

# Green Grids

## Site Suitability for Renewable Complementarity in the Ecuadorian National Grid

### Introduction

Despite its small land area, Ecuador is home to a unique combination of natural resources with vast potential for a variety of uses, including energy generation. With hydropower and natural gas as the main components of the country's national energy mix, other non-renewable sources such as wind and solar generation remain largely untapped. As the price of these technologies drop and they become more accessible, the opportunity to harness these resources becomes increasingly attractive for Ecuador to increase its energy output and phase out non-renewable technologies like gas-based ones.

This study identifies power plants that generate electricity from non-renewable sources in mainland Ecuador (excluding the Galapagos Islands) and assesses the potential to develop renewable alternatives in their vicinity.

### Renewables in Ecuador

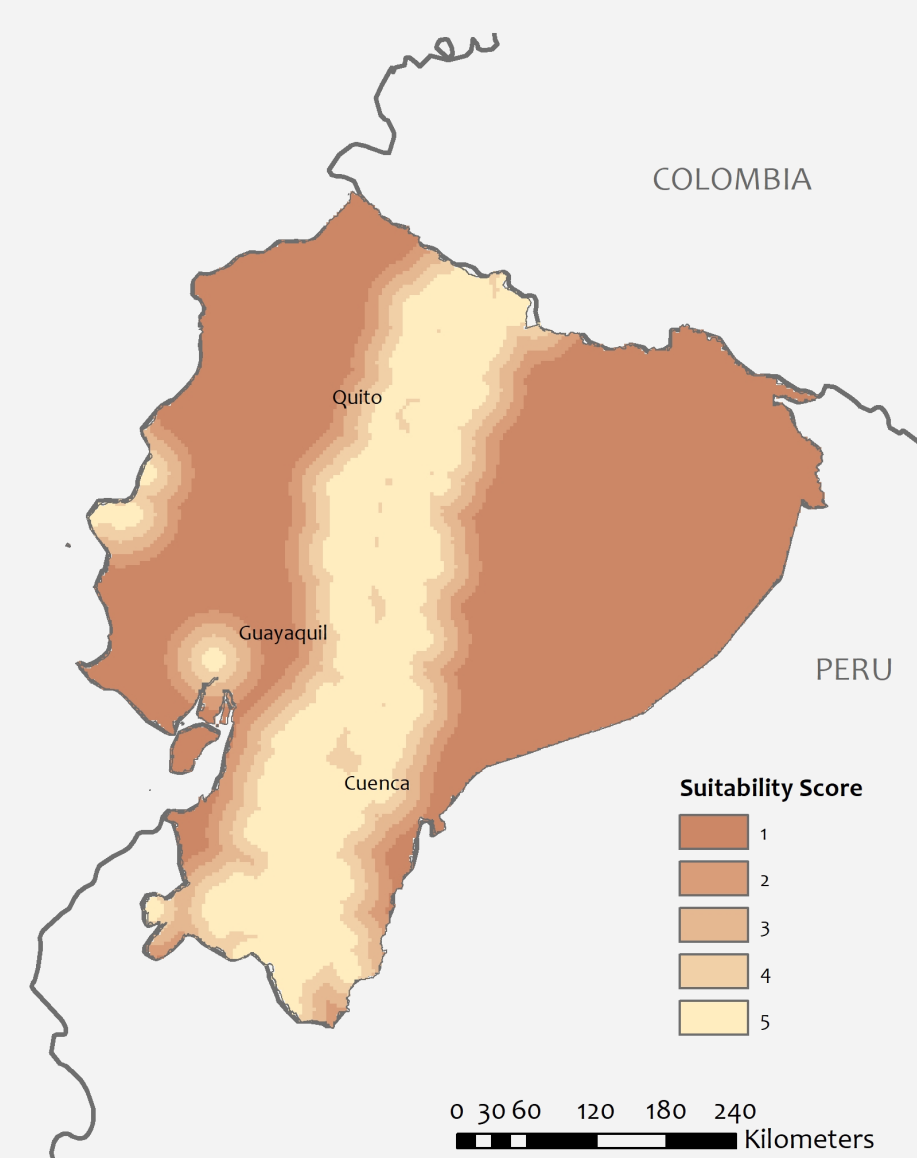
Ecuador's 2008 constitution dictates that the government is to promote the use of clean, alternative energy sources, while simultaneously furthering energy efficiency, access to public services, and protecting natural resources (Norton Rose Fulbright). The development of non-conventional renewable energies may offer an answer to all these and other challenges, in addition to diversifying the country's energy mix.

Important steps have been taken to reduce Ecuadorian reliance on fossil fuels, mainly through the development of large hydropower generation plants that aim to generate 90% of the country's energy upon completion of large projects that are currently under construction (IHA). While hydropower is and will likely remain crucial for the operation of the national grid for decades to come, Ecuador still relies on thermal generation – that which requires fuel combustion – to support its hydroelectric system. Lacking multiannual water storage, Ecuador is vulnerable to seasonal weather variations and extreme weather events such as El Niño Southern Oscillation (ENSO), which can affect rainfall patterns, possibly causing droughts that in turn, halt hydropower generation. Climate change is expected to bring similar effects in the medium to long term.

Over-dependence on hydroelectric generation leads to dependence on more expensive thermal alternatives and on foreign supply, undermining national energy security. Non-conventional renewable energy capacities, such as wind and solar photovoltaic (PV) generation have the unique potential to fill this gap and feed the grid to compensate for hydroelectric variability and contribute in making the Ecuadorian grid greener.

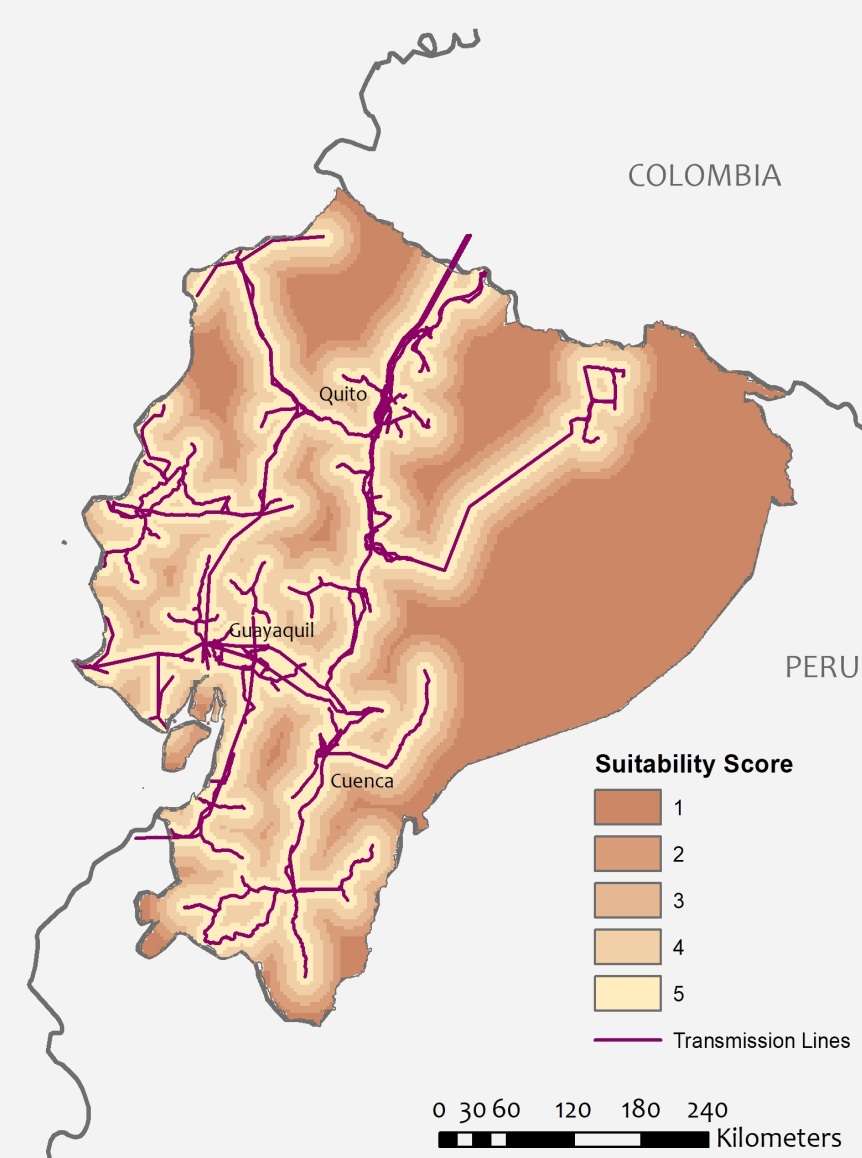
### Wind Speed

Scores were derived based on distance to areas with a recorded annual average wind speed of 6m/s or greater at 50m from ground level. The Andean region and some coastal pockets displayed the highest wind speeds.



### Transmission Lines

Scores were derived based on distance to major transmission lines and integrated into the final suitability analysis for both wind and solar PV potential. The displayed lines are part of the centralized grid, making this intermediate layer unsuitable for off-grid or independent-grid solar or wind explorations.



### Methods

**Wind Site Suitability:** The layers considered for this suitability analysis included terrain slope, wind speed at 50m above ground level, and distance to transmission lines. Areas with slope under 10% were identified as optimal, as were those with wind speeds greater than 6m/s and within close proximity of transmission lines. Distances were calculated and visualized as Euclidean distance, and then reclassified on a 1-5 scale, with 5 being optimal.

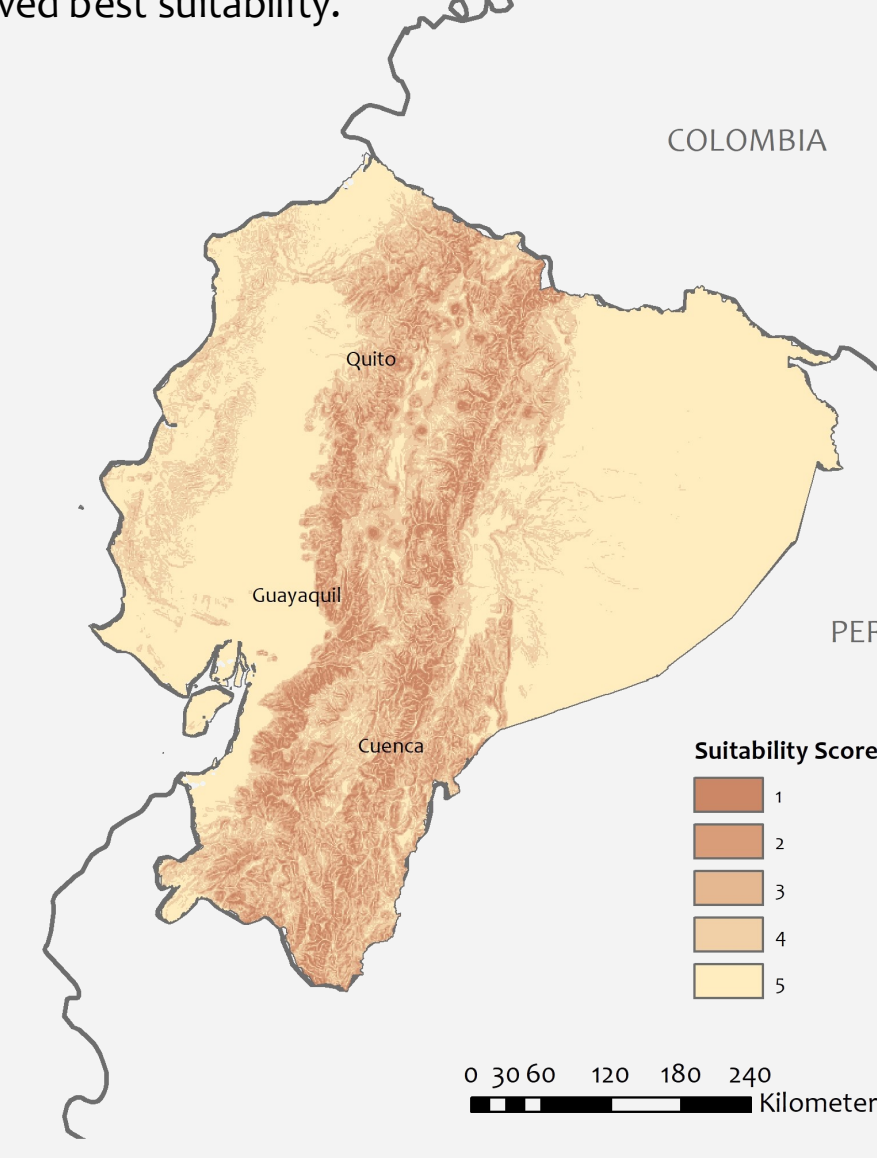
The final wind suitability map was created by aggregating the intermediate rasters using the 'Raster Calculator' tool. Given the unavailability of regulatory information on wind development requirements in Ecuador, weights were assigned to input layers (distance to transmission lines, terrain slope, wind speed) based on other studies consulted, with wind speed having greatest weight.

**Solar Site Suitability:** Similarly to the process for wind suitability analysis, this process considered terrain slope, distance to transmission lines, Global Horizontal Irradiance (GHI), and Optimum Tilt Angle (OPTA). Areas with slope under 5% were considered optimal in this case. Distances were calculated as Euclidean and were then reclassified in accordance to the 1-5 scale, with 5 being optimal.

The final solar suitability map also required use of the 'Raster Calculator' tool. Weights were assigned based on other studies, with GHI having the greatest weight.

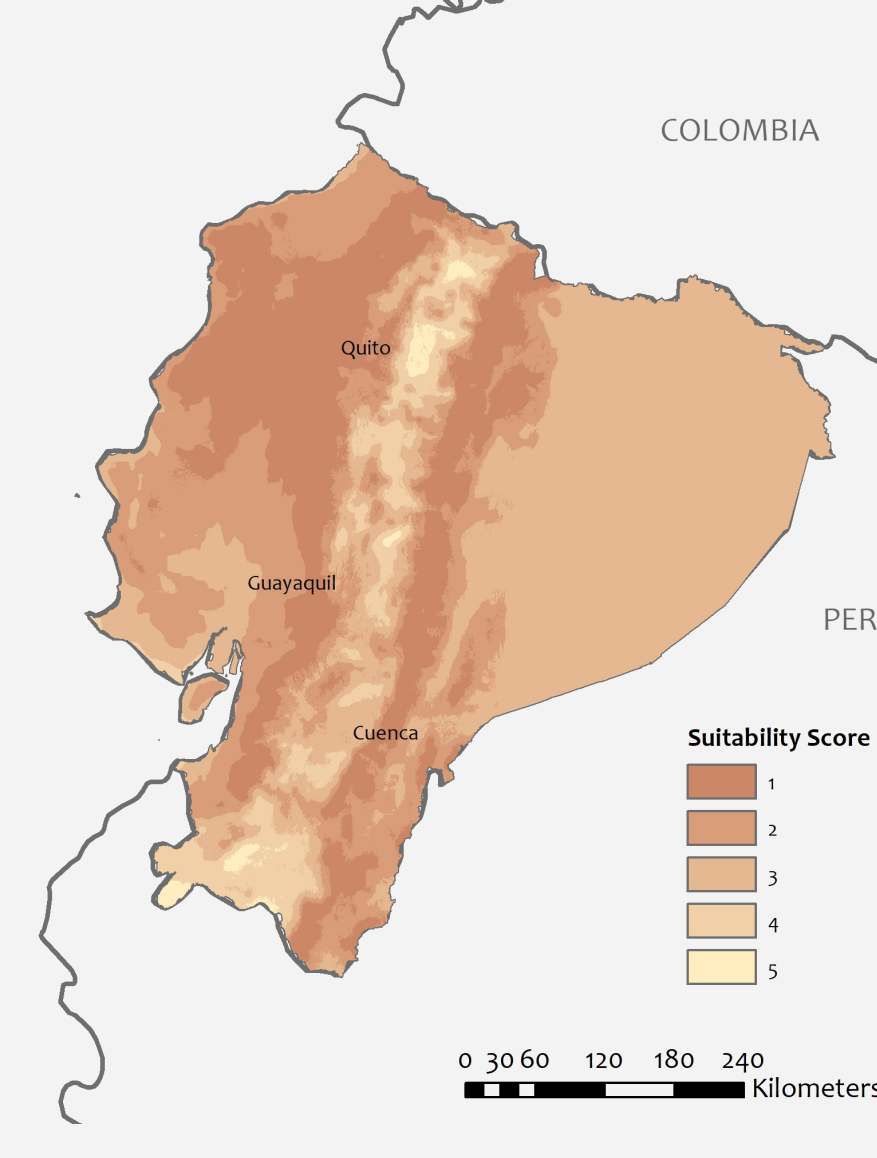
### Slope

Scores we derived based on a slope raster, which was produced from a digital elevation model. Although areas with slope under 5% were prioritized, slope was weighted differently for wind and solar PV suitability analyses, as wind turbines can be more versatile with regards to terrain. The coast and the Amazon region showed best suitability.



### Radiation

Scores were derived from a Global Horizontal Irradiance (GHI) raster displaying average annual total solar radiation incidence on a horizontal surface. Areas in the Andean region displayed highest suitability scores, most likely due to the region's elevation and weather.



### Findings

To assess the potential of renewable complementarity for thermal generation plants in Ecuador, it is necessary to study wind and solar conditions in the proximity of existing power plants. To this end, thermal power plants were identified and a 10km buffer was established around each, and the average wind and solar PV suitability score (1-5) was calculated for each buffer. Average buffer scores were then grouped into three categories: low, medium, and high potential for wind or solar development.

As seen in the tables to the left, 114 of 163 thermal power plants in Ecuador show high potential for the development of some renewable source of complementary generation. Some 26 plants show high potential for wind and 88 for solar PV. The central Andean region shows high suitability compared to the coastal and the Amazon region, with the exception of some pockets as the one observed around the city of Guayaquil.

### Conclusions

First, it must be noted this methodology serves as a starting point for scouting areas with sufficient potential to warrant further study into solar and wind generation potential. The results of this study may not accurately represent wind and solar PV site suitability in Ecuador due to data limitations. This model ranks site suitability generously, as it does not include key constraints such as land cover, land use, protected areas, and other conditions that would disqualify significant amounts of land from wind or solar development. With appropriate and available data sources, largely dependent on government agencies' responsiveness, these restrictions can be incorporated into future studies.

Considering these sources of potential error in assigning suitability scores, the results suggest some basic degree of site suitability for nearly 70% of thermal power plants. While this does not guarantee the technical feasibility of partially or totally replacing thermal generation at these sites, it opens the door to complementarity. After all, wind and solar PV generation capacities can be developed simultaneously and integrated with each other and with thermal generation. As such, this study calls for further research into the feasibility of renewable complementarity in Ecuadorin accordance with Ecuadorian development objectives and the country's environmental commitments.

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Cartographer: Vladimir Proaño  
UEP 232: Intro to GIS—Spring 2020  
Projection: WGS 1984 UTM Zone 17s,  
Transverse Mercator

### Data Sources

ESRI; Tufts M: Drive; World Bank Group—Global Solar Atlas; World Bank Group—Global Wind Atlas; Instituto Geográfico Militar (through GeoData@Tufts); Institut de Recherché pour le développement (IRD)

### Other References:

- Ecuador Country Profile, International Hydropower Association (IHA)
- Renewable Energy in Latin America: Ecuador, Norton Rose Fulbright (Oct. 2016)