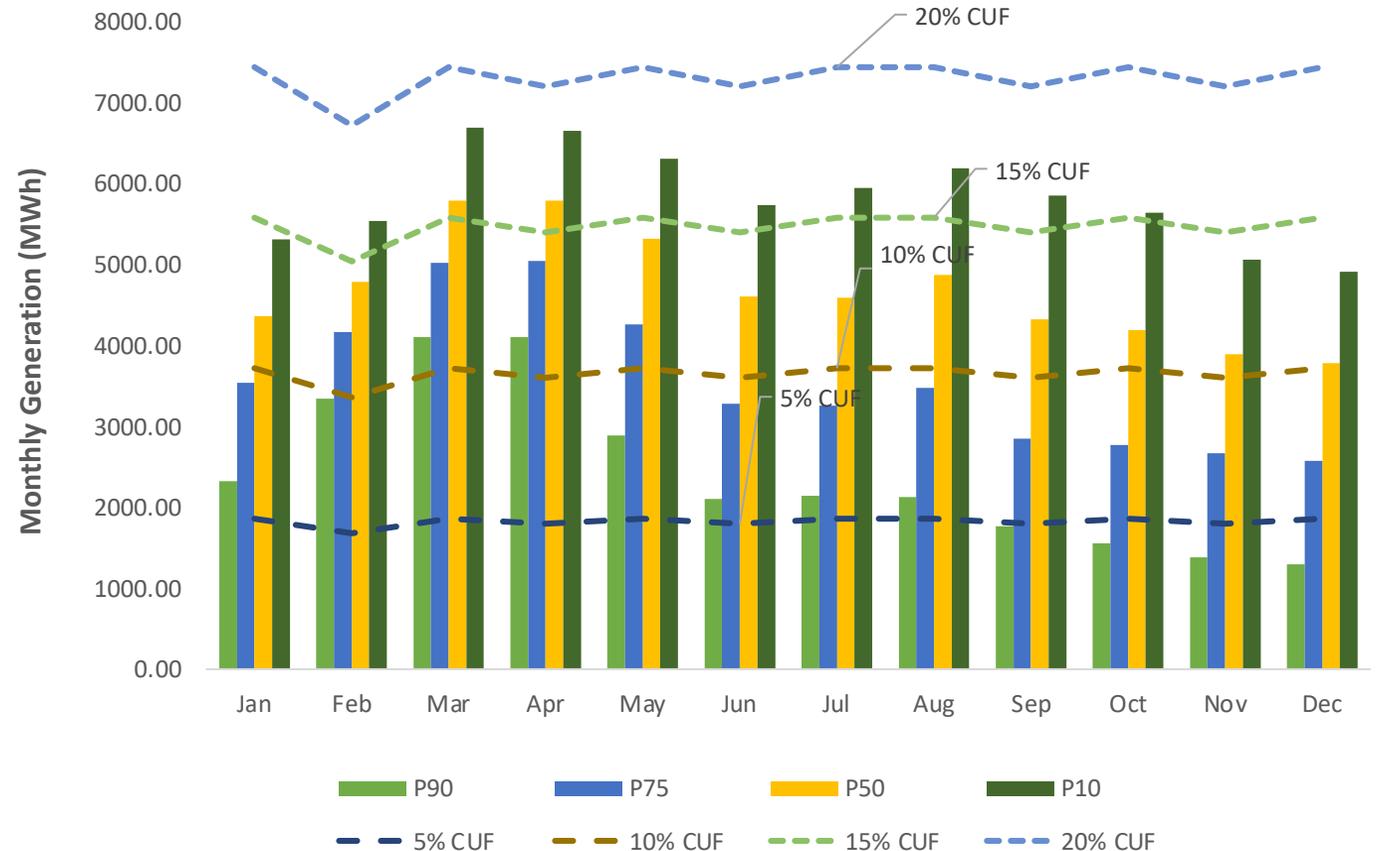
\* For Mono PERC, a standard temperature coefficient of 0.37% is considered.

## Monthly Generation (MWh) for 50 MW plant at different GHI levels – Mono PERC Technology

- Based on the calculated Genesis Ray irradiation and temperature data at the proposed site, solar energy yield is calculated at various P levels i.e., P90, P75, P50 and P10.
- P90 value of monthly generation using Mono PERC modules were highest at over 4100 MWh during the months of March and April and lowest in December at around 1300 MWh.
- P50 model gives a value of around 5800 MWh in the months of March and April and lowest of around 3800 MWh in December.
- P10 model gives over 6650 MWh in March and April, and the least value of ~4900 MWh in August.

Resource Profile	Annual Generation (GWh)	CUF
P50	56.318	12.86%
P75	42.906	9.80%
P90	29.144	6.65%
P95	22.626	5.17%
P99	15.895	3.63%

Monthly Generation of a 50 MW plant using Mono PERC modules at different P Levels



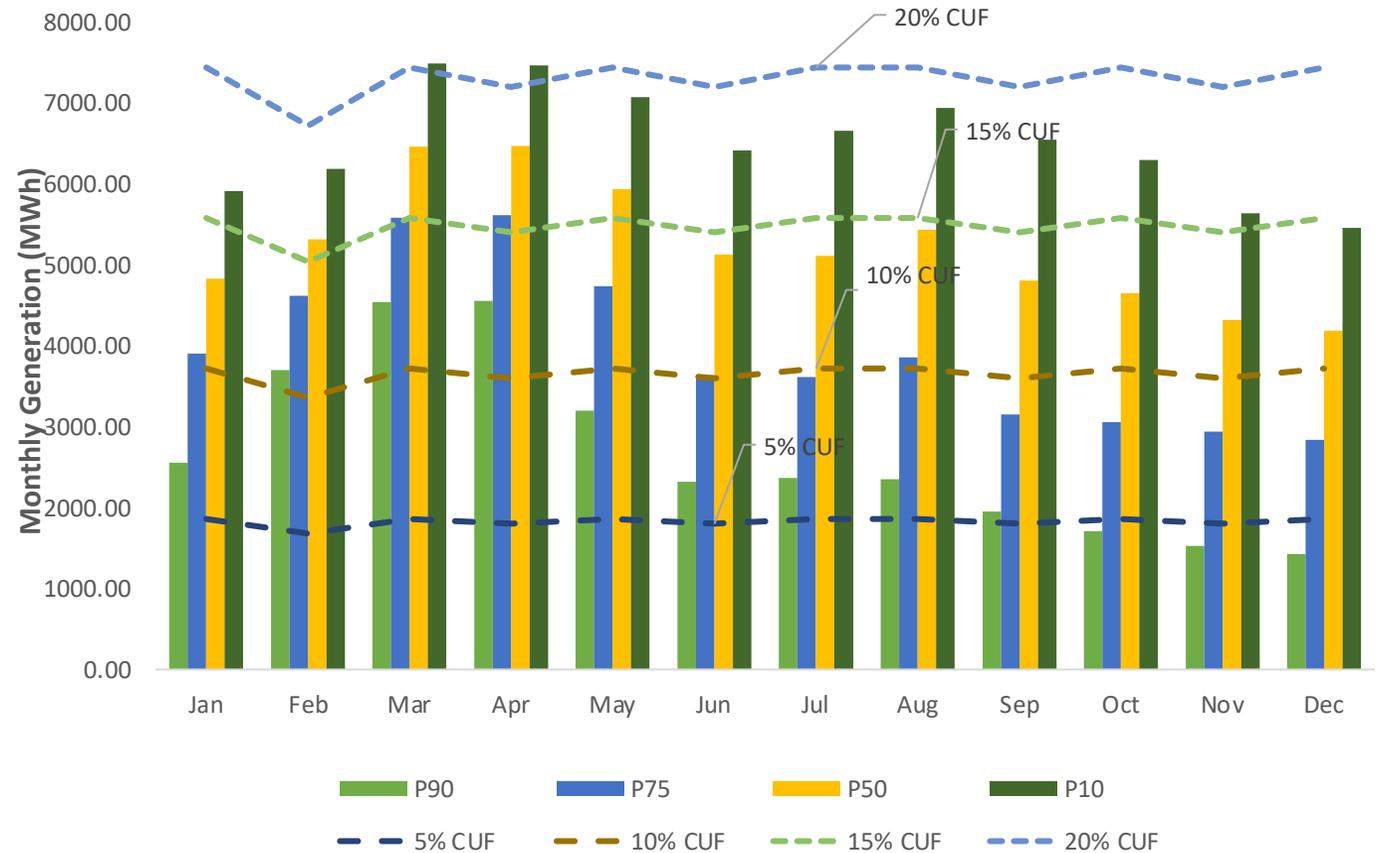
\*CUF levels considering ideal generation of a 50 MW solar plant

## Monthly Generation (MWh) for 50 MW plant at different GHI levels – Thin Film CdTe Technology

- P90 value of monthly generation using Thin-film CdTe modules were highest at over 4500 MWh in March and April and lowest in December at around 1400 MWh.
- P50 model gives a value of around 6500 MWh in the months of March and April and lowest of around 4200 MWh in December.
- P10 model gives around 7500 MWh in the months of March and April, and the least value of ~5450 MWh in December.

Resource Profile	Annual Generation (GWh)	CUF
P50	62.642	14.30%
P75	47.556	10.86%
P90	32.203	7.35%
P95	24.963	5.70%
P99	17.504	4.00%

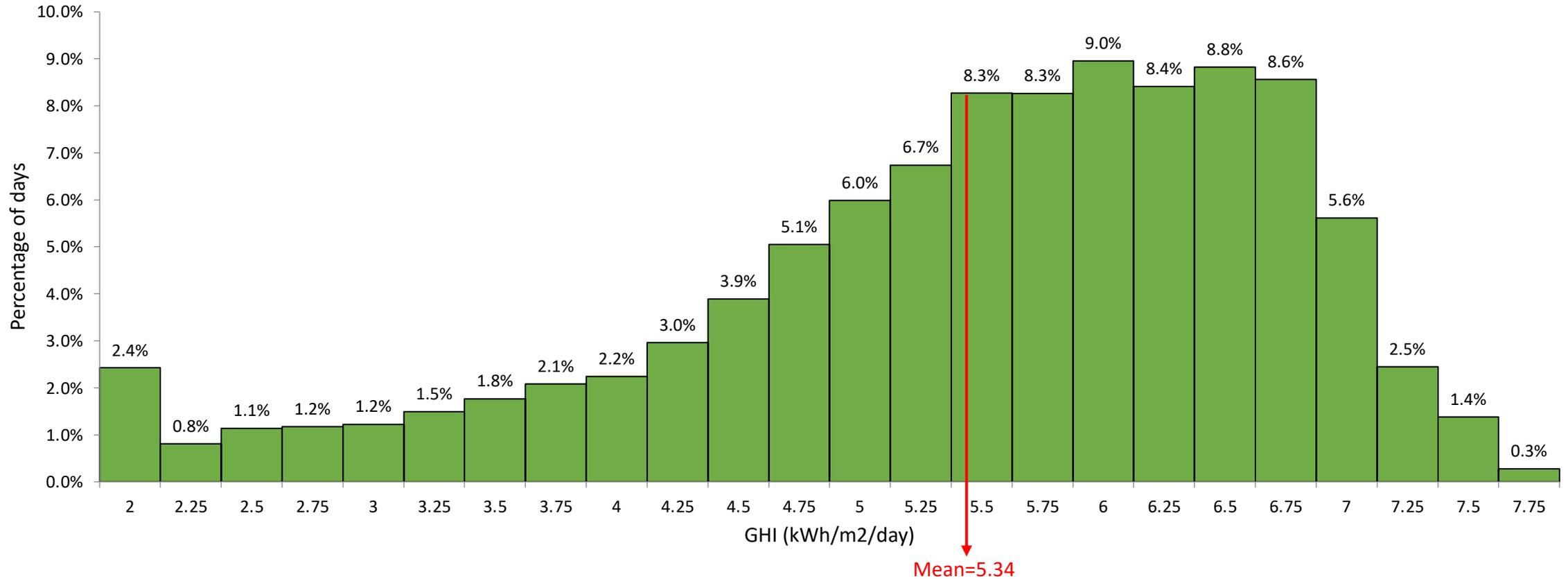
Monthly Generation of a 50 MW plant using Thin film CdTe modules at different P Levels



\*CUF levels considering ideal generation of a 50 MW solar plant

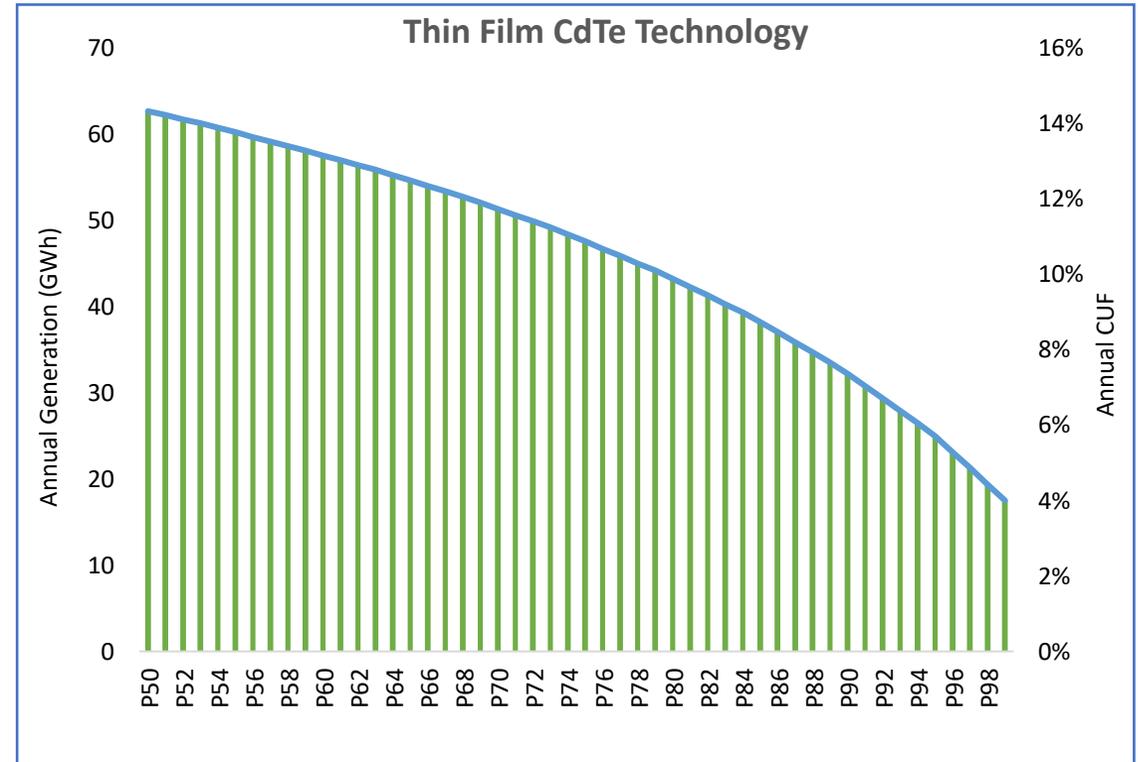
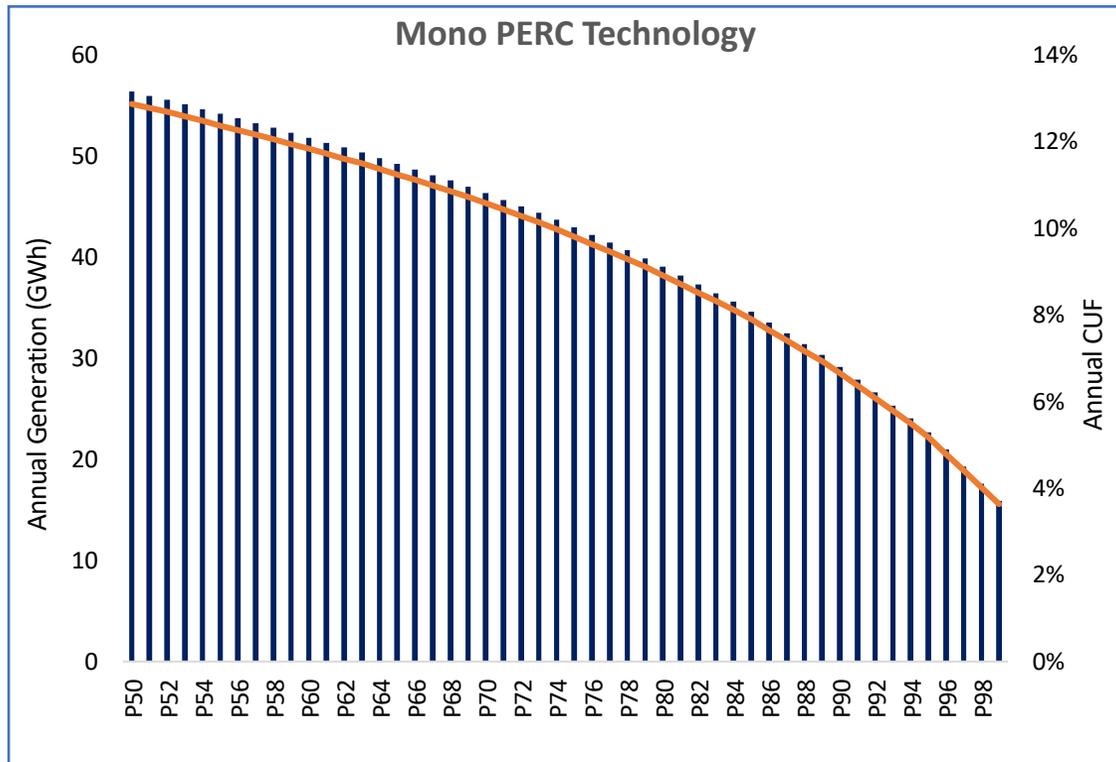
## Daily GHI

Daily GHI values for a period of 20 years



- The above chart shows the 20 years (2001-2020) daily GHI values.
- The mean of daily GHI is 5.34 kWh/m<sup>2</sup>/day.
- The standard deviation is 1.30 kWh/m<sup>2</sup>/day.

## Annual Generation & CUF for 50 MW plant at P50 - P99 GHI levels

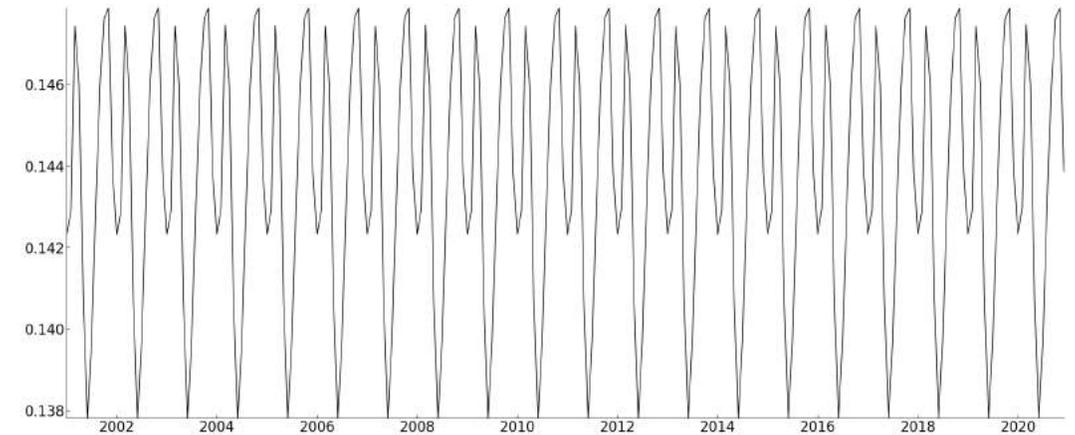


- Annual CUF for the 50 MW plant using Mono PERC and Thin-film CdTe is 12.86% and 14.30% respectively at P50 level and gradually reduces to 3.63% and 4.00% respectively at the P99 level.
- Annual Generation ranges from 56.32 GWh to 15.89 GWh for Mono PERC at P50 to P99 levels, while for Thin-CdTe, it ranges from 62.64 GWh to 17.50 GWh.

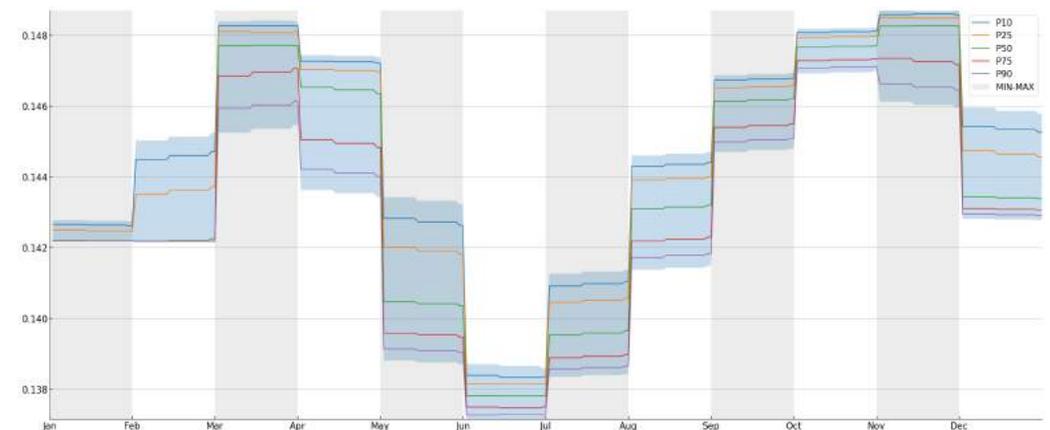
## Historical Patterns of Albedo

- Albedo is defined as the ratio of reflected to incoming solar radiation and it plays an essential role in regulating global temperatures and climate.
- Albedo of a given region depends on soil composition and moisture, vegetation types, level of urbanization, etc. and it differs significantly between surfaces, and changes with time as well.
- Albedo values become more significant in the case of bifacial photovoltaic cells that produces more energy as they collect radiation on both the front and rear sides by capturing light reflected from the surface beneath the module.
- For the site under consideration, the monthly variation of albedo in the recent past (2001-2020) shows similar patterns in all years as expected and it changes approximately from 0.138 to 0.148 within a year.
- Since the site under consideration has low albedo values, so it seems that it is mainly surrounded by vegetative/farm-land as they reflect small fractions of the incident sunlight and have low albedo value.
- Typical daily profiles (24 hour) from January to December are also calculated using 20 years of hourly Albedo data from 2001 to 2020.
- Maximum values are obtained for November month ( $\cong 0.149$ ) and minimum for June ( $\cong 0.137$ ).

Monthly Variation of Albedo for the period 2001 to 2020



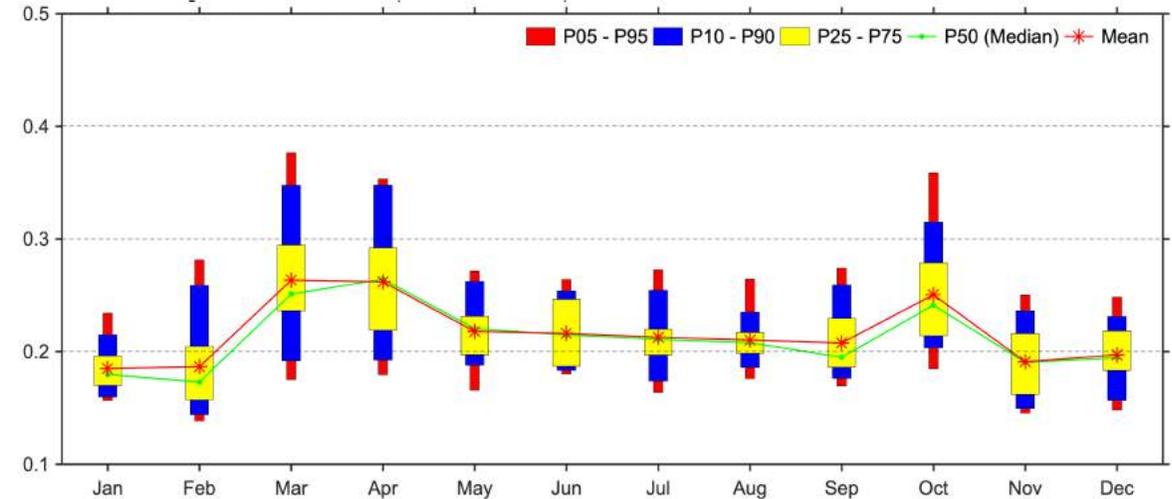
Typical Daily Profile of Albedo



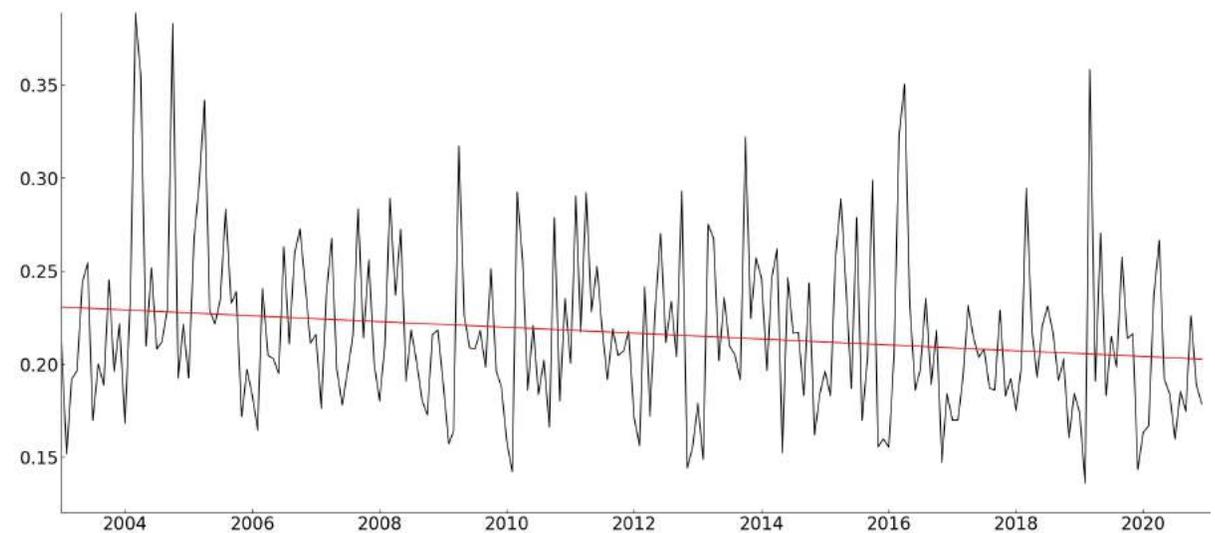
## Historical Patterns of Aerosols

- Dust particles at a location can be represented through aerosols in the atmosphere, either measured through satellite imagery or through global reanalysis model outputs.
- Aerosol Optical Depth (AOD) tells us how much direct sunlight is prevented from reaching the ground by these aerosol particles. It is a dimensionless number and is related to the amount of aerosol in the vertical column of atmosphere.
- Herein, CAMS global reanalysis (EAC4) product is used on monthly basis for the period 2003-2020 in which the AOD measurements are obtained from the column optical depth of all aerosols at visible wavelengths such as 550nm.
- The AOD over the site increases during January to April and from then onwards it seems to be washed out with the progression rainy season with a slight increase in October.
- Besides having monthly variations, the AOD at 550 nm over the considered site shows slight decreasing tendency from the year 2003 to 2020.
- Marine aerosol, polluted continental, biomass burning, etc. play major role in AOD variations over the considered site.

**Climatological Monthly Mean of AOD at 550nm (2003 to 2020)**

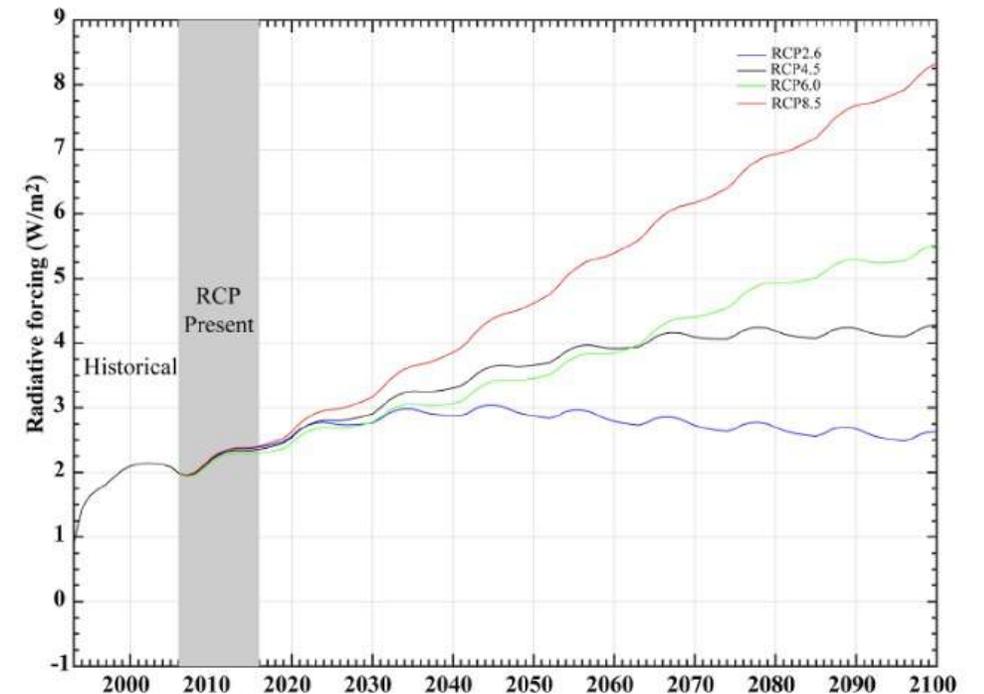


**Monthly Variation of AOD at 550nm for the period 2003 to 2020**



## Climate Change Report

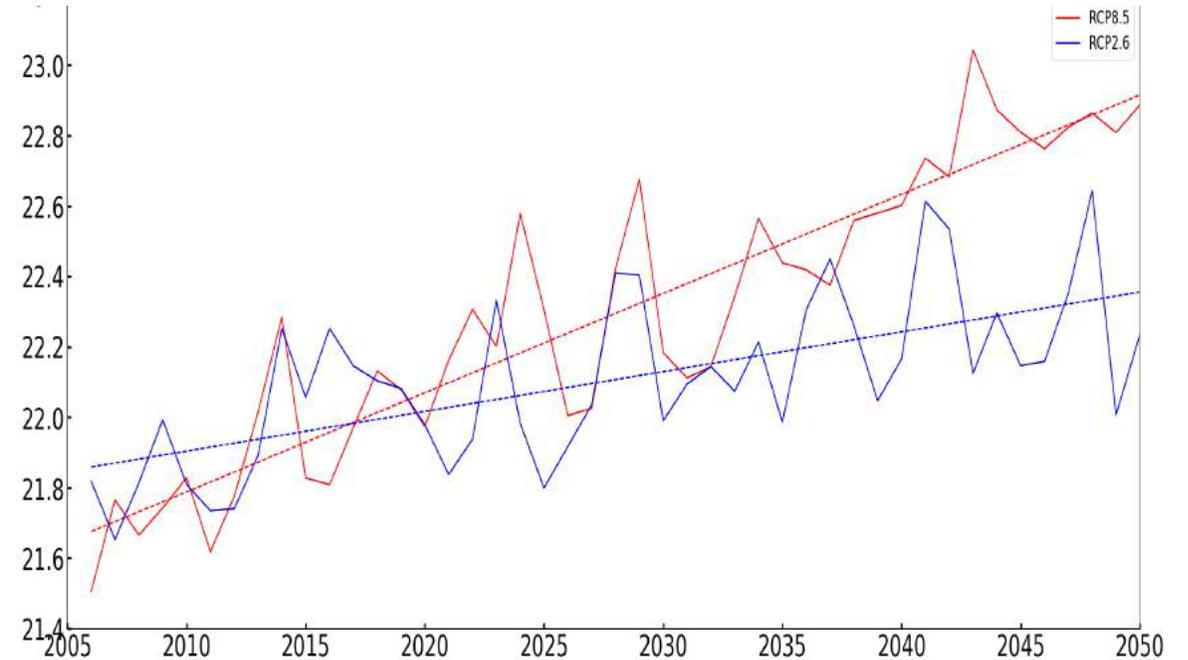
- Since state-of-the-art climate models simulate the physics, chemistry, and biology of the atmosphere, land, and oceans in great detail, they are one of the primary means to understand how climate variables have changed in the past and may change in the future.
- To see the future projections of variables like temperature, precipitation, and GHI, we have used the Regional Climate Model (RCM) simulations from the CORDEX database that are driven by using lateral boundary conditions of models that participated in Coupled Model Intercomparison Project (CMIP).
- Further, to assess the impact of climate change on these variables in near future, we considered the multi-model ensemble (MME) of available models under low (i.e., stringent mitigation scenario; RCP 2.6) and high (i.e., a scenario with very high GHG emissions; RCP 8.5) end emission scenarios. As reported in the literature, MME performs better than individual models when compared to observations.
- Here RCP stands for Representative Concentration Pathways representing the full bandwidth of possible future emission trajectories.
- Depending on population growth and the development of energy production, food production and land use, various emission trajectories are possible corresponding to the change in radiative forcing values between 2.6 and 8.5 W/m<sup>2</sup> by the year 2100.
- The name of each scenario corresponds to the growth in radiative forcing reached by 2100, for e.g.,
  - ✓ RCP2.6: - 2.6 W/m<sup>2</sup> by 2100
  - ✓ RCP4.5: - 4.5 W/m<sup>2</sup> by 2100
  - ✓ RCP6: - 6 W/m<sup>2</sup> by 2100
  - ✓ RCP8.5: - 8.5 W/m<sup>2</sup> by 2100



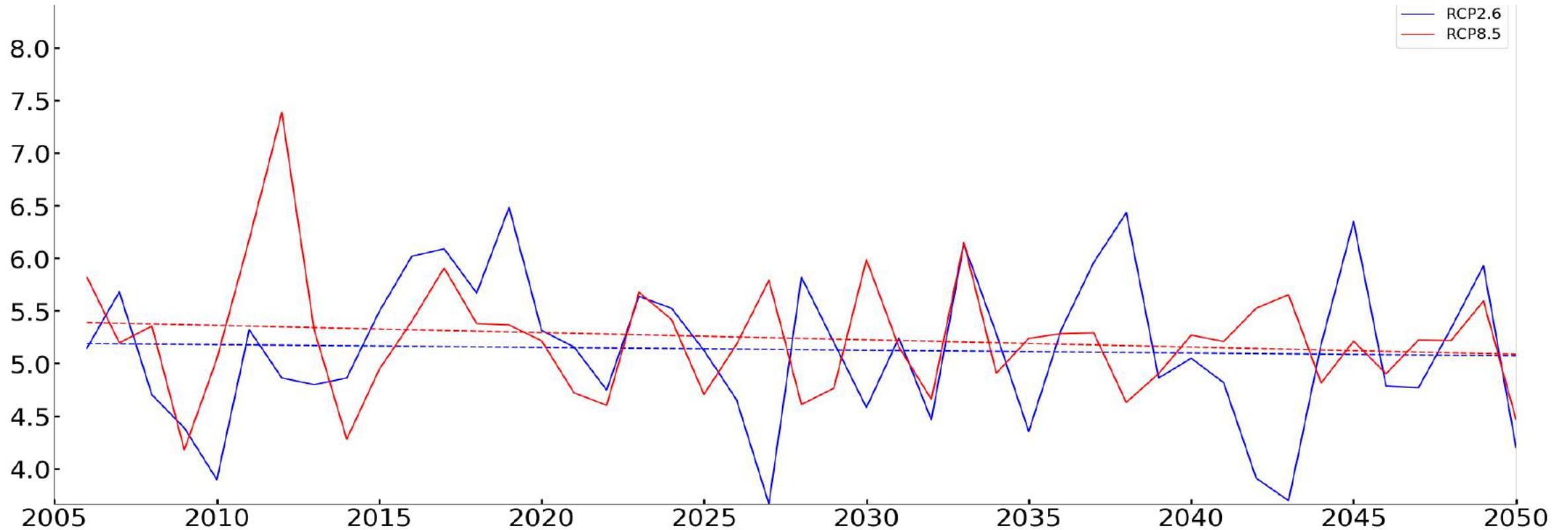
## Climate Change Report

- Observational records, reveal that as a whole Vietnam is experiencing a warming climate with an increase in the annual mean, minimum, and maximum temperatures.
- The site under consideration also shows an increasing trend in the annual mean temperatures in the recent past and is likely to upsurge in the future by approximately 0.1 and 0.28 °C per decade as reflected in the low (RCP2.6) and high-end (RCP8.5) emission scenarios.
- This increase in air temperature can lead to more intense heat waves that may have wide-ranging effects on human life and ecosystems.
- Besides this, it may also impact infrastructure and agricultural sectors, capital spending for maintenance and replacement of equipment/inventories will go up, labor and energy costs will climb, and working hours will drop.
- The increase in temperature doesn't affect the amount of solar energy a solar panel receives, it does affect how much power it generates, i.e., the main effect of temperature on solar panels is that it reduces the efficiency of the solar cells in converting solar energy into electricity.

**Annual Mean Temperature**

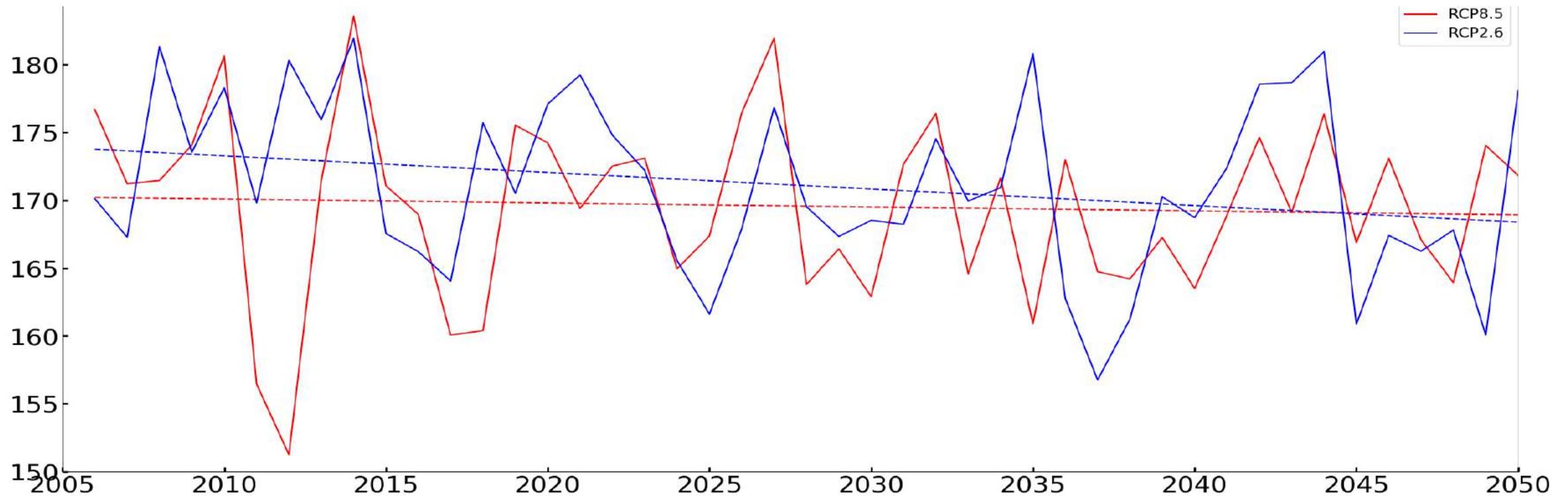


## Annual Precipitation



- In contrast to temperatures, changes in mean precipitation is much more difficult for climate models to predict.
- However, the future projections of annual mean precipitation using low and high-end scenarios reveal slight decreasing tendencies, respectively.

## Annual Mean GHI



- The site under consideration shows decreasing trend in the annual GHI approximately -1.2 and -0.3 w/m<sup>2</sup> per decade as reflected in the low (RCP2.6) and high-end (RCP8.5) emission scenarios.
- Decreasing trend in GHI values is referred as global dimming, caused by an increase in blockage in the atmosphere of light from the Sun.
- This global dimming might be due to increase in clouds and/or aerosols that will tends to cool the environment by offsetting the effect of global warming up to some extent.



# Annexure



# Elevation (Contours)

## Contours

### Layer Description:

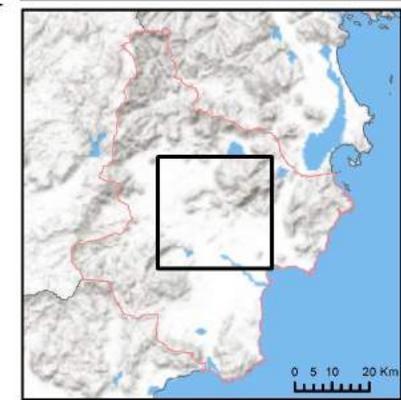
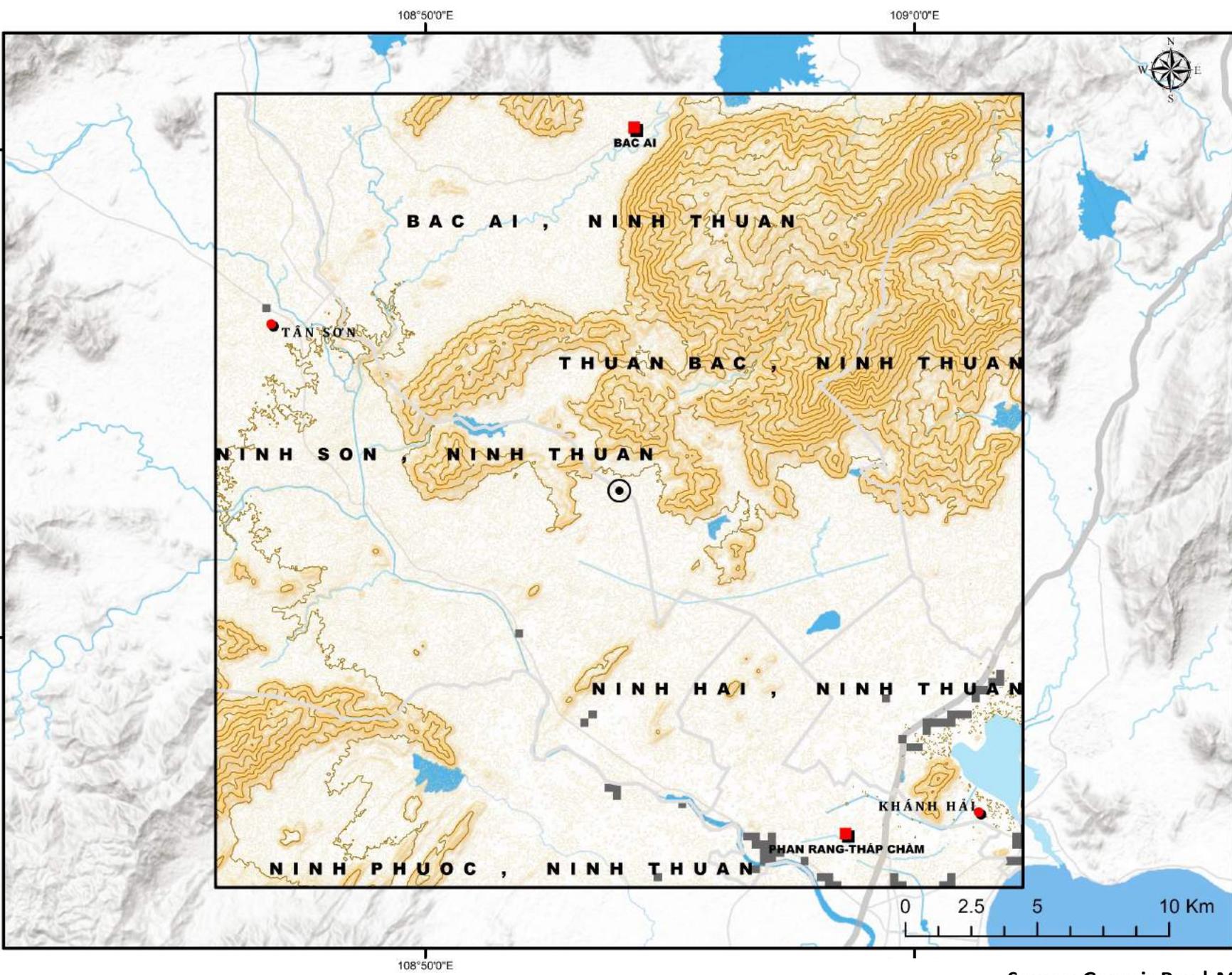
Continuous lines joining points of same elevation at an interval of 5m and 100m.

**Source:** USGS Shuttle Radar Topography Mission (SRTM) + Genesis Ray Energy

**Additional Information:** <https://earthexplorer.usgs.gov/>

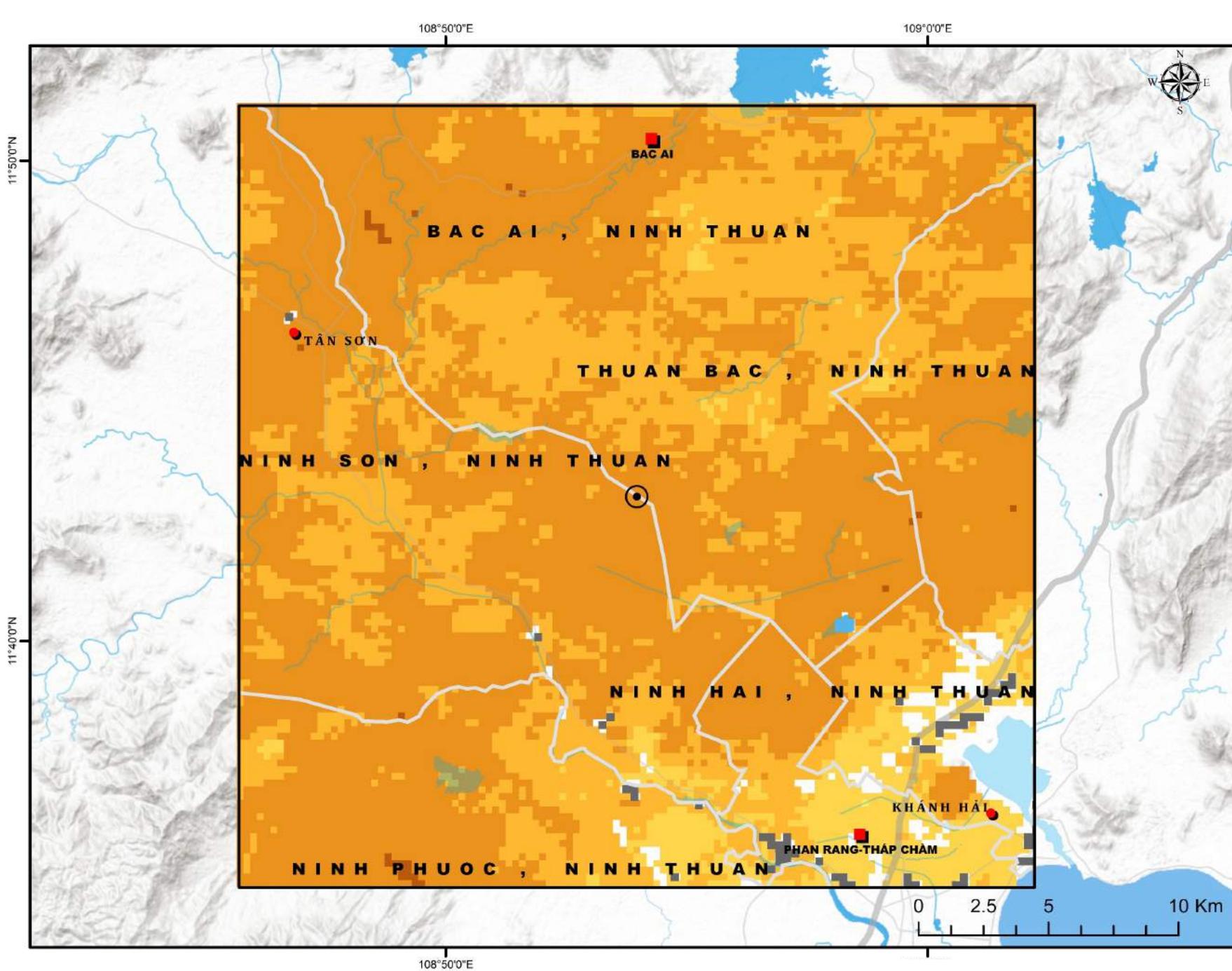
### LEGEND

- |  |   |
|--|---|
|  Cities                           |  Highway               |
|  Towns and Hamlets                |  Major Roads           |
|  Prospective Solar Plant location |  Rivers/Canals         |
|  District Boundary                |  Waterbodies           |
|  Area of Interest                 |  Contour 5m interval   |
|  Settlements                      |  Contour 100m interval |





# Soil Structure



## Sand

**Layer Description:**  
 Estimate of the proportion of sand particles (> 0.05mm) in the fine earth fraction.

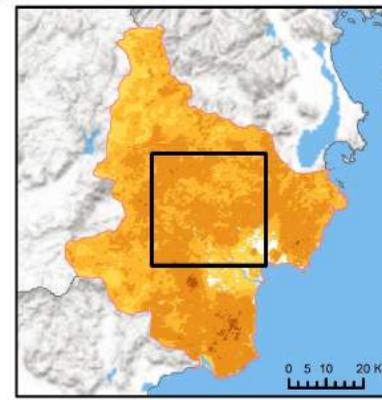
**Source:** World Soil Information  
**Spatial Resolution:** 90 meters at the equator  
**Additional Information:** <https://www.isric.org/explore/soilgrids>

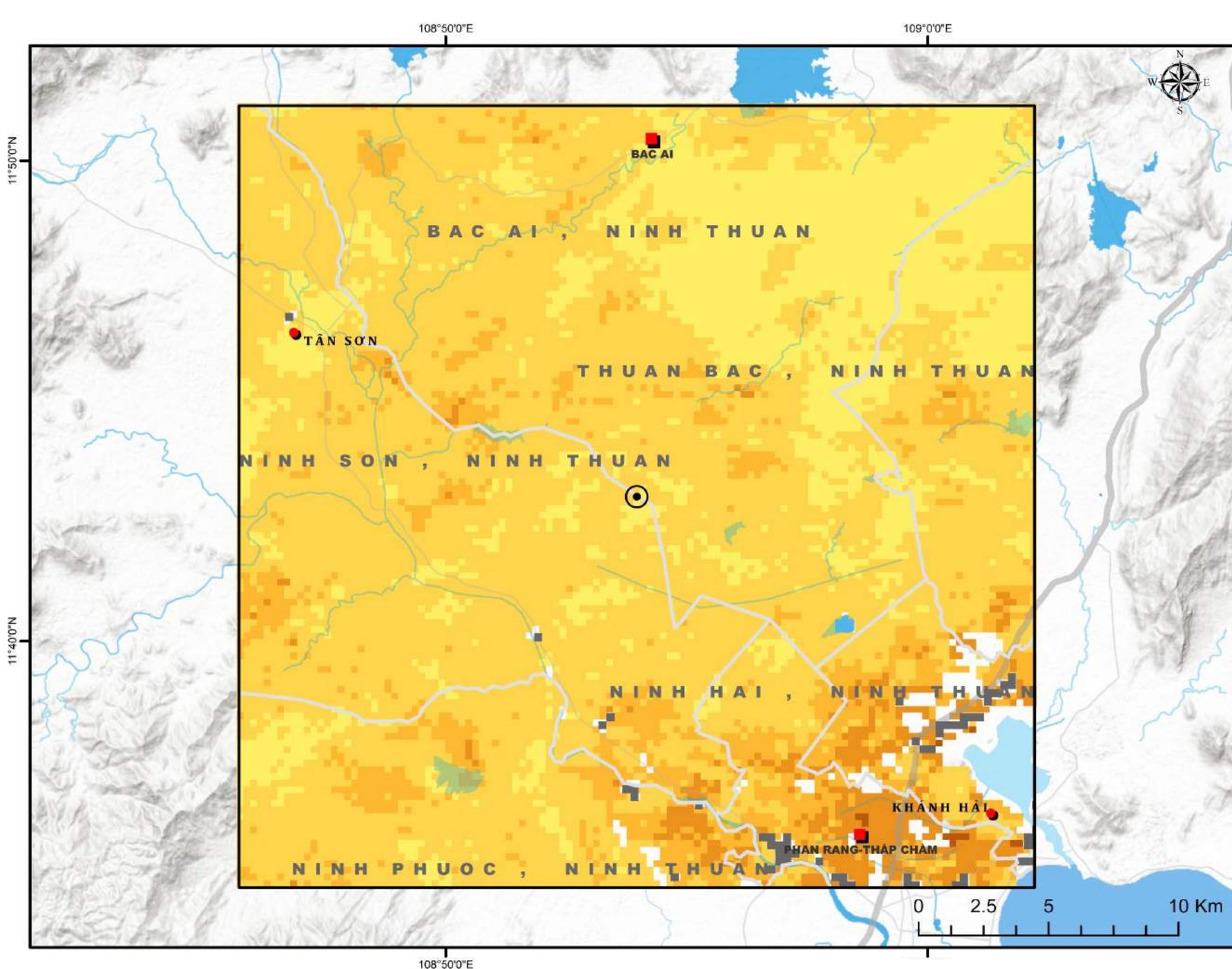
**LEGEND**

 Cities	 Settlements
 Towns and Hamlets	 Highway
 Prospective Solar Plant location	 Major Roads
 District Boundary	 Rivers/Canals
 Area of Interest	 Waterbodies

**Sand g/kg**

							
< 159.5	159.6 - 251.3	251.4 - 306.2	306.3 - 339.1	339.2 - 394	394.1 - 485.8	485.9 - 639.3	> 639.4





## Slit

**Layer Description:**  
 Estimate of the proportion of silt particles ( $\geq 0.002$  mm and  $\leq 0.05$  mm) in the fine earth fraction.

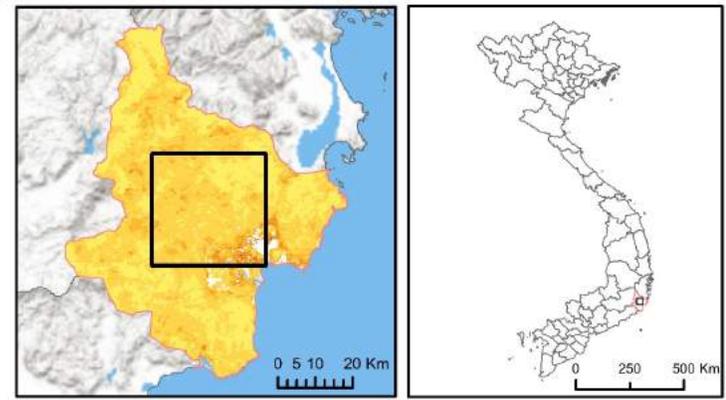
**Source:** World Soil Information  
**Spatial Resolution:** 90 meters at the equator  
**Additional Information:** <https://www.isric.org/explore/soilgrids>

**LEGEND**

Cities	Settlements
Towns and Hamlets	Highway
Prospective Solar Plant location	Major Roads
District Boundary	Rivers/Canals
Area of Interest	Waterbodies

**Silt g/kg**

< 196.8	196.9 - 274.1	274.2 - 311.8	311.9 - 330.1	330.2 - 367.8	367.9 - 445.1	445.2 - 603.9 > 603.9



# Clay

**Layer Description:**  
 Estimate of the proportion of clay particles (< 0.002 mm) in the fine earth fraction.

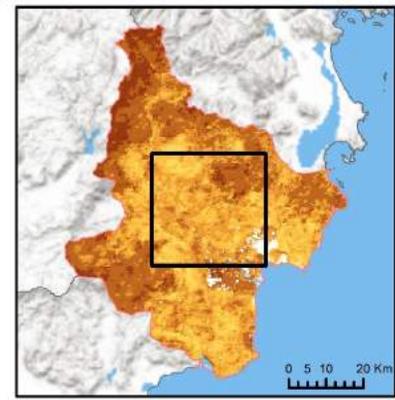
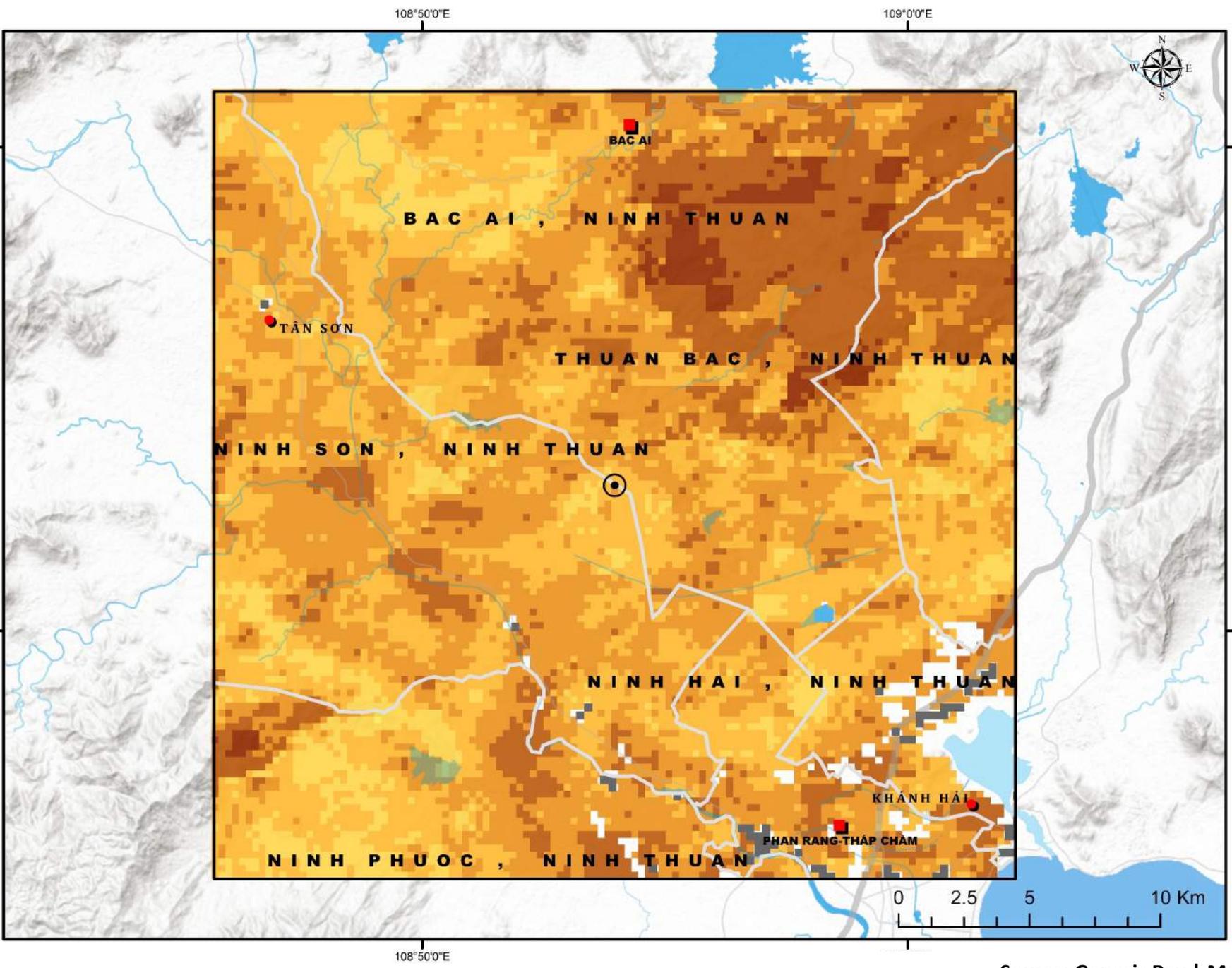
**Source:** World Soil Information  
**Spatial Resolution:** 90 meters at the equator  
**Additional Information:** <https://www.isric.org/explore/soilgrids>

**LEGEND**

Cities	Settlements
Towns and Hamlets	Highway
Prospective Solar Plant location	Major Roads
District Boundary	Rivers/Canals
Area of Interest	Waterbodies

**Clay g/kg**

< 202.3	202.4 - 289.8	289.9 - 335.8	335.9 - 360	360.1 - 384.2	384.3 - 430.2	430.3 - 517.7	> 517.7



# Ph Water

**Layer Description:**  
 Estimate of the measure of the acidity or alkalinity of the soil.

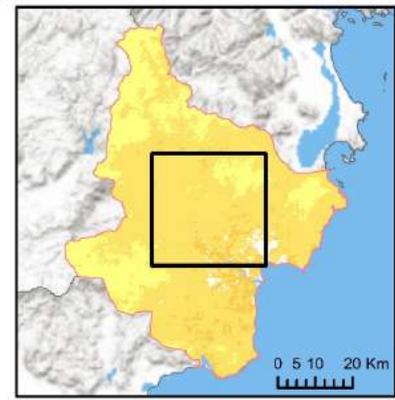
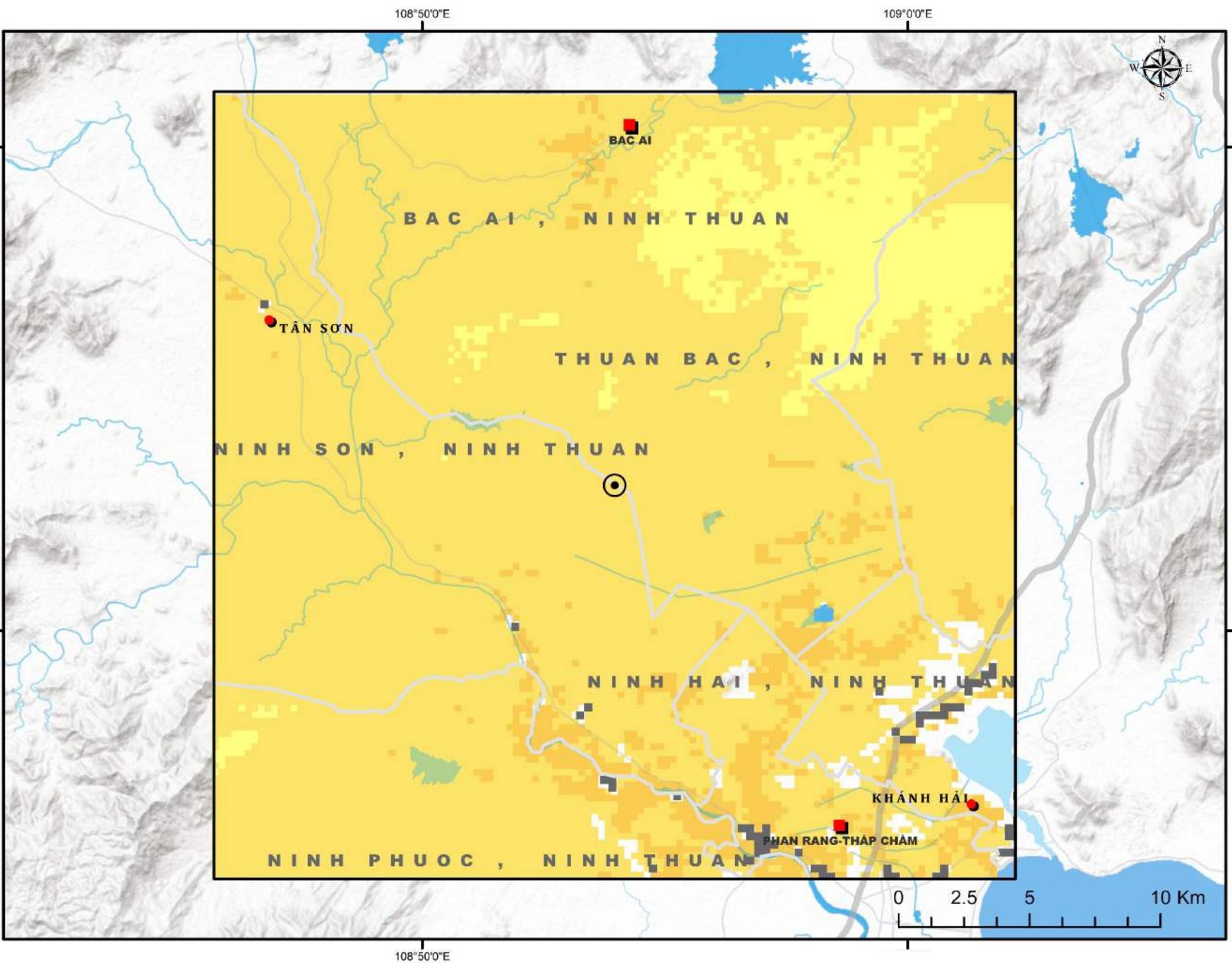
**Source:** World Soil Information  
**Spatial Resolution:** 90 meters at the equator  
**Additional Information:** <https://www.isric.org/explore/soilgrids>

**LEGEND**

 Cities	 Settlements
 Towns and Hamlets	 Highway
 Prospective Solar Plant location	 Major Roads
 District Boundary	 Rivers/Canals
 Area of Interest	 Waterbodies

**pH Water factor of 10**

							
< 58.4	58.5 - 67.9	68 - 73.5	73.6 - 76.7	76.8 - 78.6	78.7 - 81.9	82 - 87.4	> 87.4



## Soil Organic Carbon

### Layer Description:

Estimate of the soil organic carbon content in the fine earth fraction.

Source: World Soil Information

Spatial Resolution: 90 meters at the equator

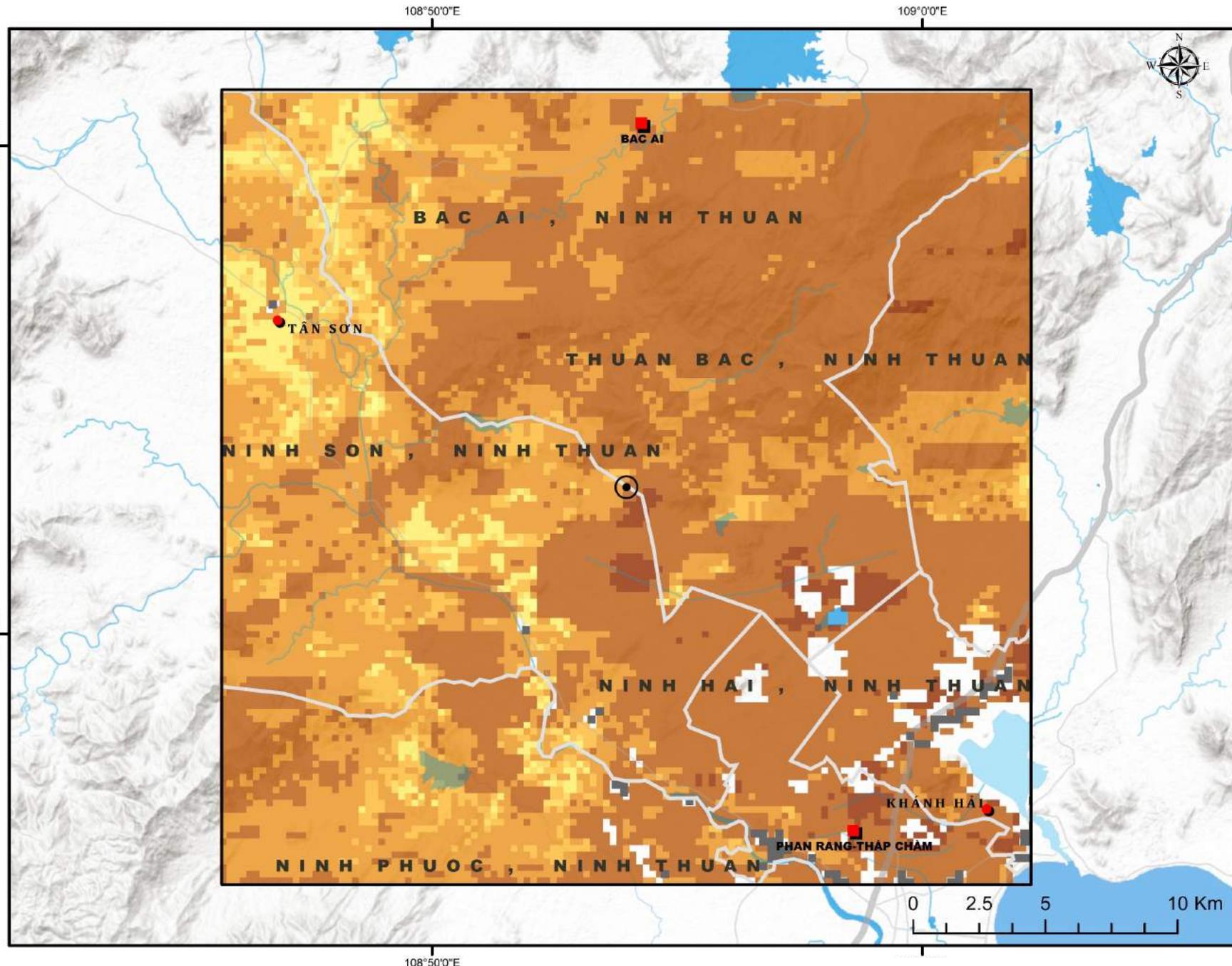
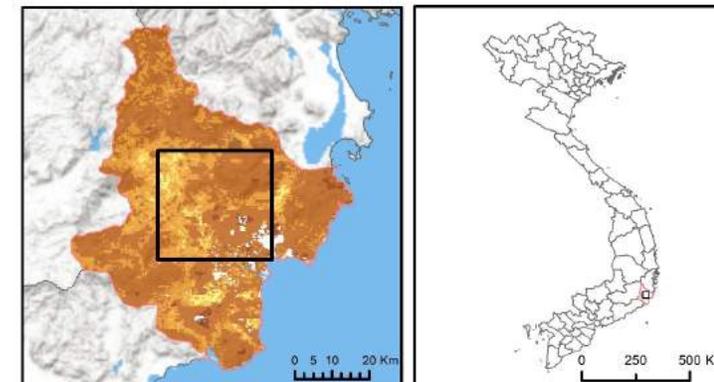
Additional Information: <https://www.isric.org/explore/soilgrids>

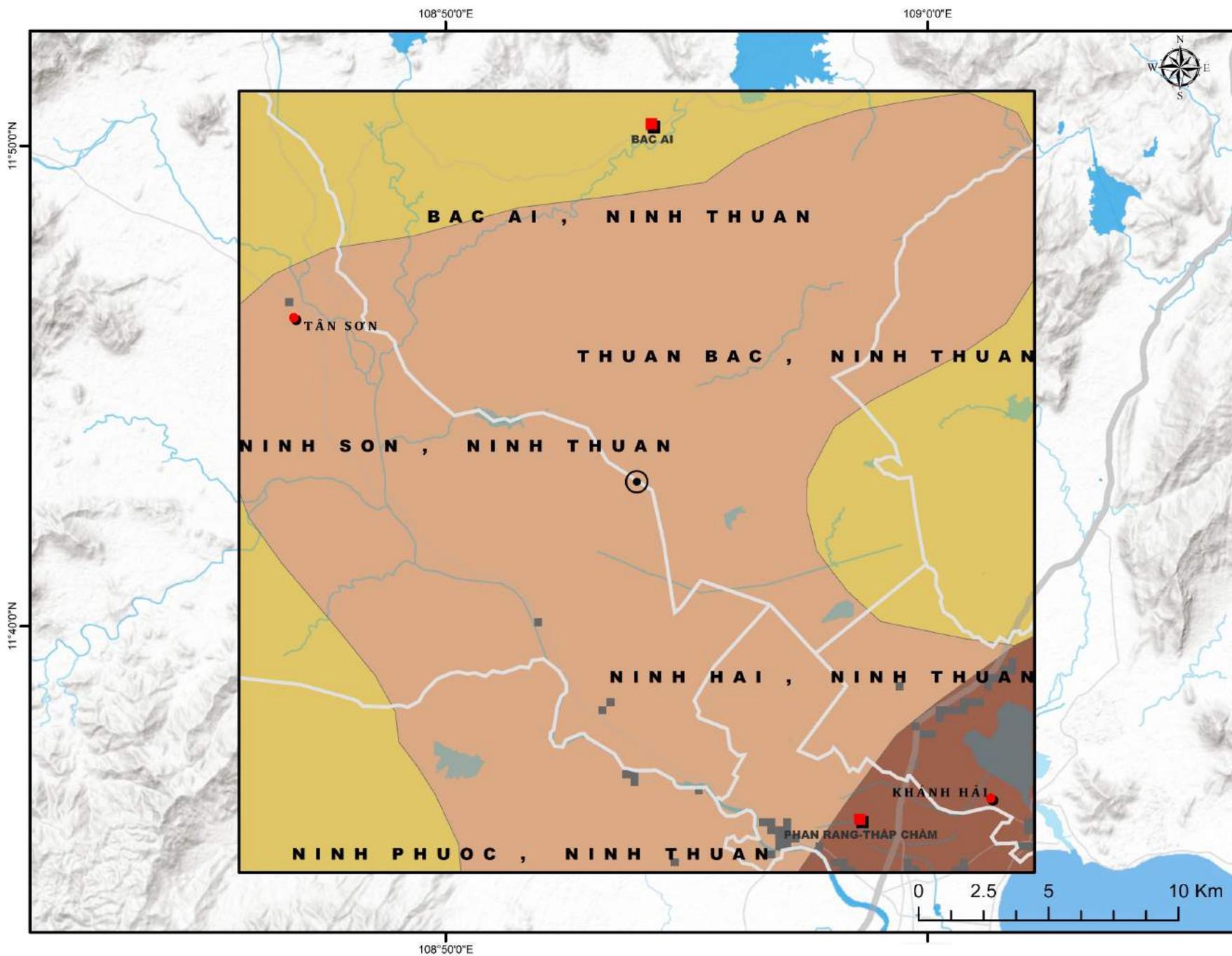
### LEGEND

- Cities
- Towns and Hamlets
- Prospective Solar Plant location
- District Boundary
- Area of Interest
- Settlements
- Highway
- Major Roads
- Rivers/Canals
- Waterbodies

### Soil Organic Carbon

dg/kg





## Soil Type

**Layer Description:**  
 Estimate of the the type of soil which is a taxonomic unit in soil science.

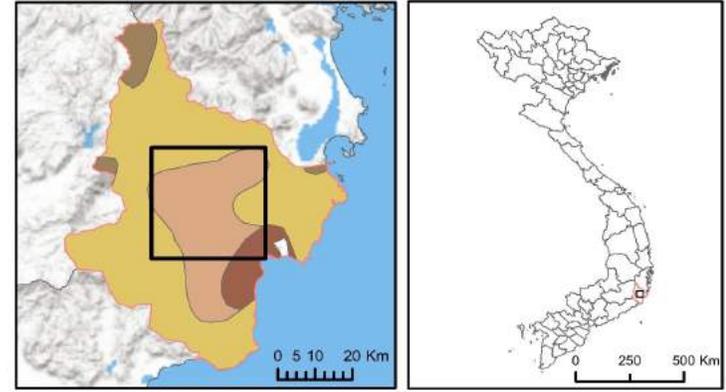
**Source:** World Soil Information  
**Spatial Resolution:** N.A.  
**Additional Information:** <https://www.isric.org/explore/soilgrids>

**LEGEND**

 Cities	 Settlements
 Towns and Hamlets	 Highway
 Prospective Solar Plant location	 Major Roads
 District Boundary	 Rivers/Canals
 Area of Interest	 Waterbodies

**Soil Type type**

			
Other	Ao (Orthic Acrisols)	Ge (Eutric Gleysols)	Lc (Chromic Luvisols)





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