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GEOSPASIAL OF SOLAR AND WIND ENERGY POTENTIAL ASSESSMENT IN CYPRUS

MASTER THESIS

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NEAR EAST UNIVERSITY

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DEPARTMENT OF CIVIL AND ENVIROENMENTAL ENGINEERING

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Nicosia
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Approval

We certify that we have read the thesis submitted by **Mohammad Tawalbeh** titled **"GEOSPASIAL OF SOLAR AND WIND ENERGY POTENTIAL ASSESSMENT IN CYPRUS"** and that in our combined opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Educational Sciences.

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Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

Mohammad Tawalbeh

24/01/2022

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Mohammad Tawalbeh

Abstract

GEOSPASIAL OF SOLAR AND WIND ENERGY POTENTIAL ASSESSMENT IN CYPRUS

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Solar and wind energy are important renewable energy sources, and they play an important role in achieving rapid decarbonization in order to reduce greenhouse gas emissions and counteract global warming caused by the use of fossil fuels. Through the use of GIS analysis, this paper investigates the spatial suitability for wind and solar farm installations based on meteorological parameters such as relative humidity (RH), maximum wind speed (Wmax), minimum wind speed (Wmin), average wind speed (Wa), maximum air temperature (Tmax), minimum air temperature (Tmin), average air temperature (Ta), dew temperature (DT), global horizontal irradiation (GHI) and direct normal irradiation (DNI). The NASA POWER database was used to find a suitable location for installing wind and PV systems in Cyprus for fourteen districts: Famagusta, Kyrenia, Morphou, Trikomo, Dipkarpaz, Lefke,Vadili,Gecitkale, Nicosia, Larnaca, Limassol, Paphos, Pano Platers, and Neo Chorio.

Furthermore, wind and solar thematic maps were generated by utilizing spatial analysis tools using ArcGIS and map classifications by applying Jenks method for parameter weighting, economic analysis were conducted. Solar and wind energy, respectively, might provide a large quantity of renewable energy in Cyprus. Similarly, due to a substantial number of suitable areas with good resource quality, there is a possibility for solar energy in Limassol, Paphos, Neo Chorio, Kyrenia, and Dipkarpaz districts, as well as wind energy in Limassol, Kyrenia, Paphos, Neo Chorio, and Dipkarpaz districts. The proposed study will assist planer and decision maker to establish a shared web platform of proposed strategies, mitigations, protection measures, thematic maps, and policies to tackle the supply needs considering environmental and mitigate greenhouse emissions by eliminate fossil fuels use.

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Key Words*:* solar and wind farm, Cyprus, renewable energy, suitable location, ArcGIS.

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List of Abbreviations

NASA**:**	National Aeronautics and Space Administration
RH**:**	Relative Humidity
Wmax:	Maximum Wind Speed
Wmin:	Minimum Wind Speed
Wa:	Average Wind Speed
Tmax:	Maximum Air Temperature
Tmin:	Minimum Air Temperature
Ta:	Average Air Temperature
DT:	Dew Temperature
GHI:	Global Horizontal Irradiation
DNI:	Direct Normal Irradiation
GIS:	Geographic Information System

CHAPTER I
Introduction

Background

Climate change is a massive environmental crisis that puts the quality of life on the planet's surface in jeopardy (Burton, 2019). Global warming is another name for this phenomenon. It means that the earth is rapidly warming and converting into a greenhouse, retaining heat and raising its surface temperature (Daniels, 2009). This phenomenon was first noticed in the mid-twentieth century, and substantial efforts have since been made to develop acceptable remedies to eliminate it and reduce its detrimental consequences. (Burton & Daniels, 2019; Daniels, 2009).

Wind energy is a source of local renewable energy that produces no greenhouse gases such as nitric oxide, carbon dioxide or methane. (Chanda and Bose, 2019; Chen et al., 2019; Rogers et al., 2019). Turbines are wind device that convert wind energy into electricity and can be used to power tall structures. (Murray et al., 2019; Caglayan et al., 2019; Ahmad et al., 2018; Cali et al., 2018; Caglayan et al., 2019).

The technique of transforming wind movements into useful energy is known as wind power. (Murray et al., 2019; Caglayan et al., 2019; Ahmad et al., 2018; Cali et al., 2018; Caglayan et al., 2019). Pumps, grinding, and turbine recycling can all be used to directly generate power. As people become more aware of global climate change, renewable energy sources have become more important, leading in rising demand for wind energy.

The Concept of Renewable Energy

There are several types of renewable energy classified based on the sources from which they are taken, and the most prominent feature of renewable energy is that it is available in all parts of the earth in one way or another. planet resources, it is energy derived from natural sources that are capable of being renewed over a period of time, without depleting the planet's resources. The types of renewable energy include solar energy, wind, rain, tides, waves, biomass and thermal energy stored in the earth's crust, which makes it an inexhaustible source of energy, its climatic or environmental damage is almost non-existent. In this research topic, the interactions between wind and solar energy and other parameters have been studied in order to find the best location for installing wind and solar farms in Cyprus

Renewable energy is energy that is extracted from the environment's natural resources and is not depleted. Wind, sun, and water, as well as tides and geothermal energy, are all sources of renewable energy. Renewable energy, unlike renewable energy based on fossil fuels and petroleum, is environmentally sustainable and does not hurt the environment, contribute to climate change, or contaminate the ecosystem through waste. It has resulted in the emergence of a slew of previously unknown diseases., which has had an impact on the lives of living organisms on the earth's surface, including humans.

Advantage of Renewable Energy

Renewable energy has a variety of advantages over fossil fuel combustion, including (Nelson and Starcher, 2018).

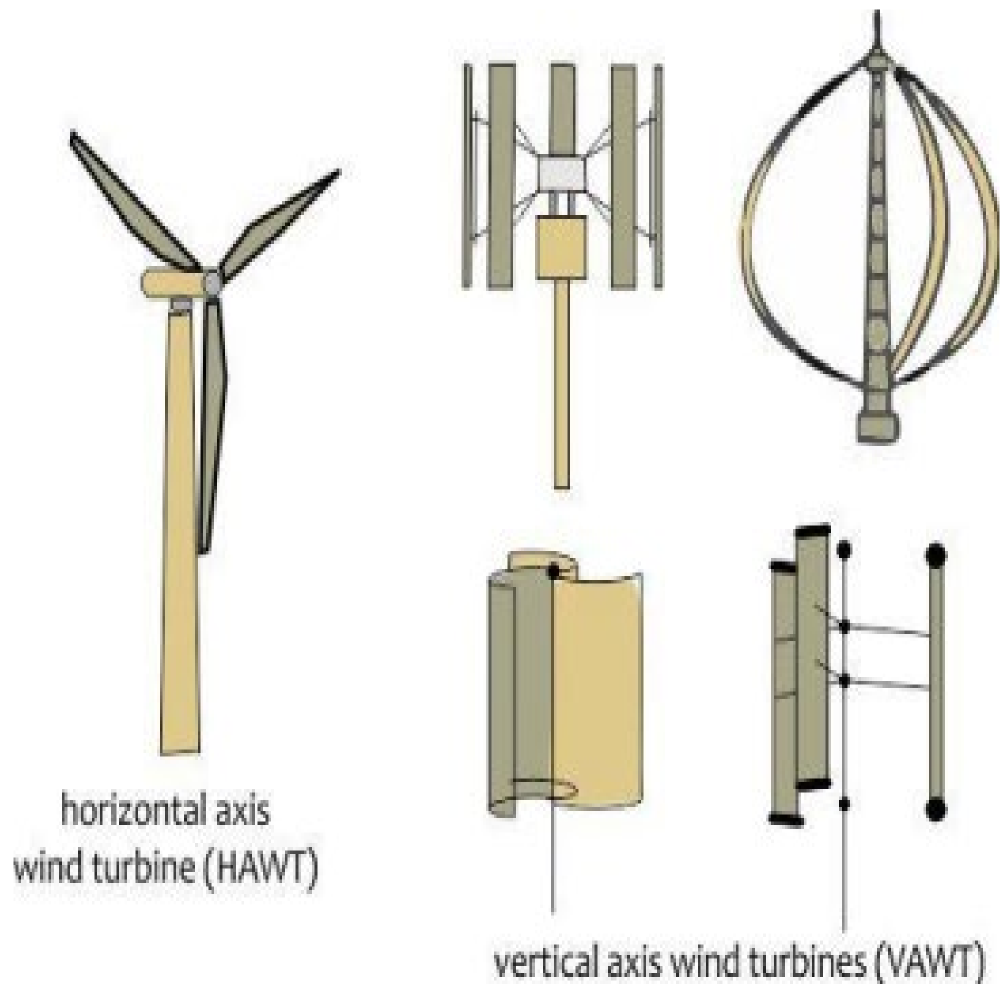
1. Renewable energy is a non-depletable resource.
2. It provides clean, renewable energy that is devoid of pollutants, impurities, and waste.
3. It promotes public well-being.
4. Energy is regarded to be eco-friendly and does not hurt the environment.
5. Provides unemployed people with a variety of job opportunities.
6. Don't contribute to the development of acid rain, which is hazardous to vegetation.
7. They defend a variety of animals, particularly endangered ones.
8. It prevents pollution of groundwater, saltwater, rivers, and fisheries.
9. Assist in ensuring food security.

Renewable Energy Sources

Wind energy. The conversion of kinetic energy generated by the rotation of wind fans by the impact of wind, which then moves the turbines, is known as wind energy. The spinning movement of turbines provides us with electricity (Figure 1.1).

Figure 1.1

Wind Turbine, Vertical and Horizontal Axis.



1. Geothermal Energy

The use of heat stored under the earth's surface in near-surface heating operations or the generation of electrical energy in deep layers by transferring high heat to steam turbines. (Figure 1.2)

Figure 1.2

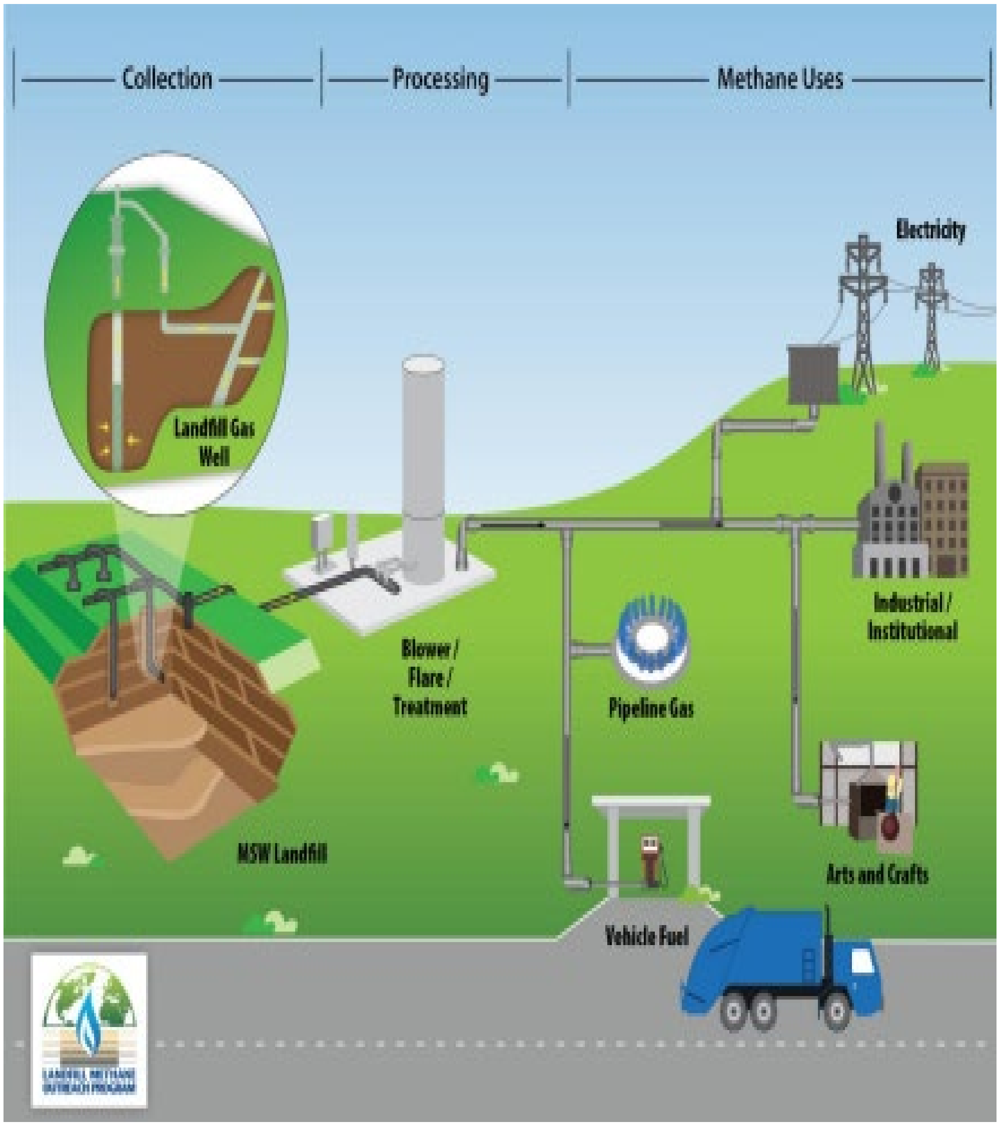
Geothermal Energy

2. Biogas

Methane is produced when animal or plant waste is fermented (biomass). Biogas is utilized as a substitute for natural gas in the generation of power, water heating, and even in home applications. (Figure 1.3).

Figure 1.3:

Biogas Procedure



3. **Solar energy**

Sunlight (light + heat) is converted to heat or electrical energy on Earth. (Figure 1.4).

Figure 1.4:
Solar Energy

Aim of the Study

Evaluate wind and solar potential in 14 locations in Cyprus. For this purpose, the NASA database as a source of meteorological information has been utilized to find a suitable location for installing the wind and PV systems in Cyprus.

As mentioned previously, there is a strong association between wind speed, solar radiation, and other meteorological parameters. Therefore, Through the use of GIS Systems, this paper investigates the spatial suitability for wind and solar farm installations based on meteorological parameters such as relative humidity (RH), maximum wind speed (Wmax), minimum wind speed (Wmin), average wind speed (Wa), maximum air temperature (Tmax), minimum air temperature (Tmin), average air temperature (Ta), and dew temperature (DT), global horizontal irradiation (GHI), global direct irradiation (GDI), global horizontal irradiation.

CHAPTER II

Solar Energy Potential and Literature Review

The world is facing an increasing of problems that resulting of the use of traditional and unclean energies, these problems represent a challenge that requires of human society to take a set of effective policies and measures to overcome these problems, and that is before the planet's resources are depleted which may led to gets out of control. Therefore, the need came to activate the role of the industrial designer in helping to reduce these problems, by exploiting and employing clean energies, in order to achieve one of the main objectives of sustainability, which is preserving the environment by conserving energy, it represents in rationalization of energy consumption as well as resorting to the use of clean alternative energies that do not have a burden on the environment or society and at the same time have an economic return.

The Main Advantages of Renewable Energy

The types of renewable energy include solar energy, wind, rain, tides, waves, biomass and thermal energy stored in the earth's crust, which makes it an inexhaustible source of energy, its climatic or environmental damage is almost non-existent. The following below are the most main advantages of renewable energy:

1- constantly renewed.
2- environmentally friendly.
3- Reduce the heat emissions.
4- Raise the level of economic growth.
5- Provides a new job opportunity.
6- Save fuel and energy with less cost.
7- Reduce maintenance cost.

In recent decades, more innovative and less costly ways of harnessing wind and solar energy have been developed. Renewable energy or alternative energy has become a more important source of energy. In addition, we are witnessing the widespread adoption of various forms of renewable energy, from rooftop solar panels to massive coastal solar farms. Even some rural communities have become completely dependent on it for heating and lighting, as it is less expensive, less harmful to the environment, and available all over the world.

Solar Power

The sun supplies the earth with more energy than the total energy needs of the world, As the energy that can be obtained from sunlight suffices the needs and consumption of the world. The sun is the main source of many energy sources found in nature. All types of energies, including petroleum, natural gas and coal, are formed due to the heat of the sun, in addition to the solar energy sources, wave energy and hydroelectric energy. Solar energy is used directly in many applications such as: heating, lighting, water heating, cooling, steam production, desalination of sea water, and thermal electricity generation, Solar energy is also used to produce electricity directly through photovoltaic cells.

How to Get Electricity from Solar Energy

The following below are the steps of converting the solar radiation to solar power:

1- Installing the array of solar panels on the roofs of houses, or in the large outdoor spaces, and the panels consist of photovoltaic (PV) cells that absorb solar radiation during the day.

2- Each solar cell contains semiconductor wafers made of two layers of silicon, positively and negatively charges, and an electric field is formed between them. This process is contributing in the generation of electric current.

3- The electric current is generated in DC form, so the inverters that installed behind the solar panel is converting the power from DC to AC, in order to be able to use in homes power.

4- After producing the AC current, this current is distributed inside the house through an electrical panel, in order of powering all electrical appliances.

5- Batteries or stored thermally store the surplus energy that is collected during the day and benefit from it at night and on rainy or cloudy days.

Solar Panel

Solar panels are the main component that generate electricity, in the listed following points are the characteristics of the solar panels:

1- Cells are made of semiconductor materials such as silicon that absorb light from the sun.

2- Silicon is naturally very shiny, so in order to take advantage of the photons and prevent them of being reflected away from the cell, an anti-reflection coating is applied to the cells.

3- A glass cover is placed on top of the solar panel to protect the silicone material from external factors and scratching.

4- The plate consists of a group of PV cells connected to each other in one frame and connected between them.

5- The standard size of the cell is 15.6 * 15.6 cm.

6- 255-285 watts panels are containing 60 cells (6 * 10), and their size is 99 * 164 cm. (Figure 2.1).

7- 315-335watt panels are contain 72 cells (6 * 12) and have a size of 99 * 196 cm. (Figure 2.1).

Figure 2.1:

255-285Watts Panel and 315-335Watt Panel

Solar Panels Types

The three main types of solar panels are as follows:

1- Monocrystalline Silicon:

The cells that make up the monolayers are silicon alloys that have been Divided Into strips. it gives an efficiency of up to 17.5% and its life span is 25 years or more. (Figure 2.2).

Figure 2.2:

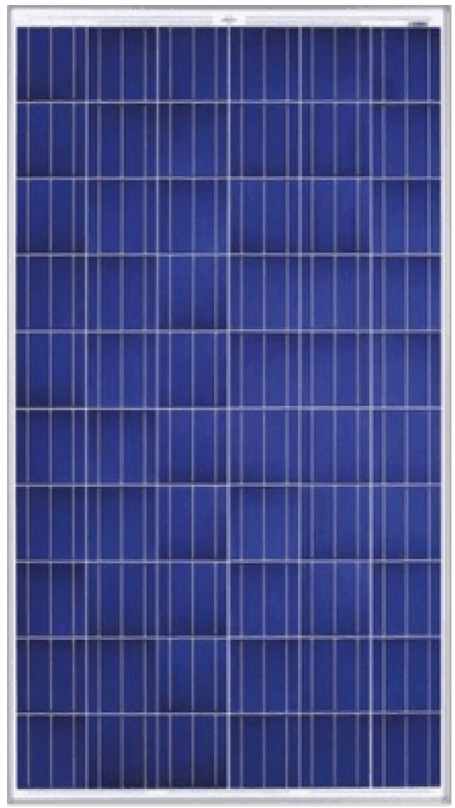
Monocrystalline Silicon Solar Panel

2- Polycrystalline Silicon:

The difference between Polycrystalline and Monocrystalline is that the cells are stacked squares, as shown in the figures. It is less expensive compared to mono cells. It gives an efficiency of up to 17.5% and its life span is 25 years or more (Figure 2.3).

Figure 2.3:

Polycrystalline Silicon Solar Panel

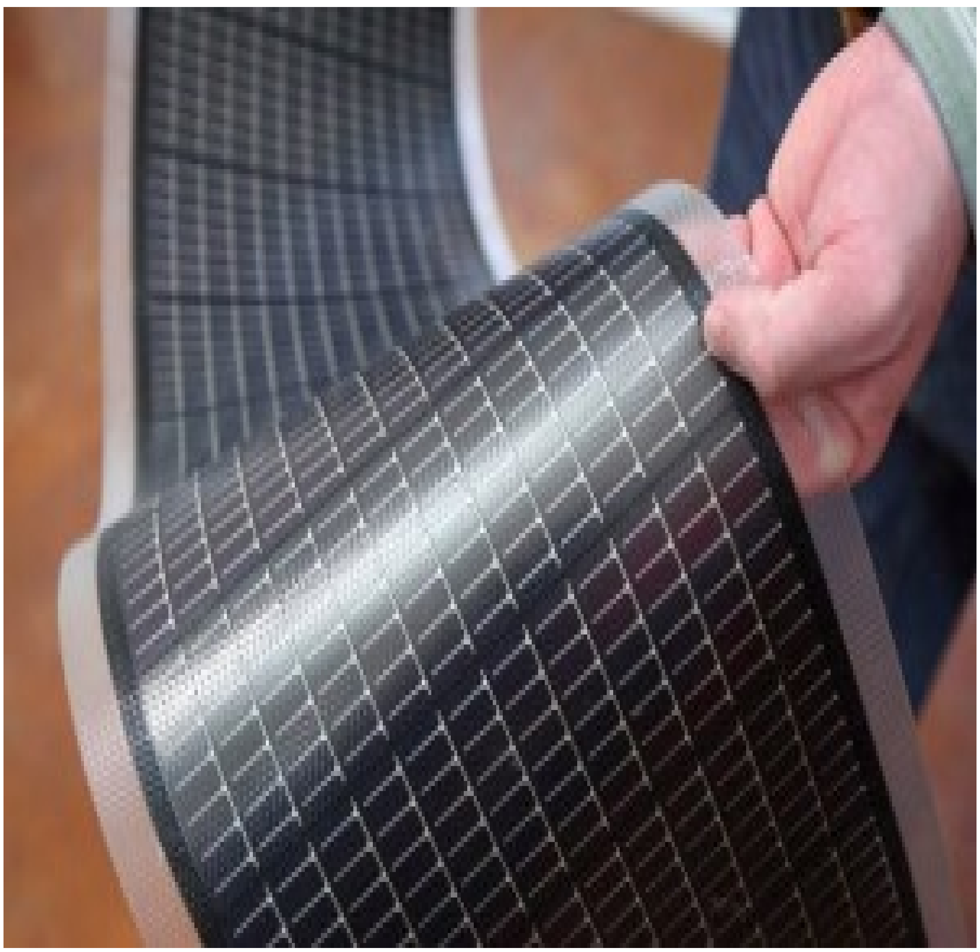


3- Thin Film.

As shown in the figure, this sort of solar panel is thin and streamlined, and it conforms to the curvature of the surface on which it is installed. Suitable for a variety of uses, including boat decks and transportation vehicles. One of its drawbacks is that it is the least efficient of the types, with an efficiency of no more than 12%. It has a shorter lifespan than single and multiple panels, lasting only up to 15 years. (Figure 2.4).

Figure 2.4:

Thin Film Solar Panel



No Advantages Between Mono and Poly Panels in Terms of Electricity Generation.

The output generated electricity of the Mono and Poly panels have no advantages between each other, as following:

1- Identical electricity generation, the electricity that generated are equal When comparing the output of 100 Watt of Mono cells with 100 Watt of Poly cells.
2- The sizes of the panels are almost identical and the area that may save is very simple. For example: The area of poly solar panel with capacity of 250-260w is 164*55 cm, as same as Mono solar panel with capacity of 250-260w, its area 164*55 cm.
3- The life span is identical for mono and poly panels.

Types of Connections

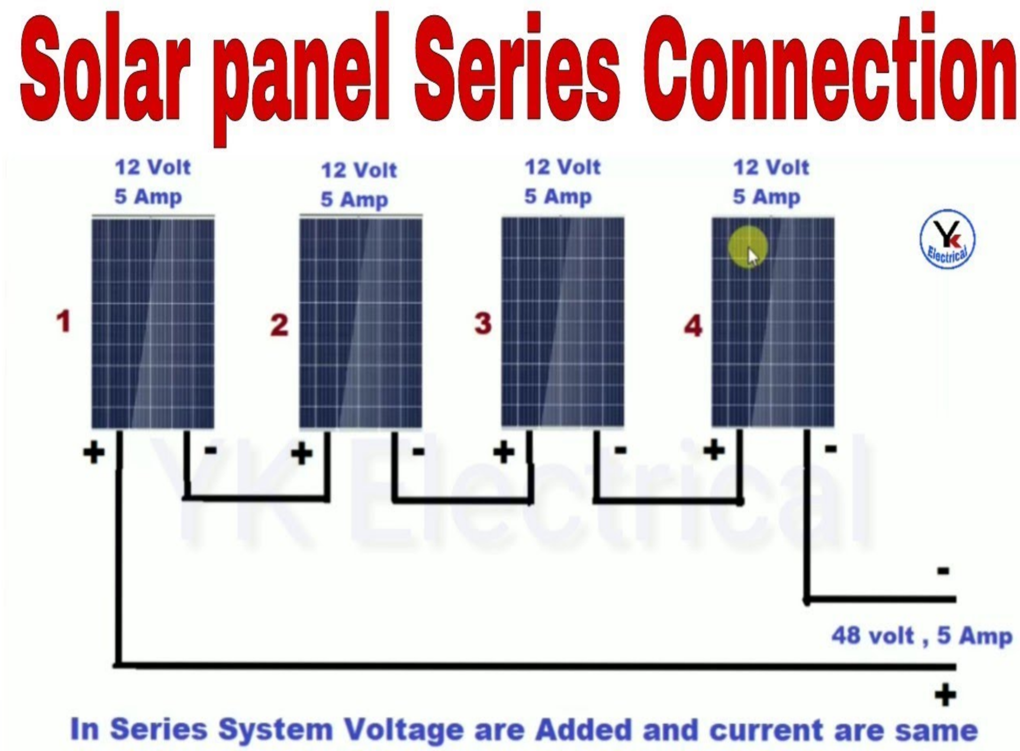
The differences of the connection are chosen according to the specifications of the inverters.

1. Series Connection:

Connect the positive (+) contact panel to the negative (-) contact in the corresponding panel, and in all panels, we find in the rear cable the positive pole is equipped with a male connector (red color) and female connecter (black color). So, male will be connected with female in the and female with male connectors corresponding panel (Figure 2.5).

Figure 2.5

Series Connection



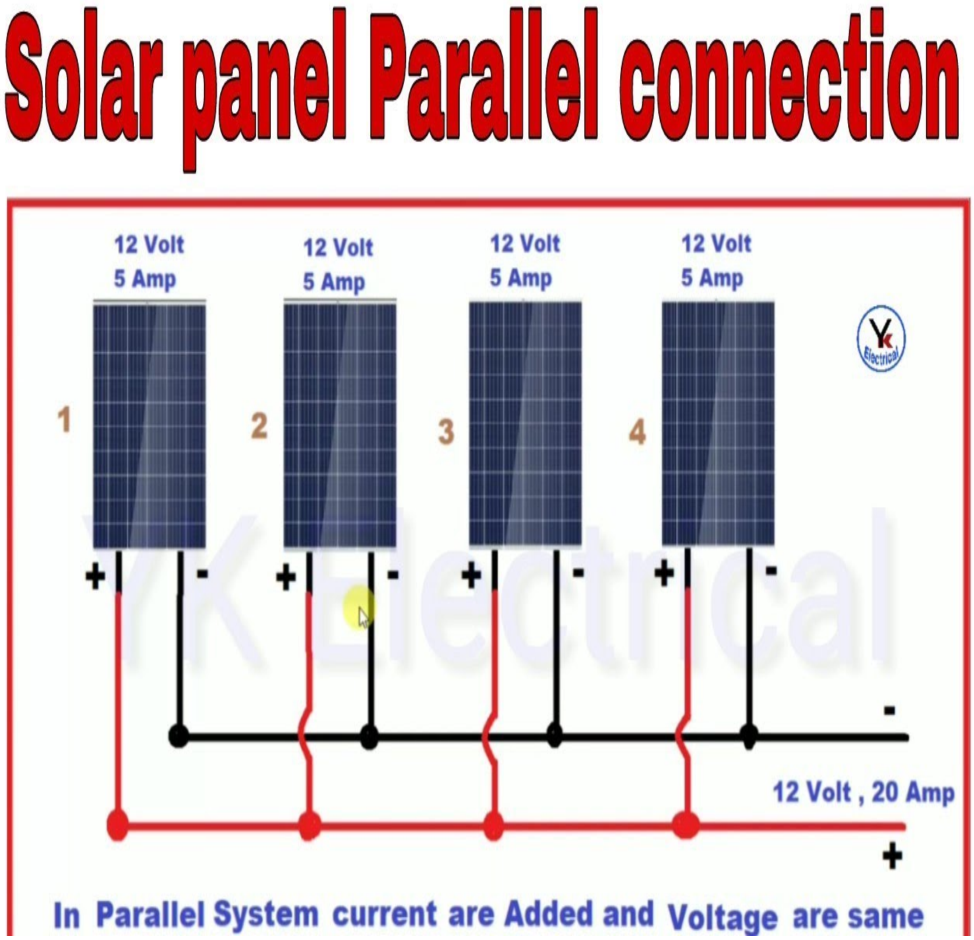
The method of the connection is chosen according to the specifications of the charging regulator or inverter, for example if the charging regulator accepts 150 Volt. So, the panel connections must not be more than 4 panels in series. It's always better to choose the regulators that accept a large number of panels that connected in series, in order to increase the voltage and decrease the parallel connections.

1. Parallel Connections:

Connect the positive (+) contacts of all panels together and connect all the negative (-) contacts together, in this case, two- and three-phase connections must be used to make these connections. If the connected lines are more than three in parallel, then it must be collected in (Combiner Box) by using a copper bar (Figure 2.6).

Figure 2.6

Parallel Connections

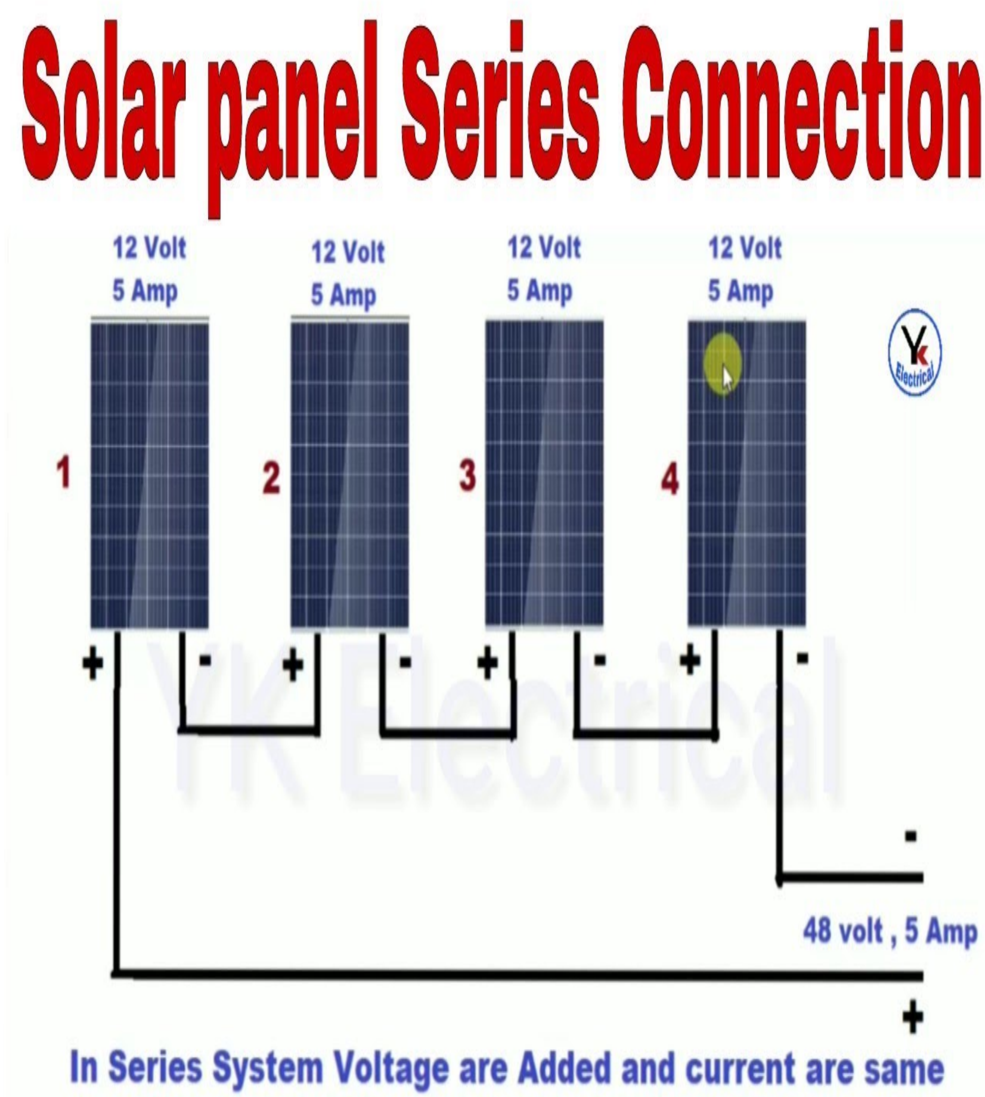


2. Series and Parallel Connections.

In this method, it is taken into account that the voltage is identical for each of the lines to be connected in parallel. For example, 3 panels are connected in series and two lines are connected in parallel, with a total of 6 panels (Figure 2.7).

Figure 2.7

Series and Parallel Connections



Type of Glass

Usually, 3.2mm thick glass is used in the manufacture of solar panels. To obtained more absorb of the solar radiation and decrease the reflecting of it, the double-sided of the panel should be rough, which will increase the cost of the panels but gives high efficiency. The glistening panel with less efficacy resulted of lack of absorption of solar radiation. (Figure 2.8).

Figure 2.8

The glistening Panel

Solar Panel Capacity Measurement

An ordinary multimeter can be used to measure the solar panel (Figure 2.9).

Figure 2.9

Multimeter Device.

There are two different readings that need to be checked to make sure if the solar panels are working properly, and to inspect how much is the energy has been generated.

1. **Volt Measurement:**

a. The solar panels must be completely separated from the battery and charging regulator.

b. Direct the panel towards the sun.

c. Ensure that the (Avometer) is set to measure the voltage between the positive and negative electrode of the panels.

2. Ampere Measurement:

a. The same steps are taken as above, but by setting the Avometer to measure the current.

b. Measure the power of the panel after reading these values using the following equation:

(Power = Volts * Amperes)

For example: If the Volt is equal 3.75 and Ampere equal 6.

The power of the panel is equal to (3.75*6= 225 Watt).

NOTE: It is impossible to obtain the same value of the power that written on the panel when measuring the voltage and current in the previous method, but it gives you approximately 80% of the real examined in the lab in a specific factor.

Advantages of Relying on Solar Energy to Generate Electricity

1. Safe, secured and reliable.
2. Effective and economically viable lighting for remote areas.
3. Flexible; The size of the solar cell system can be increased as needed in the future.
4. Lighting of areas isolated from the network.
5. Supplying remote communication stations.
6. Pumping water to irrigate agricultural crops.
7. Lighting the residential homes.
8. Lighting the streets and roads.
9. Solar energy is both sustainable and renewable, which means it will never run out of power. It is a renewable energy source that can also be utilized to produce other types of energy. It may be used to power vehicles, heat water, and light dwellings.
10. Obtaining solar energy will not necessitate extensive maintenance in the future.
11. Solar power plants and solar panels in residences produce have no emissions and have no negative environmental impact.
12. Sustainability: Solar energy is considered as the best alternative to fossil fuel products such as oil, gas, and coal because these resources are rapidly depleting,

whereas solar energy is indestructible due to its reliance on sunlight, which is predicted to continue to shine for billions of years.

13. Environmentally friendly: Compared to fossil fuels, the technology used to produce solar energy has little impact on the surrounding environment, making it a safe and clean source of energy for all organisms.
14. Countries will have self-sufficient in energy production: Solar energy provides independence in energy production at the international level.
15. Competitiveness: Renewable technologies contribute to reducing the costs of renewable energy as much as possible, so that it becomes highly competitive against other traditional types of energy, and thus solar energy has affected the economic side all over the world.
16. Independence: provides self-sufficiency in terms of generating electrical energy and storing it as needed, as well as ensuring that the house is powered even if there is a power outage.
17. Saving money: While the process of installing solar panels is costly, the financial savings will be significant in the long run, as it contributes to the generation of electric power for the individual and results in the near-permanent elimination of electricity bills.

Disadvantages of Relying on Solar Energy to Generate Electricity

Despite its many benefits, solar energy has some significant drawbacks, includin g the following:

1. Solar energy is dependent on the amount of energy gathered by solar panels during the day, which fluctuates depending on the season and time of day.
2. Solar panels' efficiency in transferring solar energy to electricity is low, averaging around 20%, despite their expensive cost.
3. When there are clouds, fog, or rain constantly exposing them to sunlight, their ability to collect solar energy is reduced, which may increase their damage due to exposure to external conditions such as rain, snow, dirt, dust, wind, and temperature differences.

Tips to Benefit from Solar Energy

There are some things that are recommended to be taken into account to achieve the highest possible use of energy, and to maintain its durability, including the following:

Avoid of washing solar panels with cold water, which may lead to crack and damage the cells.

1. A storage battery should be used to store excess energy created; use a high-quality battery rather than a low-cost one, as some types of batteries are toxic and dangerous if damaged.
2. The solar panel must be set in a proper angle, which may be different between one area to another.
3. Must not be any barriers that prevent the solar radiation to be reached to the panels, such as trees or Electricity poles.
4. Cleaning the solar panels during the night in weekly basis, to not lose its efficiency of absorbing the solar radiations.
5. Batteries shouldn't be set in a dark, hot, or poorly ventilated place.
6. Solar energy is a non-exhaustive form of renewable energy that is safe, continuous, and ecologically benign. Despite the drawbacks, current science is working to close the gaps that could lead to increased reliance on it as a key alternative to fossil fuel derivatives.

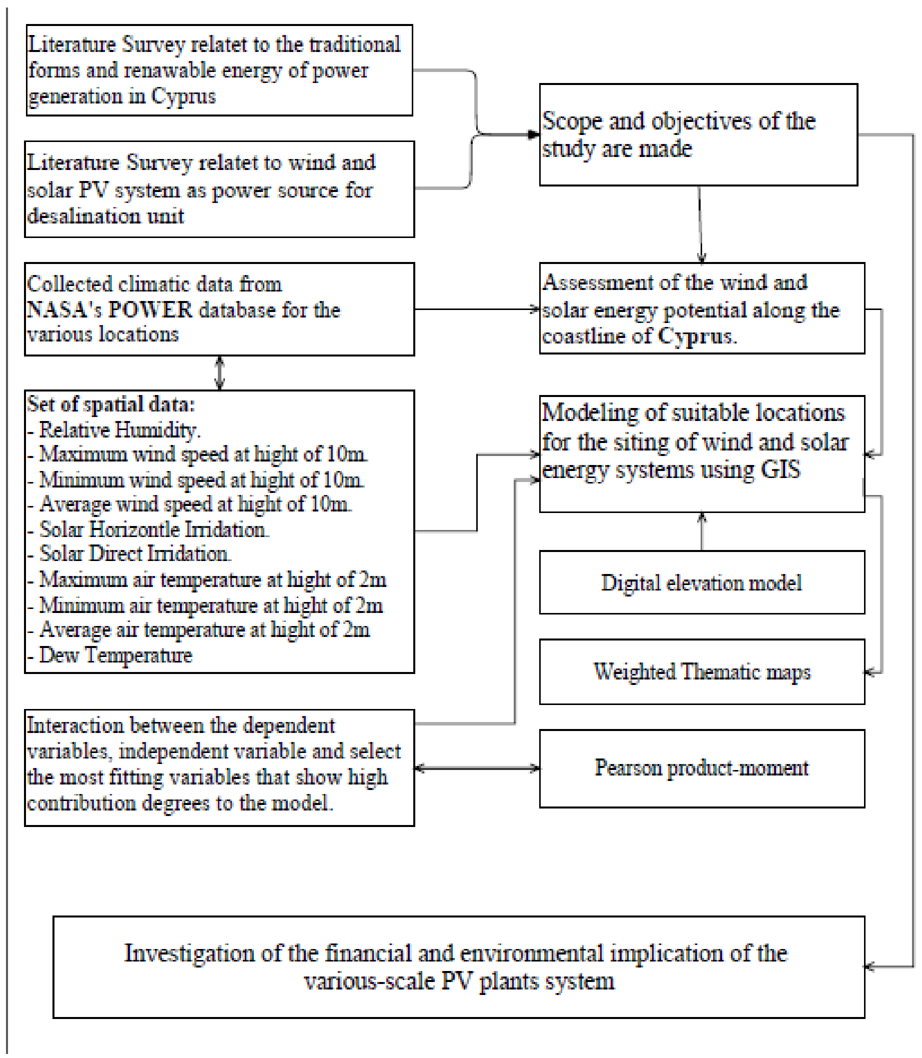
CHAPTER III

Material and Method

The wind and solar energy potential in Cyprus are investigated in this section. (Figure 3.1) illustrates a schematic diagram of the methodology that was created in this study.

(Figure 3.1).

Schematic Description for the Proposed Methodology



Study Area and Data Set

After Sicily and Sardinia, Cyprus is the third biggest island in the Mediterranean, with a total area of 9,251 km2 and 1,733 km2 of woodland. It is located at the end of the southwestern part of the Mediterranean Sea, about 380 km from northern Egypt, 105 km from western Syria and 75 km from southern Turkey. The climate of Cyprus is a strong Mediterranean climate with full seasons and a large difference in temperature in the seasons, as well as with regard to rain and the weather in general. Summer is hot and dry from mid-May to mid-September, while winter is rainy and volatile from early November to mid-March, with two short seasons, spring and fall, in between. In the summer, the island is under the influence of the air heights coming from the Great Continent, which settles over Central Asia. It is a season marked by high temperatures and nearly clear skies. Several successive depressions cross the Mediterranean Sea from west to east between the regions of Erosia and the African belt in the winter, affecting Cyprus. These depressions generate atmospheric disturbances, resulting in the majority of the year's rainfall in this season. The average rainfall in Cyprus from December to February is around 60% of the island's overall average of 500 mm.

In general, several studies evaluated the wind energy potential (Arreyndip et al. 2016, Rafique et al. 2018, Gökçekuş et al. 2019) and solar energy potential (Owolabi et al. 2019; Kassem et al. 2019; Kassem et al. 2021; Kassem et al. 2018; Kassem et al. 2020b) in different locations using the NASA database. Moreover, the NASA POWER database showed good agreement with the measurement data of global solar irradiation based on the previous scientific studies (Kassem et al. 2020c; Belkilani et al. 2018; Gairaa and Bakelli 2013). Consequently, the monthly data that were provide by NASA POWER datasets were utilized for evaluating the wind and solar energy potential at the selected locations in Cyprus. Figure 3.2 shows the reclassified aspect map and the selected locations. The data includes RH, Wmax at 10m, Wmin at 10m, Wavg at 10m, GHI, GDI, Tmax at 2m, Tmin at 2m, Tavg at 2m, and DT are among the data.

Evaluation of Solar Potential

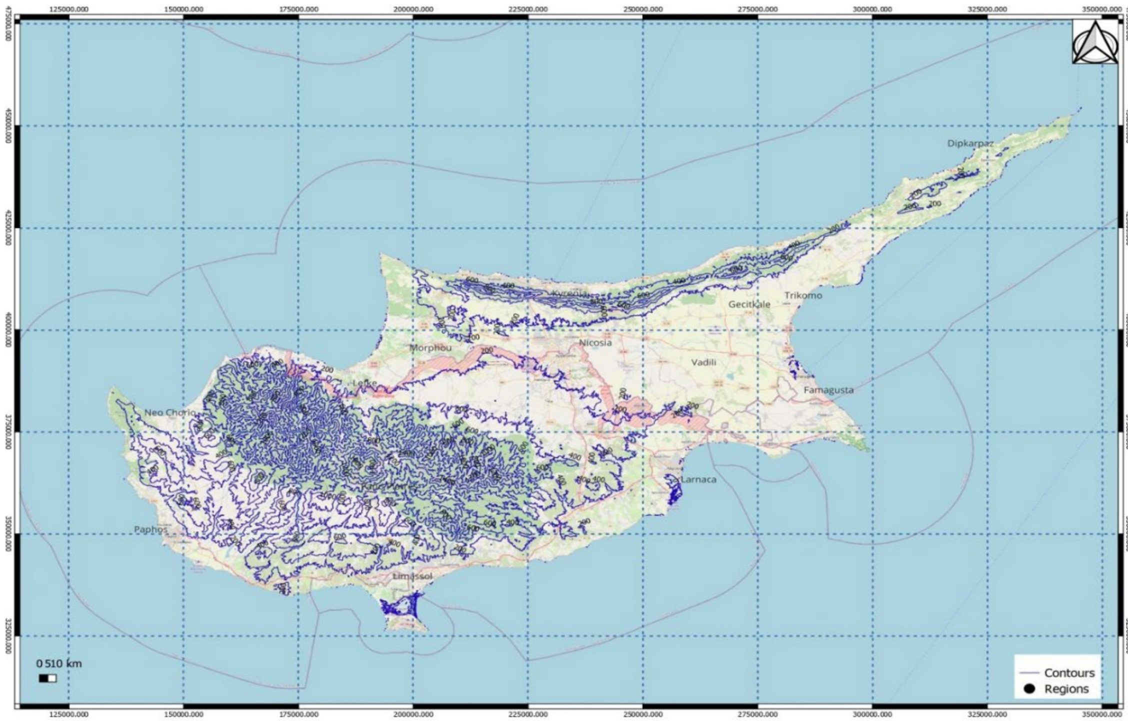
Solar energy potential is classified into two categories: geographical potential and technical potential (Zhang et al. 2020). The geographical potential is determined by the annual amounts of total solar radiation at a certain region, taking into account current physical, social, environmental, and cultural constraints. While a location's technical potential is defined as the amount of geographical potential that can be converted into electricity utilizing a photovoltaic system.

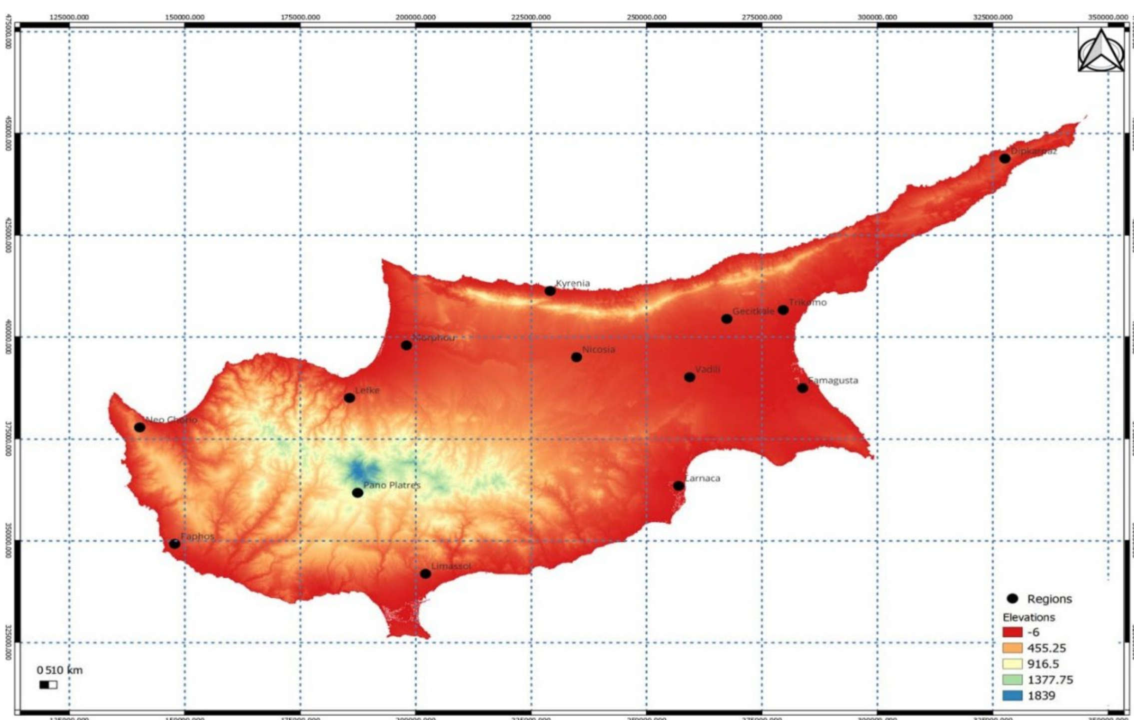
Moreover, according to the scientific researchers (Sabziparvar and Shetaee, 2007; Solangi et al. 2019; Hafeznia et al. 2017), The amount of solar irradiation is influenced by dust, sun angle, humidity, and the geographical location of the region. They also influenced the performance of PV system (Tercan et al. 2021). Hence, the location with high value of solar irradiation should be the suitable location for installing the photovoltaic system in the future.

In the literature, it is found that that location with less air temperature and relative humidity has high electricity production from PV system (Doorga et al. 2019; Zoghi et al., 2017; Solangi et al., 2019) since the ambient temperature and relative humidity affect the performance of solar panel (Kassem et al. 2020). Consequently, the suitable location for installing the PV system is selected based on solar irradiation, ambient temperature and relative humidity.

Figure 3.2

Topographical at Selected Locations





The Theoretical Framework of Methods

Inverse Distance Weighting Method

The spatial estimation of solar potential in term of solar radiation (SR) is dependent on the spatial interpolation that simplifies SR from a limited number of stations to other locations with no measurement of SR (Ozelkan et al. 2016; Shukla et al. 2020; Tercan et al. 2021). Inverse distance weighting (IDW) and kriging and cokriging are the common spatial interpolation models (Tercan et al. 2021; Ozelkan et al. 2016; Joyner et al. 2015). The IDW model, which involves weighting the inverse of the distance between two locations in the sample, is one of the simplest spatial local deterministic interpolation algorithms. (Shukla et al. 2020). Developed the IDW on the idea that the value of an estimated point is better connected with the value of a closer known point than a far one (Rodrguez-Amigo et al. 2017; Firozjaei et al. 2019; Tercan et al. 2020) The following formulae are used to calculate the IDW equation. (Chen and Liu 2012; Firozjaei et al. 2019).

$$b(x) = \frac{\sum_{i=1}^{n} w_i b_i}{\sum_{i=1}^{n} w_i} \quad (1)$$

$$w_i = d_i^{-k} \quad (2)$$

Where b_i points represent known values; $b(x)$ represents the unknown value; n represents the number of known values; d_i represents the distance between point i and the unknown point; w_i represents the weight assigned to point i; k represents the power parameter.

Clustering-Classification Technique

The goal of classification is to categorize each data object precisely into a target class. Normally, classification is achieved by sorting the instances with reference to the feature values using decision trees (Mittal et al. 2019). Clustering is a technique for combining a group of objects that are typically related to one another (Chen et al. 2012). Clustering is a crucial part of data analysis (Mittal et al. 2019; Mann and Kaur 2013). It is the challenge of arranging a group of objects in such a way that objects in the same group are more connected to one another than objects in other groups (Mann and Kaur 2013). To identify the optimal arrangement of values into distinct groups, several approaches are utilized, including Natural Breaks classification method (Jenks), K-mean clustering method, Fuzzy c-mean, Gaussian Mixture Model Clustering, and Clustering Large Applications method. (Papaioannou et al. 2015; Mittal et al. 2019; Mann and Kaur 2013).

Jenks' natural breaks method was employed in this study. It's a data categorization approach for determining the best way to divide values into distinct classes so they may be presented on a choropleth map (Koo et al. 2017). It is popular and is used extensively in geographic information systems (GIS) packages. Fundamentally, because Jenks's method is a within-groups variance minimization approach, it determines class breaks to maximize homogeneity within classes (Stefanidis and Stathis 2013). The Jenks Optimization approach aims to minimize variance within classes while maximizing variance between them. It's a data classification strategy that divides data into classes based on natural groups in the distribution. Gaps between clusters of values are defined as "class breaks" in data distribution. Inherited groupings and patterns in data can be discovered using this strategy, decreasing disparities inside a class while highlighting differences between created classes.

In this study, each factor's effect is categorized into five levels, ranging from 1 to 5, as follows: very high = 5, high = 4, moderate = 3, low = 2, and very low = 1. Because all of the hypothesized factors had varying degrees of influence, correlation analysis was used with varied weights for each element. This analysis takes into account the impact of each component on the others. As a result, five different types of effects are used: very high, very high, high, moderate, low, and very low. A total of ten thematic maps were created.

Wang Liu Method

The method was utilized to fill sinks and depression area in the extracted discrete element method (DEM), preserve downward slope along flow path, in addition to enhance hydrological analysis for surface elevations (Wang liu. 2006). Using the least-cost search algorithm, the used technique computes a spill elevation value for each grid cell without prior demarcation of the sink catchments, allowing for the gradual construction of propagation spill elevation values and optimal flow pathways from outlets. Based on previous research (Cormen et al. 1996; Sedgewick 2002), In the field of artificial intelligence, least-cost search is often referred to as best-first search or priority-first search. The main idea behind the algorithm is to select the direction with the lowest cost for future searches and extensions. (Dechter and Pearl 1988). The spill elevation is used to determine the expense of the search. The DEM's boundary cells are thought to be possible outlets. Their spill altitudes, which represent the costs of seeding the best pathways, are allocated to their original elevation values.

$$h(bk) = S(bk) = E(bk) \quad (3)$$

Where $h(bk)$ represents estimated cost for boundary cell, bk represents outlet for optimal path, $S(bk)$ represents the spill elevation of boundary cell bk, and $E(bk)$represents original elevation value of boundary cell bk.

The highest priority is nominated to the cell with the least-cost (the lowest elevation) to serve the root of the first tree for optimal expansion and track. The least-cost boundary (central cell) cell is tested, then immediate interior neighbors were identified. The links between neighbors represent the optimal paths for these interior cells, after that the nodes of the tree were added to the lowest cell on the border, processed node were marked as least- cost boundary cell. The utilized equation to following function to estimate costs for optimal expansion and path:

$$h(nj)S(nj)maxf\{E(nj\ ), S(c)g\}, j{\sim}1, 2, \ldots, 7 \quad (4)$$

Where; nj is the jth neighbor of the central cell c, $h(nj)$ is the cost estimate for expanding optimal paths, $S(nj)$ is the spill elevation value for neighbor cell, $E(nj\ )$ is the original elevation of the j^{th} neighbor of the central cell c, and $S(c)$ is the central cell c spill elevation, which is the cost of the optimal path assigned between the root and the central cell being processed.

The spill elevation value for the neighbor cell nj is computed using its original elevation $E(nj\ )$ and the center cell's spill elevation $S(nj)$ and is assigned as the cost of widening the best path from this neighbor cell.

Correlation Analysis

Pearson product-moment is used for the correlation with the solar radiation data, followed by a parametric method for normal distribution and a non-parametric method for non-normal distribution series, respectively, to investigate the interaction between the dependent variables and independent variables and select the most fitting variables that show high contribution degrees to the model (Kassem, and Gokcekus 2021). RH, Wmax, Wmin, Wavg, Tmax, Tmin, Tavg, and Tdew are the dependent variables in this study. Solar radiation is the independent variable (solar horizontal irradiation and solar direct irradiation). The correlation coefficients and P-values were calculated using Minitab 17 software.

CHAPTER IV
Results and Discussion

Data Characteristics

As mentioned previously, NASA average monthly weather data were collected by NASA POWER datasets are used in this study. Figure 4.1 illustrates the average monthly weather data for the selected locations. It is found that the values of air temperature are within range of 22.49-25.10℃ for Tmax, 15.65-20.50 for Tmin, 19.12-21.71℃ for Ta and 10.94-15.46℃ for DT. Moreover, it is observed that the lowest and highest GHI values are recorded in Limassol and Lefke, with a value of 165.61kWh/m^2 and 153.28kWh/m^2 and 6.16m/s, respectively. Additionally, it is noticed that the DNI values are varied from 160.40 kWh/m^2 and to 188.85kWh/m^2, which are obtained in Limassol and Lefke, respectively. Furthermore, it is noticed that the values of WS are within the range of 3.88 (Vadili)-5.10 (Kyrenia) m/s. Besides, it is found that RH values are ranged between 60.89% (Pano Platres) and 70.64% (Kyrenia) as shown in Figure 4.1.

Moreover, using the inverse distance weighting the seasonal incidence of global GHI, DNI, RH, Wmax, Wmin, Wa, Tmax, Tmin, Ta and DT of Cyprus are presented in Figure 4.2 It should be known that areas with low value of climate parameter are colored red, whereas areas with high value are shown in blue. The figure clearly illustrates those areas with high potential for wind power and solar power installations.

Figure 4.1

Average Monthly Weather Data for All Selected Data

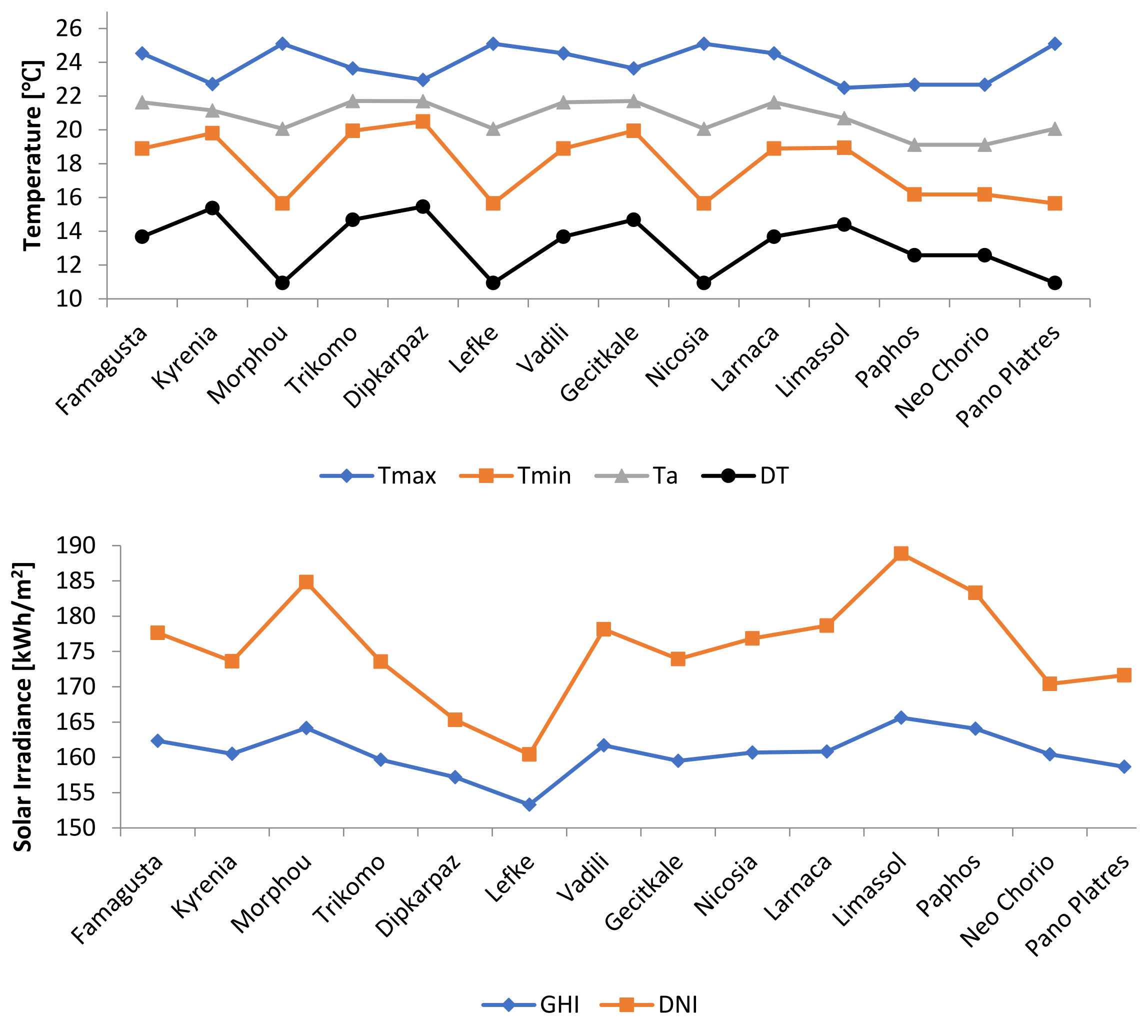
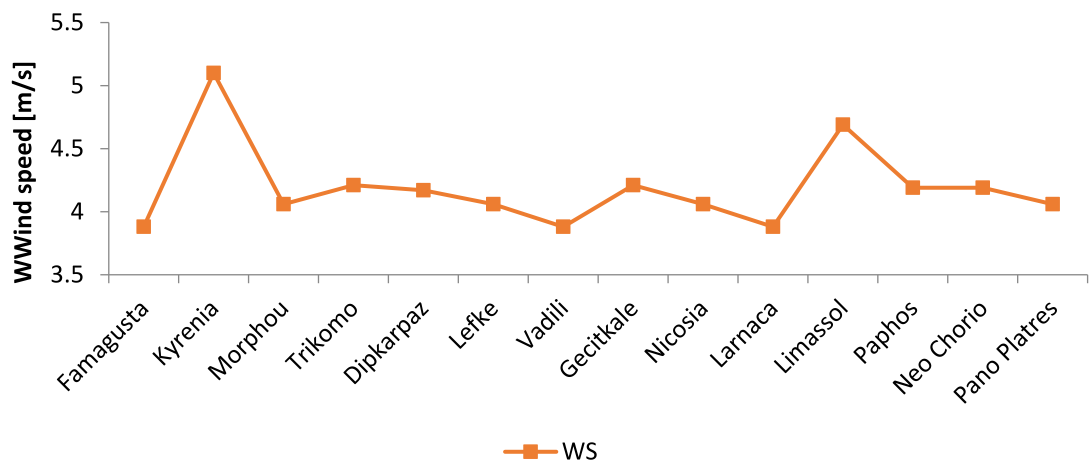


Figure 4.1 (Continued).



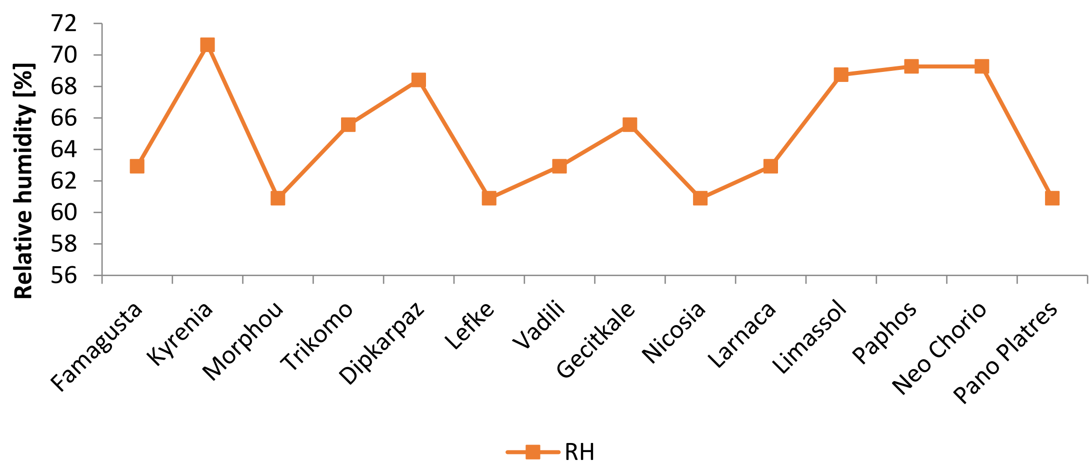


Figure 4.2

The Selected Weather Parameters Maps

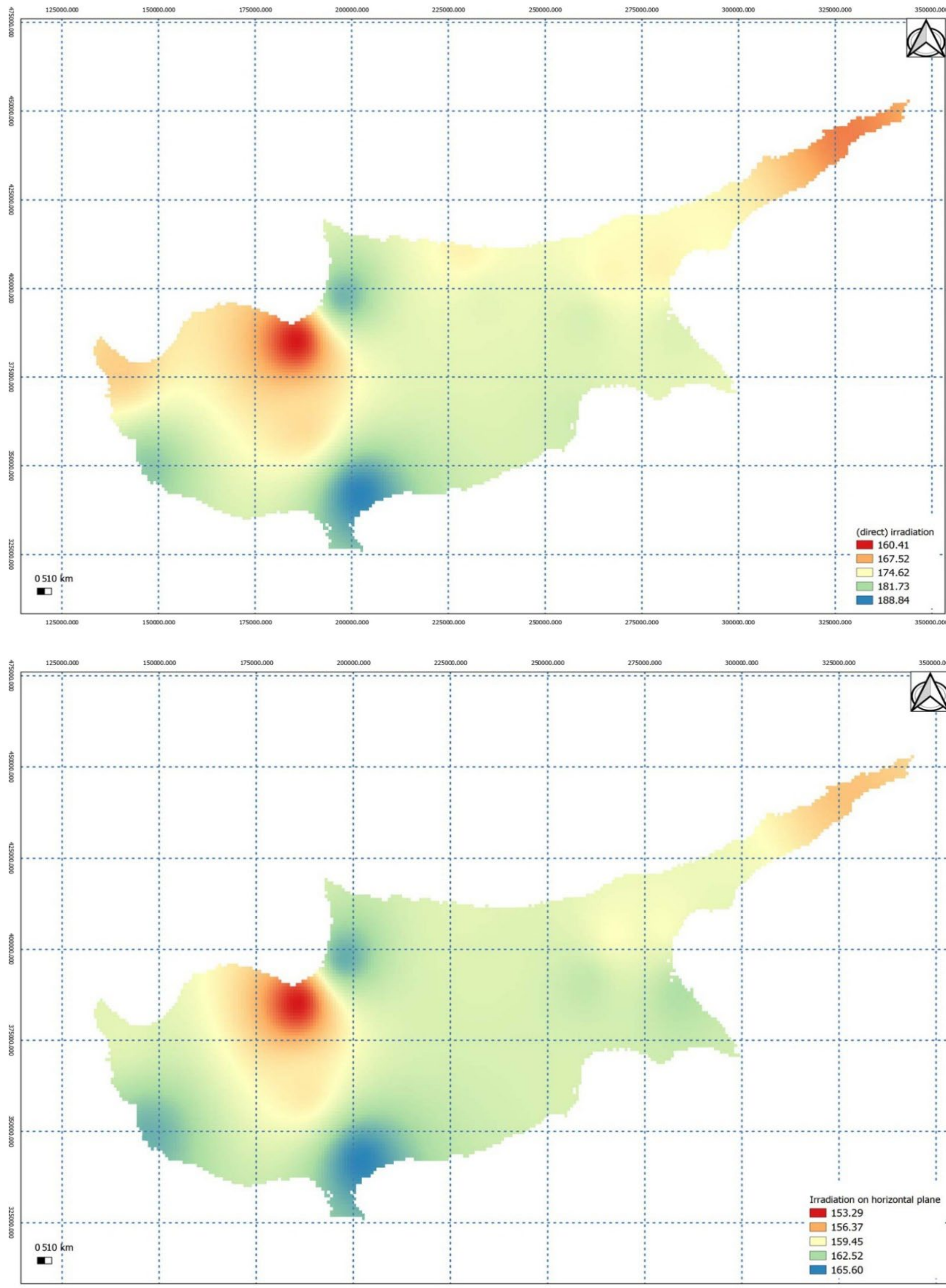
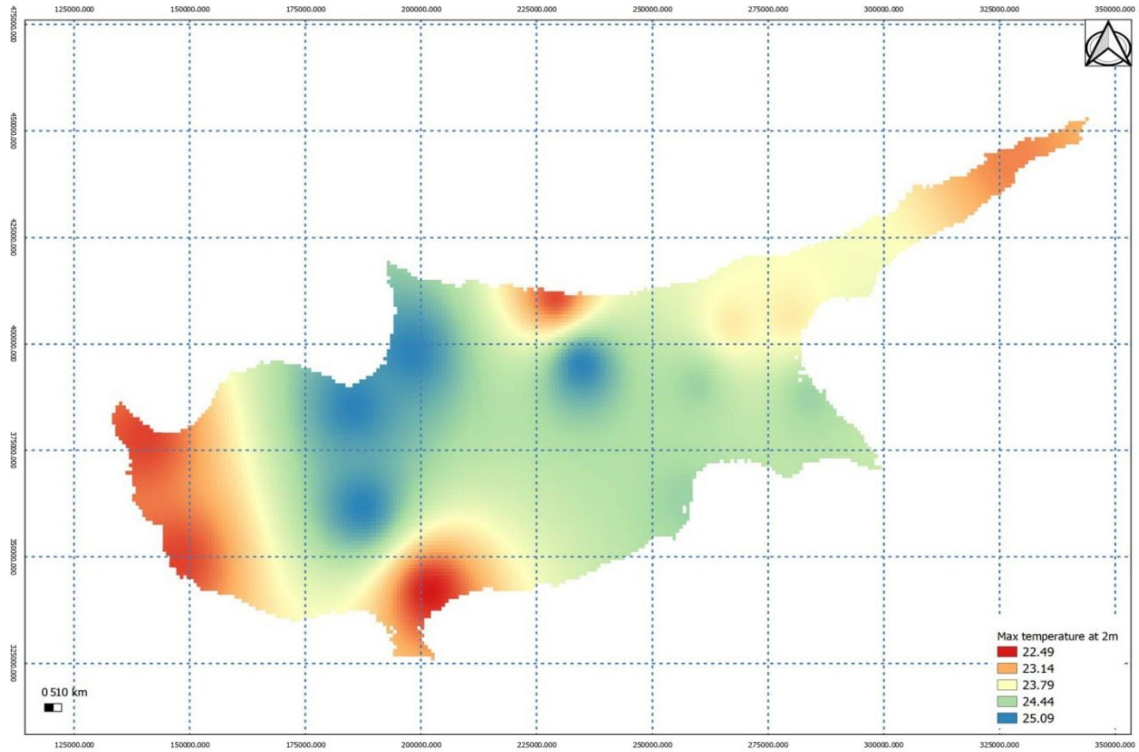


Figure 4.2 (Continued).



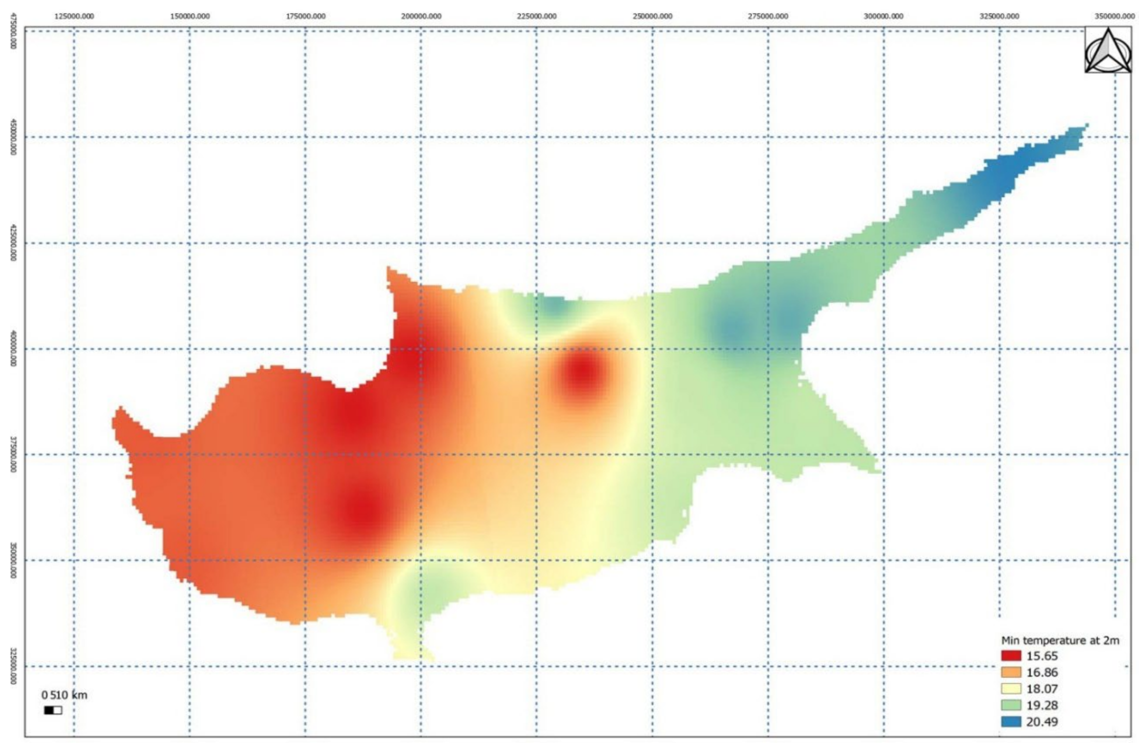
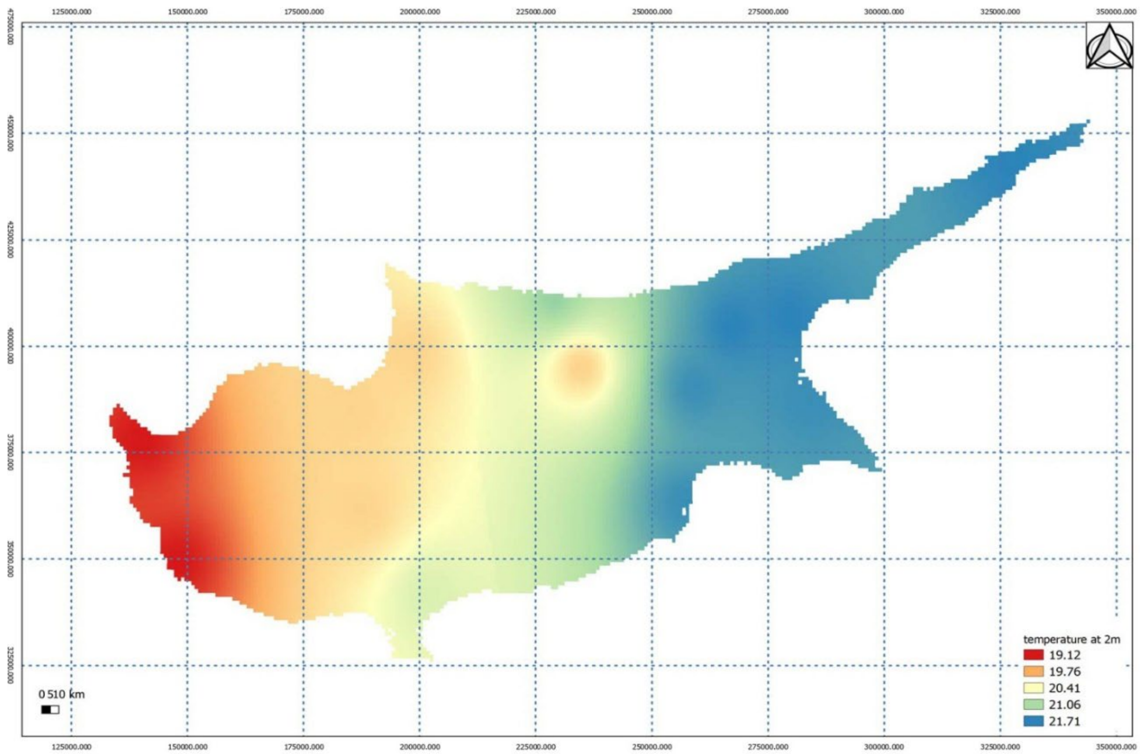


Figure 4.2 (Continued).



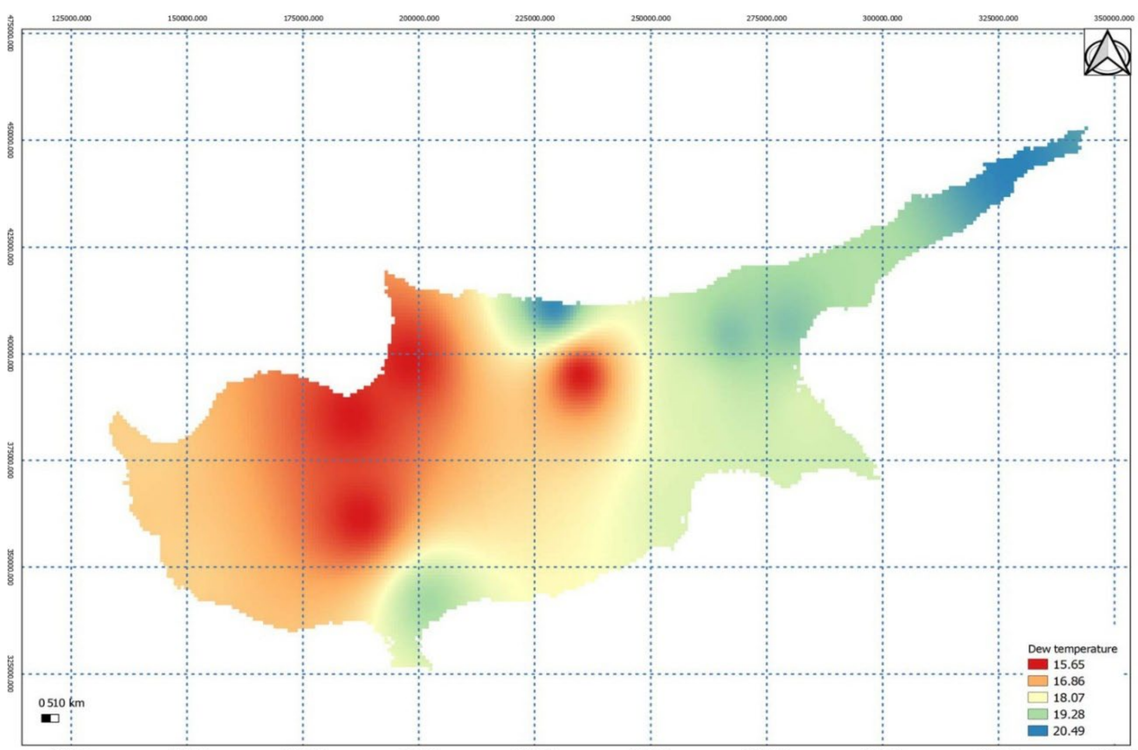
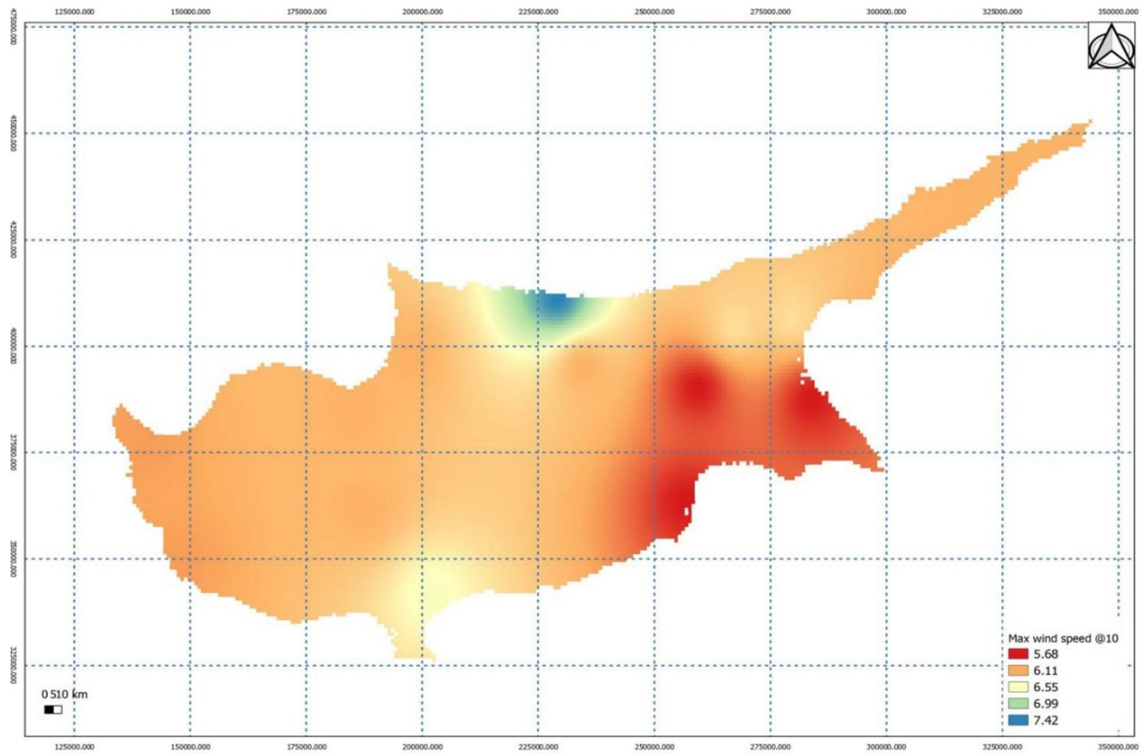


Figure 4.2 (Continued).



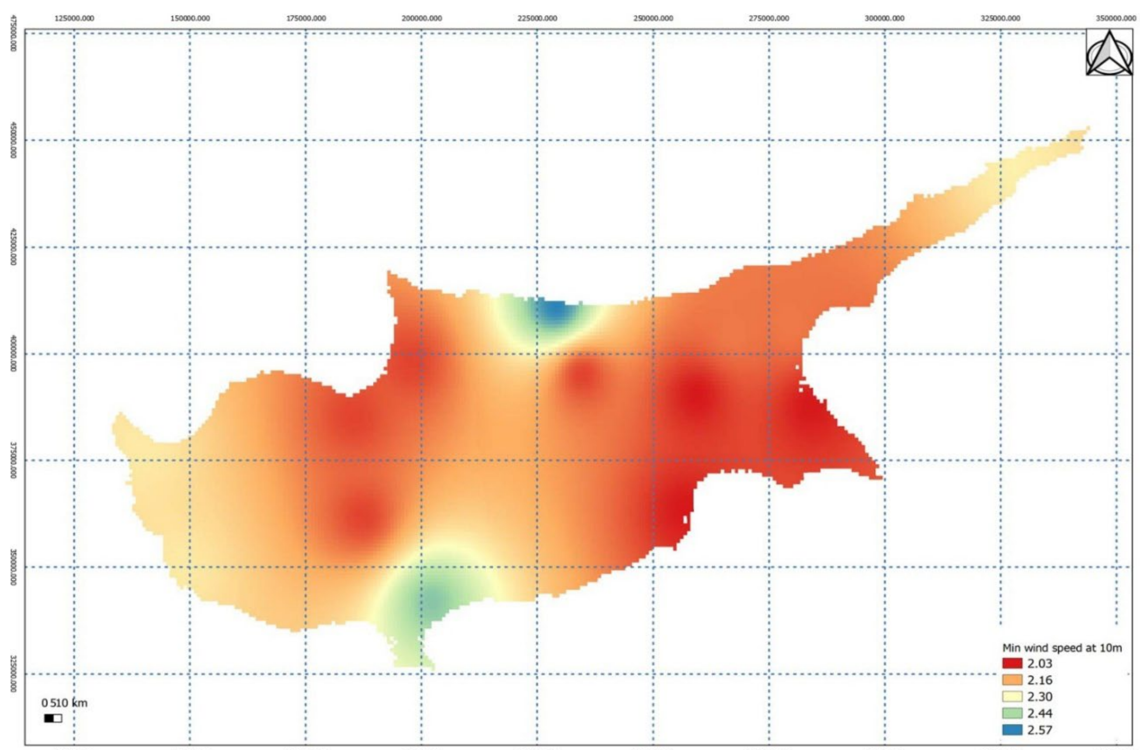
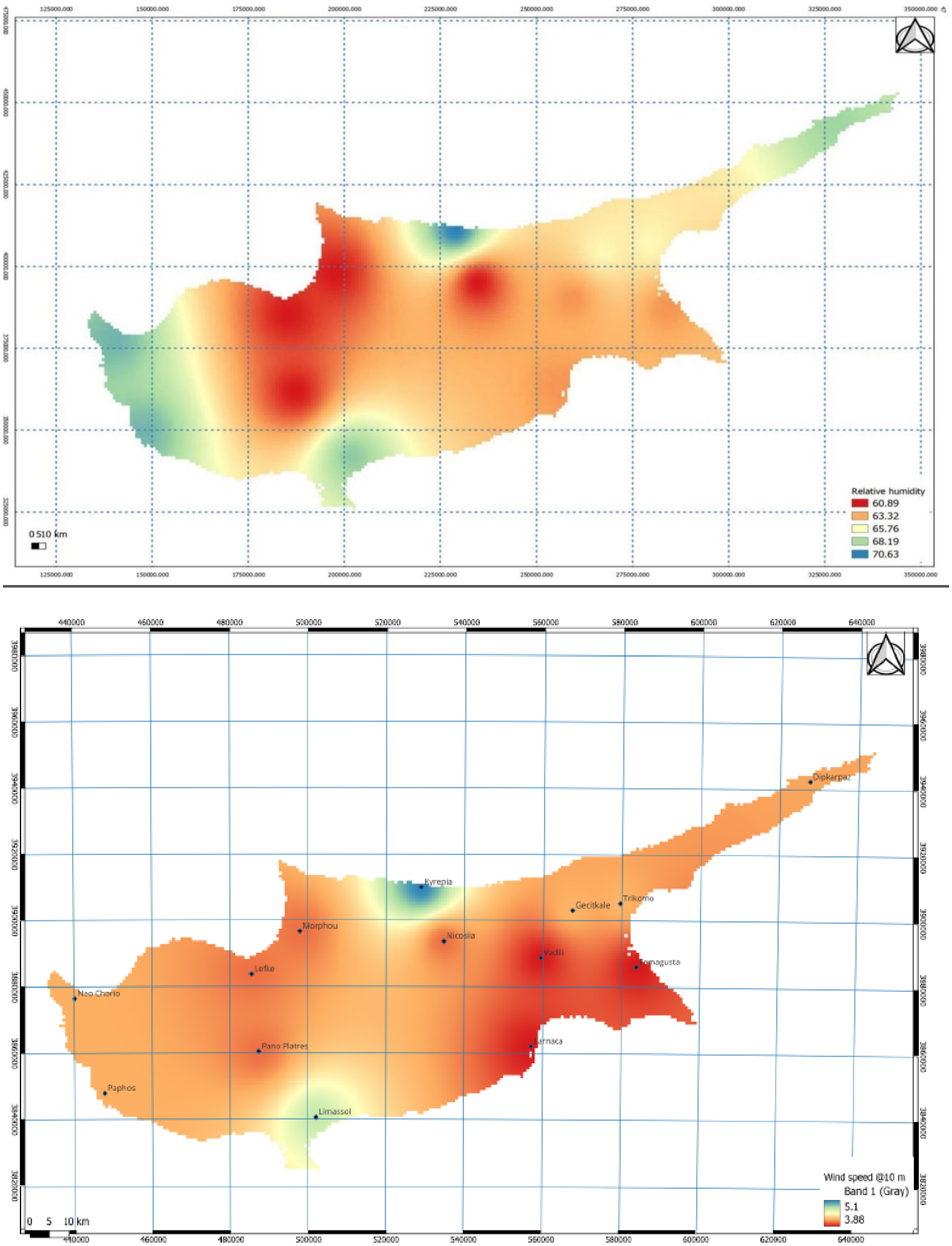


Figure 4.2 (Continued).



Criteria, Weights and Potential Maps

According to the literature reviews, there is a considerable positive association between climate characteristics and wind and solar energy potential. A number of research looked into the key factors that controlled wind speed and solar radiation properties. For example, (Meenal and Selvakumar. 2018) discovered that the most critical parameters that affect the calculation of global solar radiation are daylight hours, maximum temperature, and relative humidity. Temperature, altitude above mean sea level, and sunshine hours are shown to be the most relevant input variables for estimating solar radiation (Yadav et al. 2014). Sunshine hours, water vapor pressure, and ambient temperature are all related, according to (Mohammadi et al. 2016). Temperature is the most significant effect on the availability of solar radiation at that location, according to (Rao et al. 2018). According to (Chang et al. 2017), wind speed and solar radiation are nearly anti-phase, meaning that wind and solar energy might be complimentary in terms of electricity generation in the study location. Moreover, the findings indicate that wet-bulb temperature played a significant role in predicting the PV-output. Several scientific researchers (Hosseini et al. 2019; Simsek et al. 2021) verified this. (Hosseini et al. 2019) looked at the effect of dew development on solar panel performance. The results showed that as the amount of dew on the module's surface rose, the solar panel's performance declined. (Simsek et al. 2021) investigated the impact of dew development on PV panel performance. They discovered that when the amount of dew formation increased, the energy generation of PV panels reduced dramatically. Finally, it can be argued that two-parameter input variable combinations are sufficient for accurately estimating PV output. (Franke et al. 2021) discovered that meteorological data and usage characteristics for various land uses have a significant impact on the overall generation potential.

As mentioned previously, eight selected parameters have been found to influence of the most suitable locations for the placement of solar and wind farms based on the previous scientific studies. In addition, the nominated parameters have the most substantial impact on potential area of wind speed and solar irradiation potential area based on their rate and calculated weight, taking into consideration the cross-pollination between parameters. The parameters are RH, Wmax, Wmin, Wavg, Tmax, Tmin, Ta and DT. Consequently, the influence of the selected weather parameters on the solar radiation (GHI and DNI) and wind speed are discussed in this section.

(Tables 1 and 2) list the calculated percentages that were concluded by multiplied proposed weight of effect (RL) and rate (FR) to the overall total weight. Then thematic maps are prepared to show the influence of the climate parameters on the GHI, DNI and Wa.

In general, the weights corresponding to the distinct layers impacting the placement of solar and wind farms on the island were determined using the calculation of priority weights of a set of criteria after setting the exclusion and assessment criteria for the research areas. Following that, a reclassification method was used to normalize the different layers by assigning cell values to the input raster.

In this graph, the reclassified layers for eight nominated factors are shown (Figures 4.3-4.9). For instance, (Figures 4.3-4.6) illustrate the effect of air temperature on solar radiation and wind speed. It is found that a negative correlation between Tmax and solar irradiation and wind speed. High value of Tmax is shown in blue, whereas low value is shaded red. For example, the Kyrenia and Limassol have the highest value of wind speed (5.10m/s for Kyrenia and 4.69m/s for Limassol) and solar radiation (160.49kWh/m2 for Kyrenia and 165.61kWh/m^2 for Limassol), while they have the lowest value of Tmax (22.49℃ and 22.71℃ for Kyrenia and Limassol, respectively). Moreover, in Figures 4.4-4.6, it is found that a positive correlation was observed between the air temperatures (Tmin, Ta and DT) and solar radiation. Similarly, it observed that significant positive correlations between air temperatures (Tmin, Ta and DT) and wind speed.

In this study, the weighted linear combination technique was then used using the ArcGIS spatial data analysis function's weighted overlay function. A single map layer was created using the weighted combination of evaluation criteria layers, which comprised both appropriate and unfavorable places.

The illustrated thematic map (Figure 4.10) showing the interaction between climate parameters and solar irradiation, for maximum temperature, relative humidity and minimum wind speed showing a weak relation with solar, while the minimum temperature, temperature, dew temperature, maximum wind, wind showing no relation.

the extracted weighted map showing a higher values of potential solar radiation in Limassol, Kyrenia, Dipkarpaz, Paphos, Neo chorio compared to actual data while Famagusta, lefke , Nicosia, Vadili and Pano platers showing lower values as summarized in (Table 3).

Moreover, the illustrated thematic map (Figure 4.11) showing the interaction between climate parameters and wind speed, for maximum temperature it showing a high negative relation with wind for example Kyrenia had a maximum wind speed of 5.10 m/s and the lowest maximum temperature value while the minimum temperature and direct irradiation have weak relation, temperature and horizontal irradiation showing no relation in other hand relative humidity showing a positive high such as relation while dew temperature have a moderate positive relation for example kyerina ,and limassol had a maximum wind speed of 5.10, 4.69 km /hr respectively , and the highest values of dew temperature . the extracted weighted map showing a higher values of potential wind speed in limassol, Kyerina, Dipkarpaz, paphos compared to actual data while famgusta, lefke, Nicosia showing lower values as illustrated in (Table 4).

Table 1.

Categorization, Calibration and Weight Evaluation of the Factors Affecting Solar Radiation

Factors	**Domain of effect**	**Descriptive level (potential area)**	**Proposed weight of effect (RL)**	**Rate (FR)**	**Weighted rating (FR*RL)**	**Total weigt**	**Percentae**
Tmax	22.49	Very High	5	2.0	10	30.0	18%
	23.14	High	4		8		
	23.79	Moderate	3		6		
	24.44	Low	2		4		
	25.09	Very Low	1		2		
Tmin	15.65	Very High	5	1.0	5	15.0	9%
	16.86	High	4		4		
	18.07	Moderate	3		3		
	19.28	Low	2		2		
	20.49	Very Low	1		1		
Ta	19.12	Very High	5	1.0	5	15.0	9%
	19.76	High	4		4		
	20.41	Moderate	3		3		
	21.06	Low	2		2		
	21.71	Very Low	1		1		
DT	10.94	Very High	5	1.0	5	15.0	9%
	12.07	High	4		4		
	13.2	Moderate	3		3		
	14.32	Low	2		2		
	15.45	Very Low	1		1		
RH	60.89	Very High	5	2.0	10	30.0	18%
	63.32	High	4		8		
	65.76	Moderate	3		6		
	68.19	Low	2		4		
	70.63	Very Low	1		2		

Table 1 (Continued).

Wmax	5.68	Very High	5	1.0	5	15.0	9%
	6.11	High	4		4		
	6.55	Moderate	3		3		
	6.99	Low	2		2		
	7.42	Very Low	1		1		
Wmin	2.03	Very High	5	2.0	10	30.0	18%
	2.16	High	4		8		
	2.3	Moderate	3		6		
	2.44	Low	2		4		
	2.57	Very Low	1		2		
Wa	3.88	Very High	5	1.0	5	15.0	9%
	4.18	High	4		4		
	4.48	Moderate	3		3		
	4.79	Low	2		2		
	5.09	Very Low	1		1		
				11	165	165	100%

Table 2.

Categorization, Calibration and Weight Evaluation of the Factors Affecting Wind Speed

Factors	Domain of effect	Descriptive level (potential area)	Proposed weight of effect (RL)	Rate (FR)	Weighted rating (FR*RL)	Total weight	Percentage
Tmax	22.49	Very High	5	4.0	20	60.0	23.5%
	23.14	High	4		16		
	23.79	Moderate	3		12		
	24.44	Low	2		8		
	25.09	Very Low	1		4		
Tmin	20.49	Very High	5	2.0	10	30.0	11.8%
	19.28	High	4		8		
	18.07	Moderate	3		6		
	16.86	Low	2		4		
	15.65	Very Low	1		2		
Ta	19.12	Very High	5	1.0	5	15.0	5.9%
	19.76	High	4		4		
	20.41	Moderate	3		3		
	21.06	Low	2		2		
	21.71	Very Low	1		1		
DT	10.94	Very High	5	3.0	15	45.0	17.6%
	12.07	High	4		12		
	13.2	Moderate	3		9		
	14.32	Low	2		6		
	15.45	Very Low	1		3		
RH	60.89	Very High	5	4.0	20	60.0	23.5%
	63.32	High	4		16		
	65.76	Moderate	3		12		
	68.19	Low	2		8		
	70.63	Very Low	1		4		

Table 2. (Continued).

Wmax	153.29	Very High	5	1.0	5	15.0	5.9%
	156.37	High	4		4		
	159.45	Moderate	3		3		
	162.52	Low	2		2		
	165.61	Very Low	1		1		
Wmin	160.41	Very High	5	2.0	10	30.0	11.8%
	167.52	High	4		8		
	174.62	Moderate	3		6		
	181.73	Low	2		4		
	188.84	Very Low	1		2		
				17	255	255.0	100%

Figure 4.3

Maximum Temperature (Tmax) vs Average Wind Speed (Wa), Global Solar Irradiation

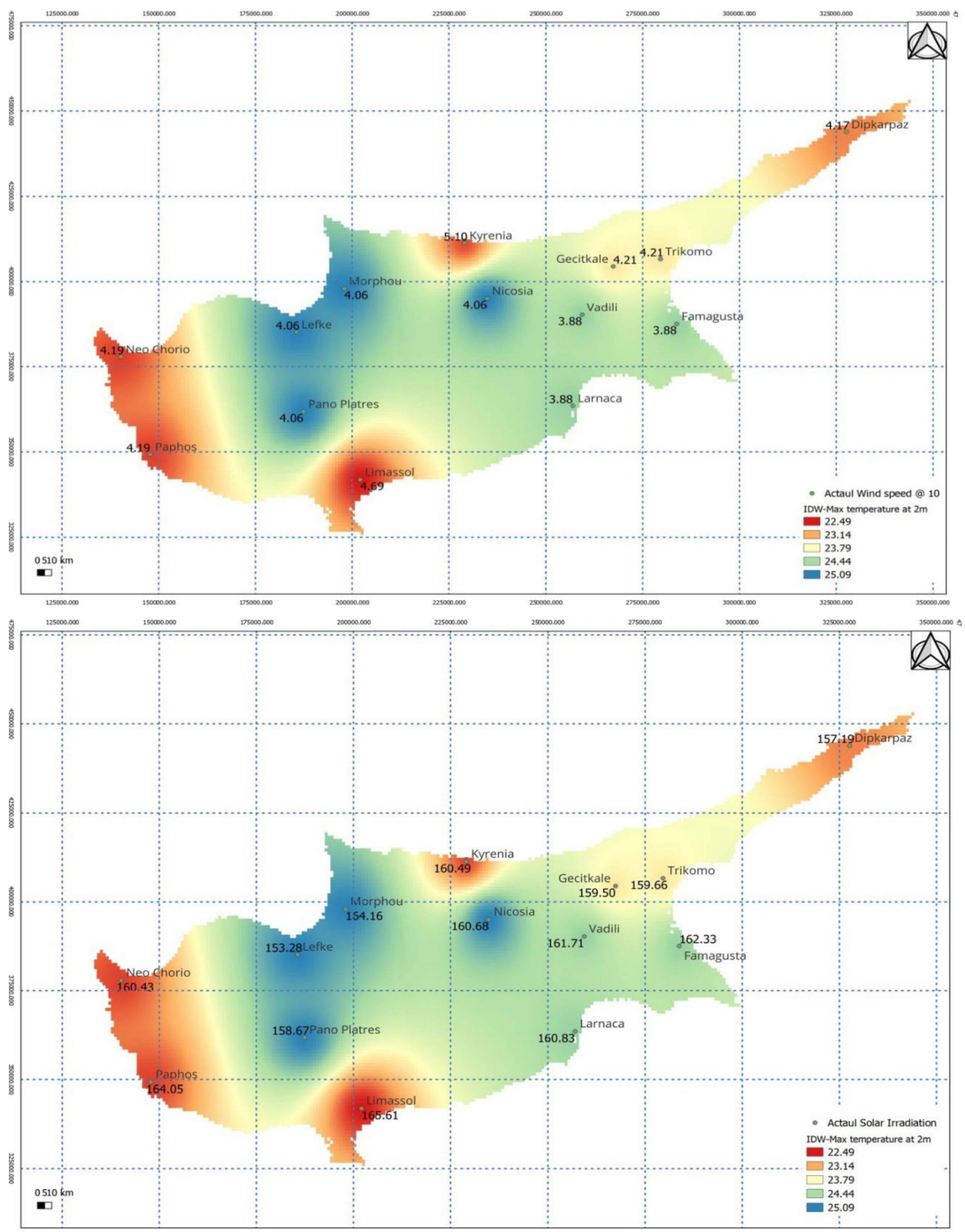


Figure 4.4

Minimum Temperature (Tmin) vs Average Wind Speed (Wa), Global Solar Irradiation

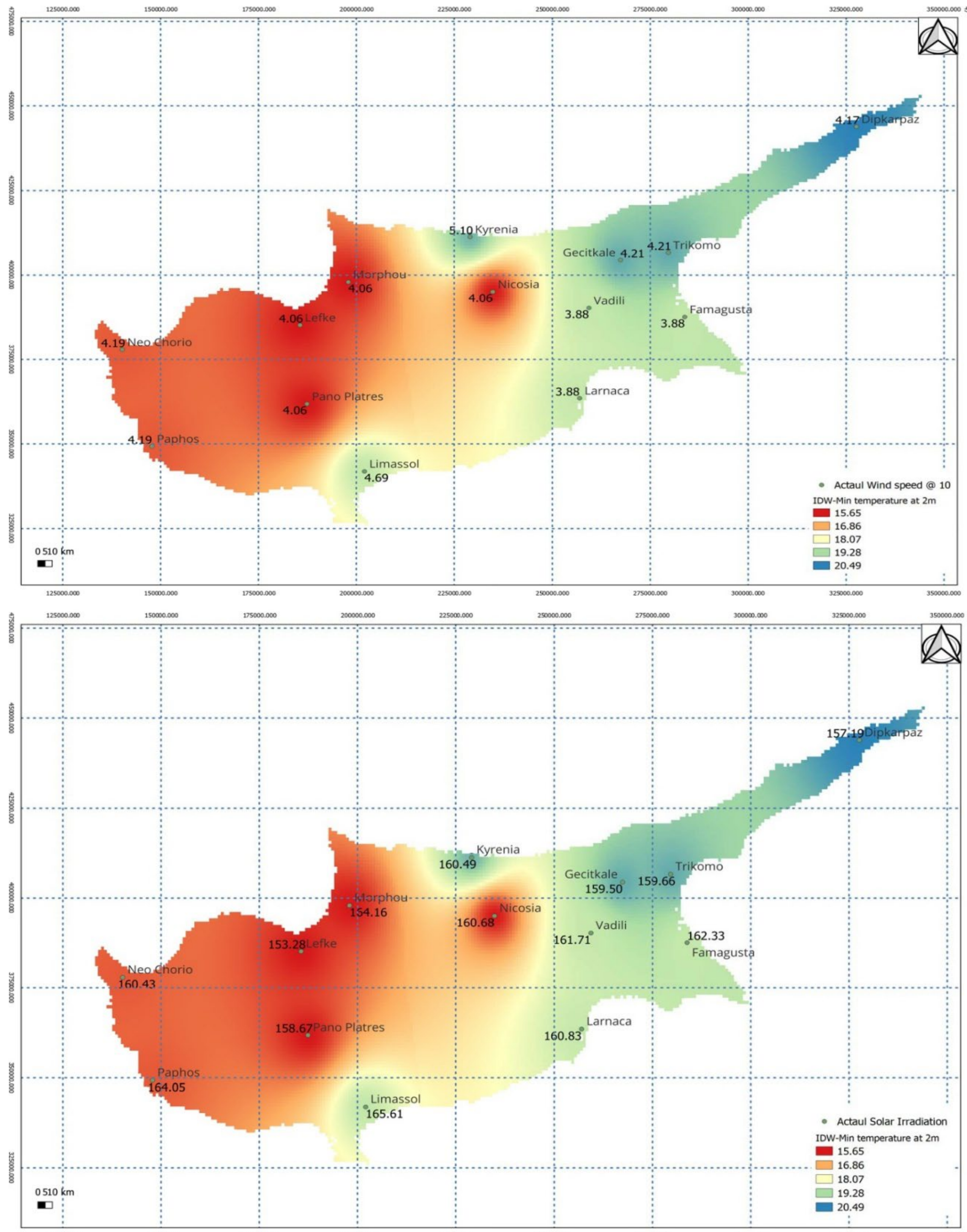


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Figure 4.5

Average Temperature (Ta) vs Average Wind Speed (Wa), Global Solar Irradiation

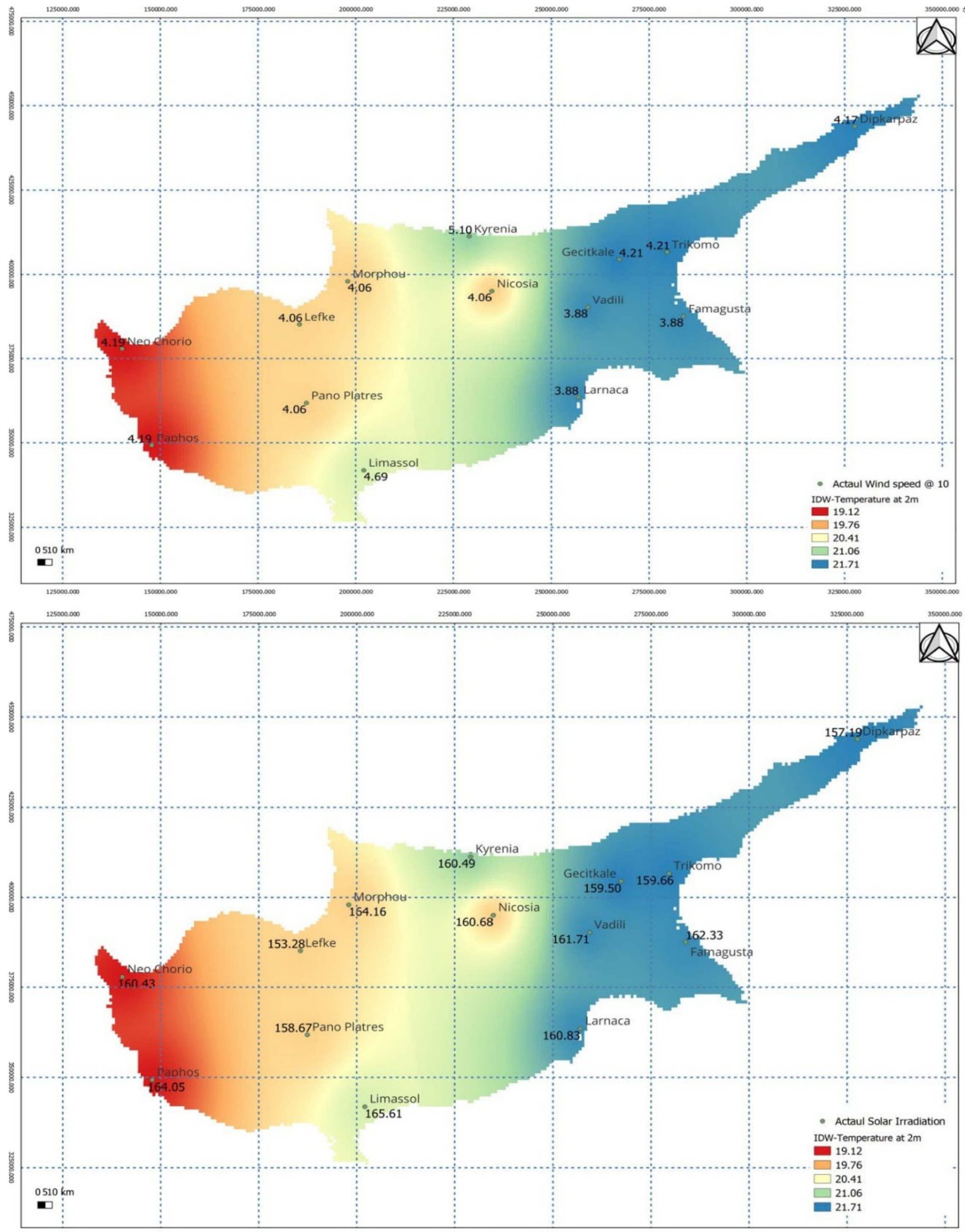


Figure 4.6

Dew Temperature (DT) vs Average Wind Speed (Wa), Global Solar Irradiation

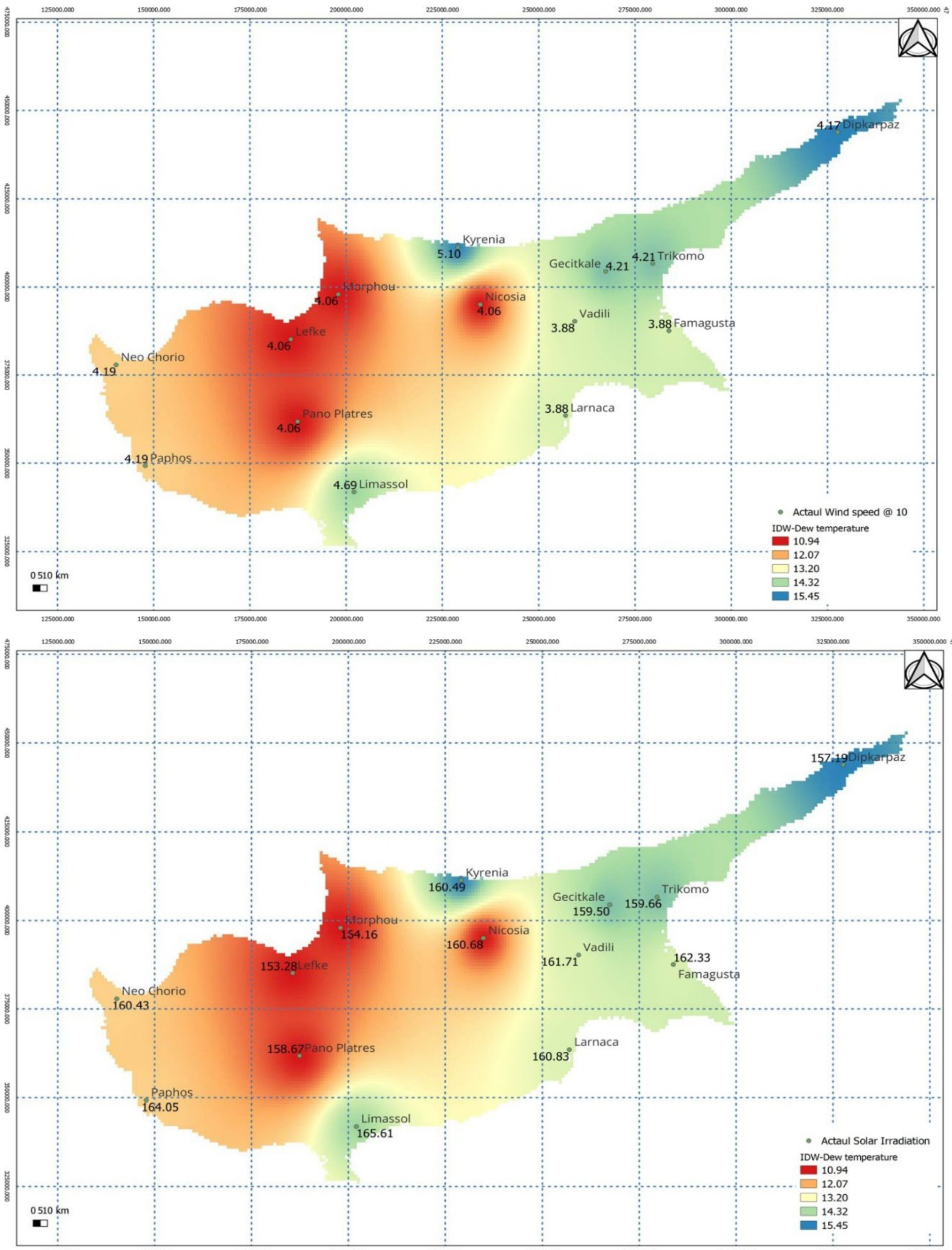
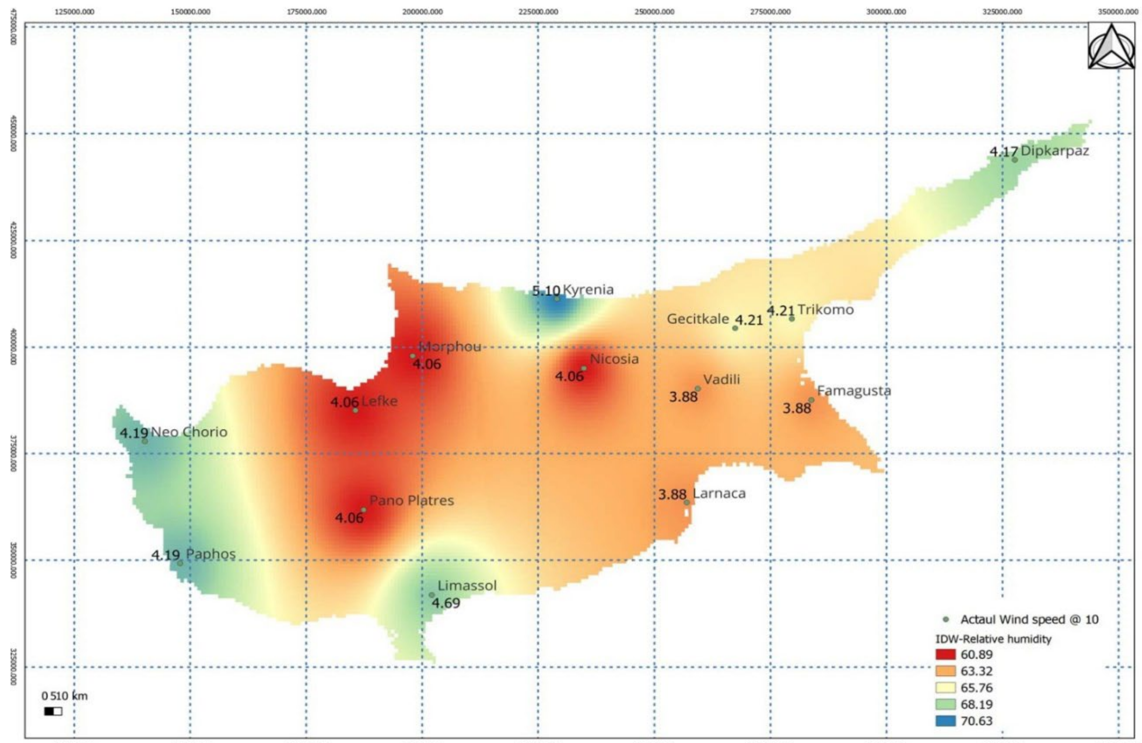


Figure 4.7

Relative Humidity (RH) vs Average Wind Speed (Wa), Global Solar Irradiation



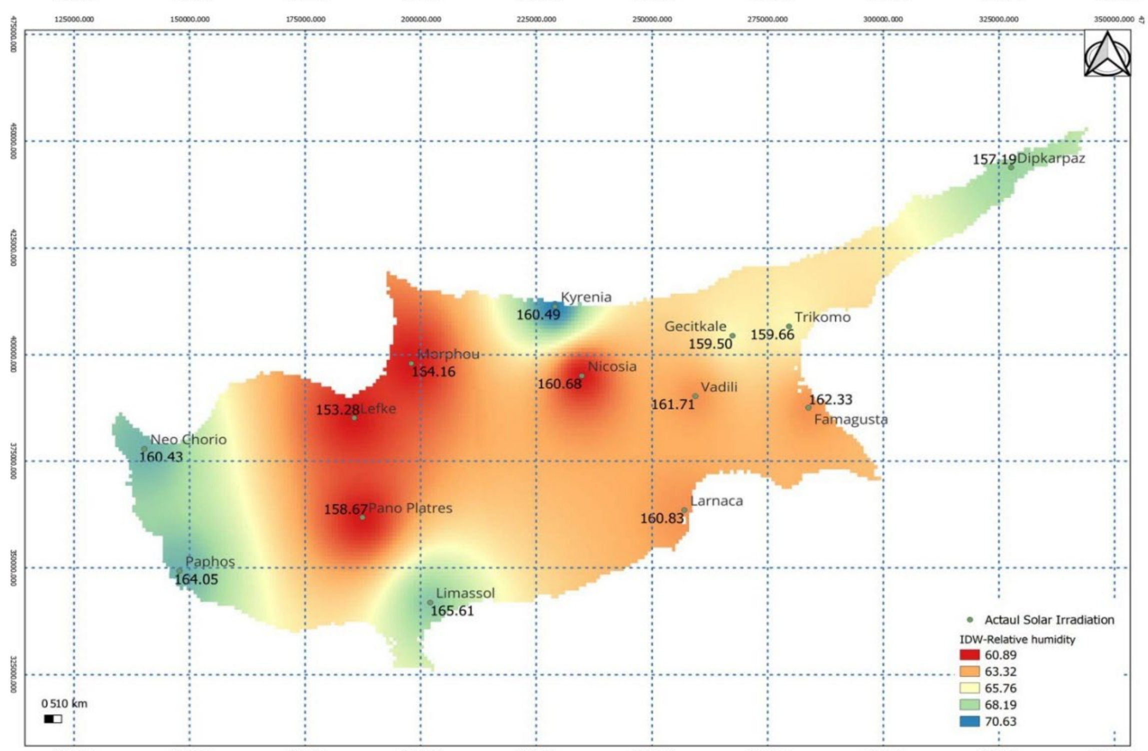


Figure 4.8

Maximum Wind Speed (Wmax), Minimum Wind Speed (Wmin) and Average Wind Speed (Wa) vs Global Solar Irradiation

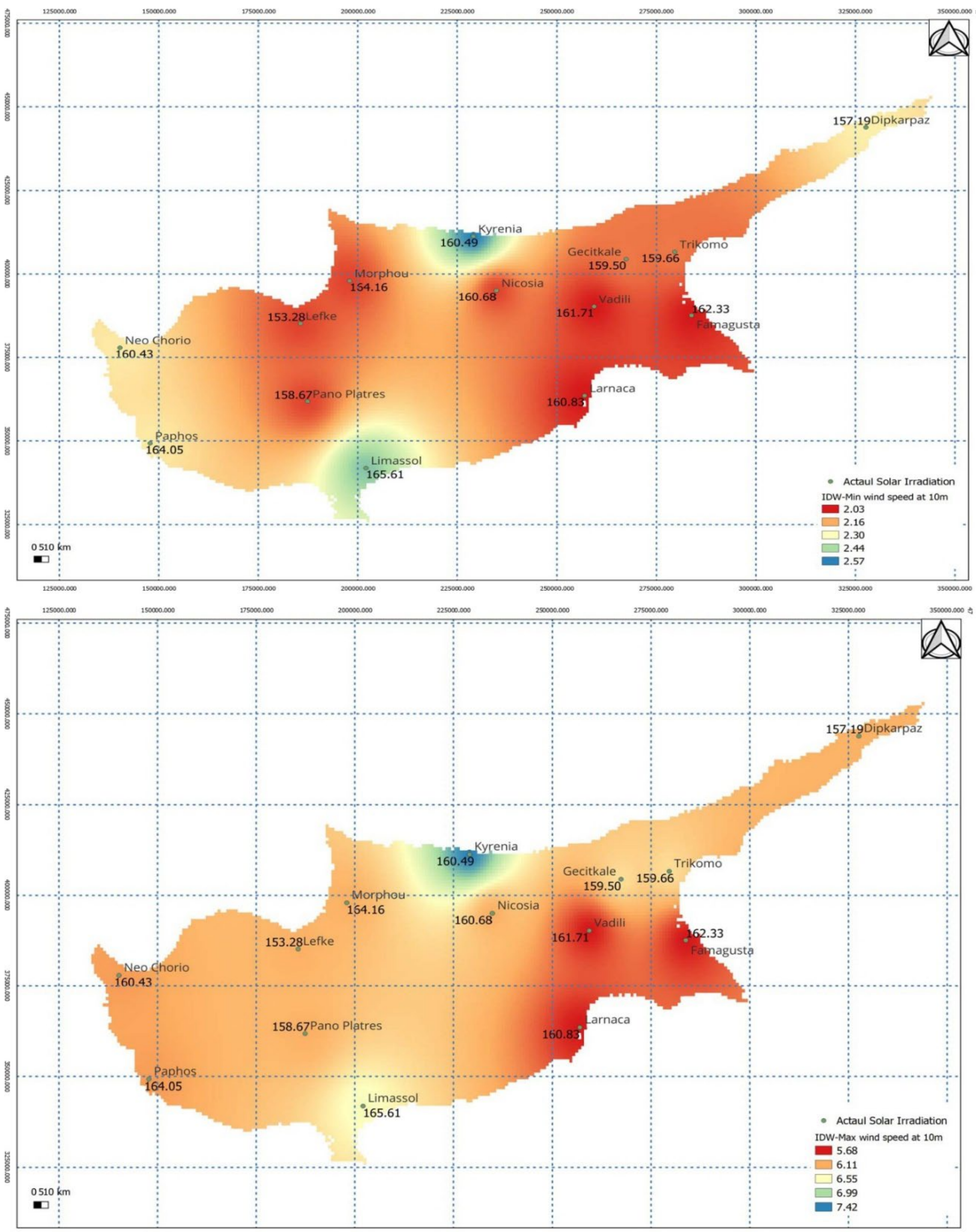


Figure 4.8 (Continued).

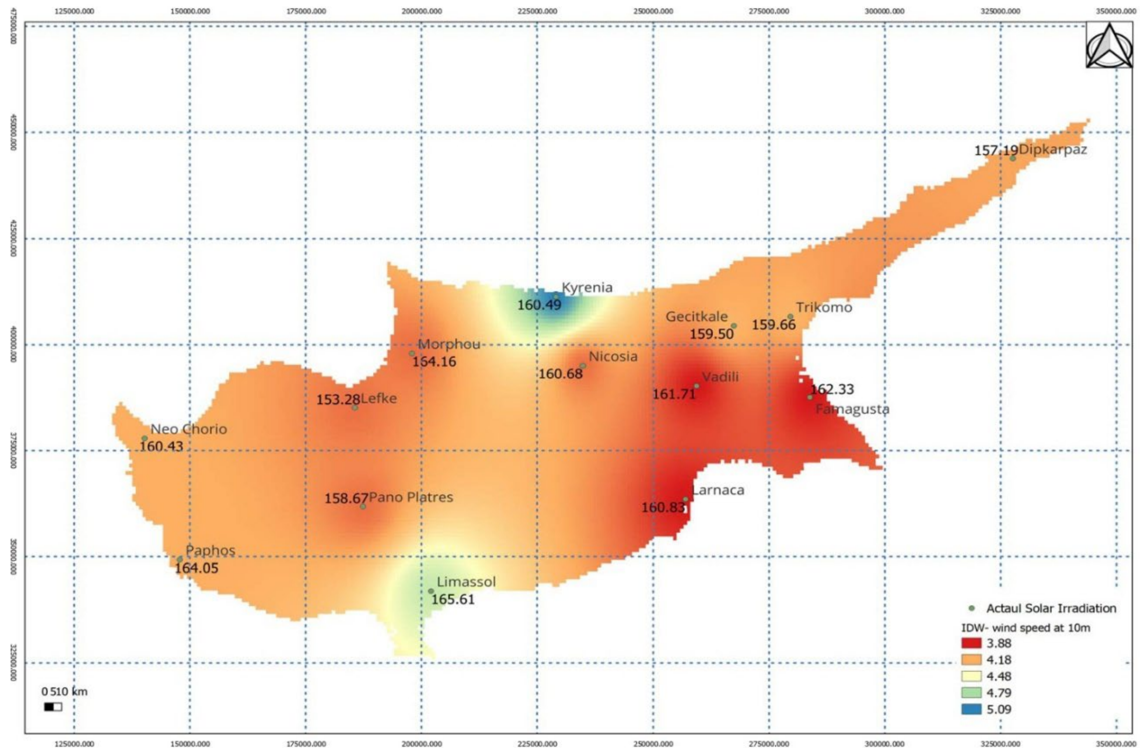


Figure 4.9

Global Horizontal Radiation (GHI) and Direct Normal Radiation (DNI) vs Average Wind Speed (Wa)

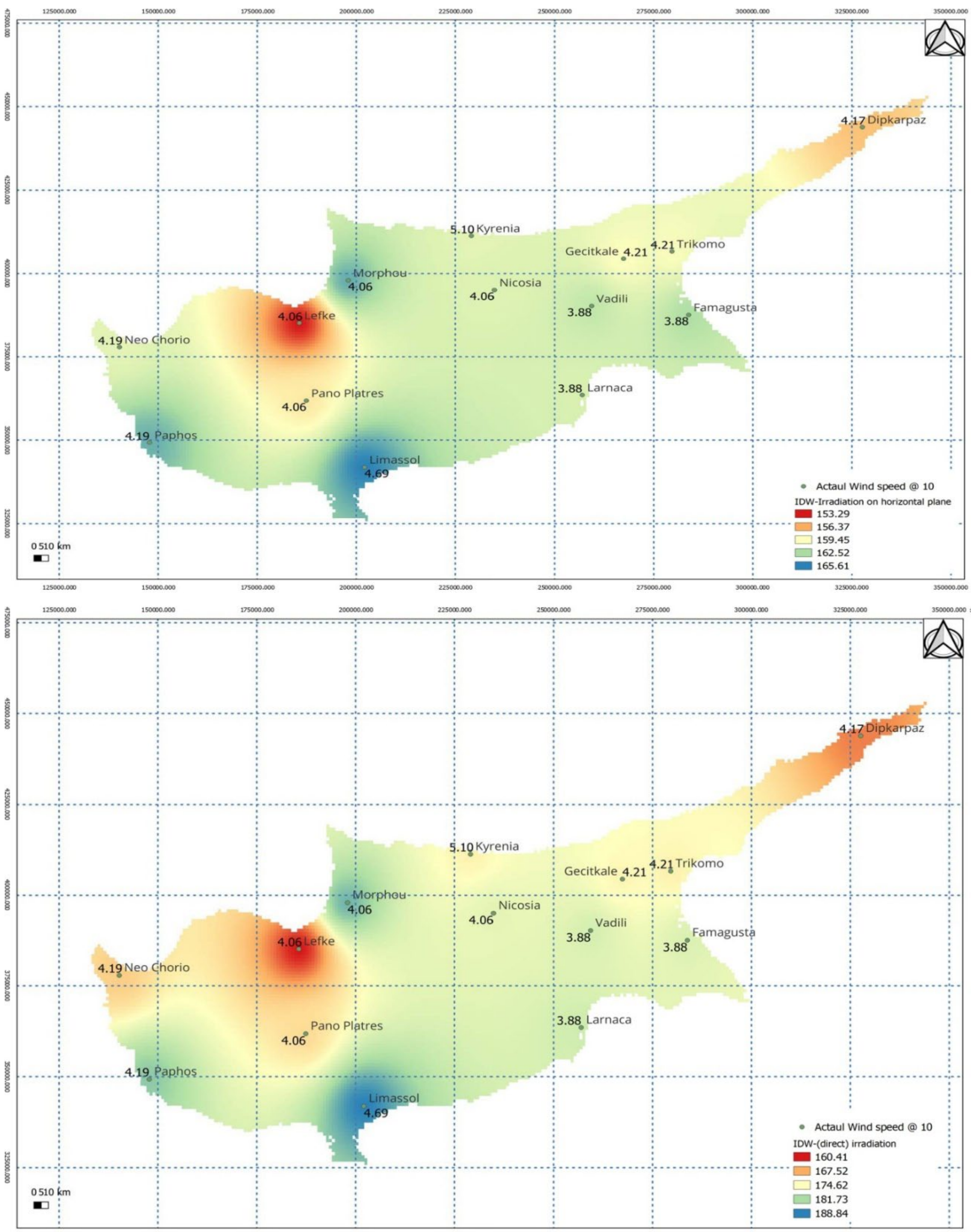


Figure 4.10

Weighted Thematic for Solar Irradiation

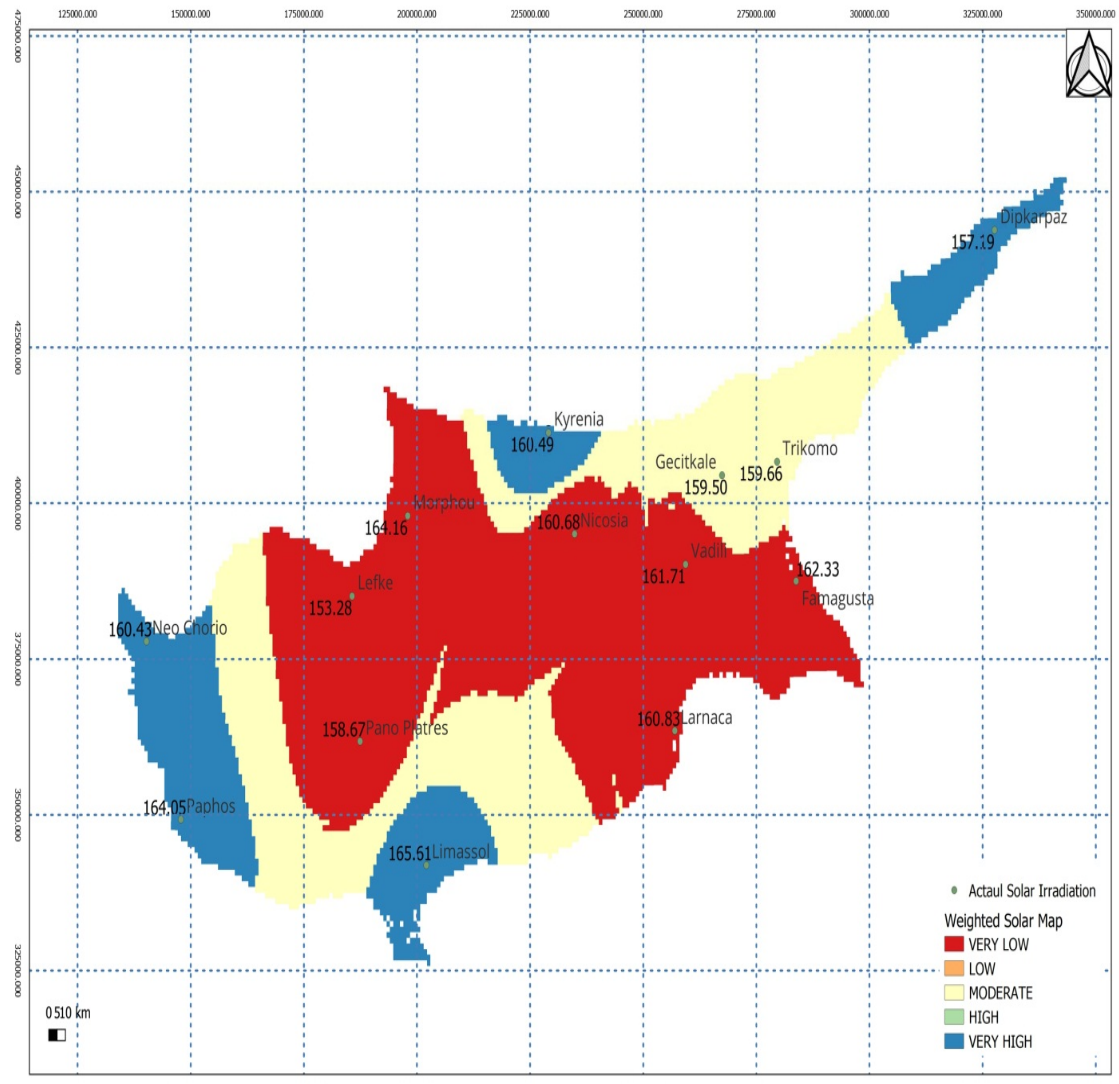


Figure 4.11

Weighted Thematic for Wind Speed

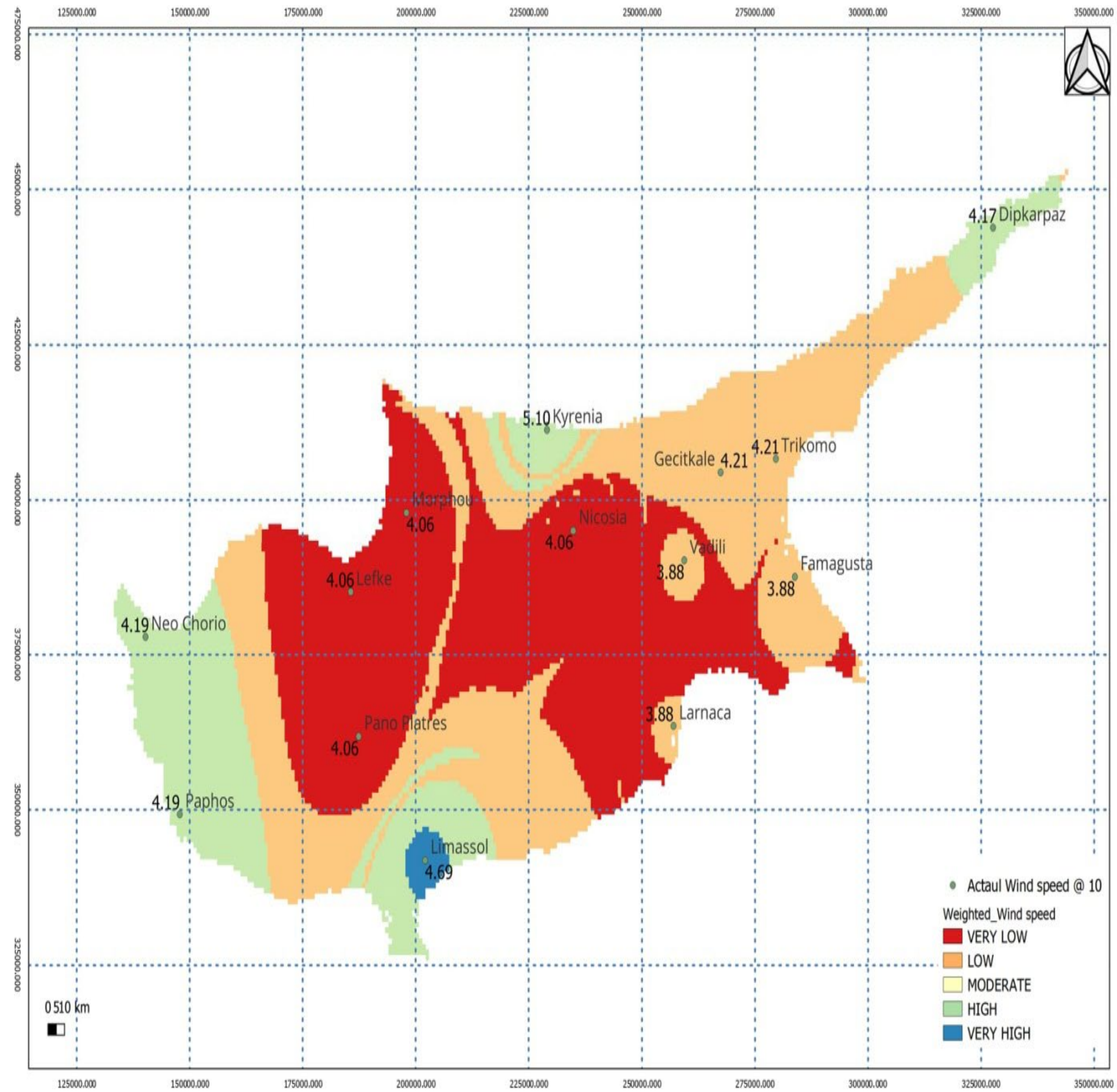


Table 3.

The Potential Area for Solar Radiation

Class. no.	Indication	Area [km^2]	Percentage [%]	Locations
1	Very low	4588.10	50%	Morphou, Lefke, Nicosia, Pano Platres, Larnaca, Famagusta, Vadili
2	moderate	3002.27	32%	Trikomo, Gecitkale
3	Very high	1660.63	18%	Paphos, Neo Chorio, Dipkarpaz, Limassol, Kyrenia
Total		9327.57	9327.57	

Table 4.

The Potential Area for Wind Speed

Class. no.	Indication	Area [km^2]	Percentage [%]	Locations
1	Very low	3,924.78	42 %	Morphou, Lefke, Nicosia, Pano Platres
2	low	3,605.34	39 %	Gecitkale, Trikomo, Famagusta, Vatili, Larnaca
3	high	1,644.31	18%	Paphos, Neo Chorio, Dipkarpaz, Kyrenia.
4	Very high	76.57	1%	Limassol
Total		9327.57	100%	

CHAPTER V

Conclusion

As previously stated, NASA average monthly weather data from NASA POWER datasets were used in this study, including Tmax, Tmin, Ta, DT, GHI, DNI, RH, Wmax. Wmin and Wa. The study's goal is to look at the spatial suitability of wind and solar farm installations based on meteorological characteristics. By assessing the wind and solar potential in 14 different locations in Cyprus. The NASA database was used as a source of meteorological information to determine a suitable area in Cyprus for placing the wind and PV systems.

The nominated ten parameters have the most substantial impact on potential area of wind speed and solar irradiation potential area based on their rate and calculated weight, taking into consideration the cross-pollination between parameters. The calculated percentages shown in table 1 and 2 were concluded by multiplied RL with FR to the overall total weight.

Ten thematic maps as illustrated were extracted and georeferenced to EPSG Projection 6312 (Cyprus Coordinate System CGRS93 / Cyprus Local Transverse Mercator). Reclassification of maps was done by utilizing a spatial analysis tool in ArcGIS software taking into consideration the calculated percentage for each thematic map.

Maximum temperature at 2m thematic map showing a lowest negative relation with solar irradiation, while showing a higher negative relation with wind speed, in Kyreina and Limassol lower maximum temperature were recorded of 22.71 22.49 respectively while they had a higher wind speed of 5.10, 4.69 respectively while solar radiation recorded 160.49, 165.61 respectively.

Minimum temperature at 2m thematic map showing a lowest relation with solar and wind speed, in Pano Platres and Nicosia lower minimum temperature values were recorded of 15.65 while they had a moderate wind speed of 2.07 while solar radiation recorded 158.67, 160.68 respectively.

Temperature at 2m thematic map showing a lowest relation with solar and wind speed, in Trikomo, Dipkarpaz, and Gecitkale higher temperature values were recorded of 14.68, 15.46, and 14.68 while they had a moderate wind speed of 6.38,6.15 and 6.38 respectively while solar radiation recorded 158.66,157.19 and 165.61 respectively.

Dew temperature thematic map showing a lowest positive relation with solar and moderate positive with wind speed, in Trikomo, Dipkarpaz, and Gecitkale higher temperature values were recorded of 21.70 while they had a moderate wind speed of 6.38,6.15 and 6.38 respectively while solar radiation recorded 158.66,157.19 and 165.61 respectively.

Relative humidity thematic map showing a lowest positive relation with solar and a high positive with wind speed, in Kyreina and Limassol higher humidity values were recorded of 70 .64 and 68.74 respectively while they had a higher wind speed of 5.10, 4.69 respectively while solar radiation recorded 160.49, 165.61 respectively.

Minimum, maximum and normal wind speed at 10m thematic maps showing a lowest negative relation with solar, in Famagusta and Larnaca lower minimum wind speed values were recorded of 2.03, maximum wind speed values were recorded of 5.68 and wind speed values were recorded of 3.88, while solar radiation recorded had a moderate values 177.64 ,178.66 respectively.

Direct irradiation and Irradiation on horizontal plane thematic maps showing a lowest relation with wind speed, in Lefke lower direct irradiation value was recorded of 153.28 and horizontal irradiation of 160.40 while wind speed recorded a moderate value of 4.06.

The illustrated thematic map showing the interaction between climate parameters and solar irradiation, for maximum temperature, relative humidity and minimum wind speed showing a weak relation with solar, while the minimum temperature, temperature, dew temperature, maximum wind, wind showing no relation. the extracted weighted map showing a higher values of potential solar radiation in limassol, Kyerina, Dipkarpaz, paphos, Neo chorio compared to actual data while famgusta, lefke, Nicosia,Vadili and Pano platers showing lower values.

The illustrated thematic maps showing the interaction between climate parameters and wind speed, for maximum temperature it showing a high negative relation with wind for example kyerina had a maximum wind speed of 5.10 km /hr and the lowest maximum temperature value while the minimum temperature and direct irradiation have weak relation, temperature and horizontal irradiation showing no relation in other hand relative humidity showing a positive high such as relation while dew temperature have a moderate positive relation for example kyerina ,and limassol had a maximum wind speed of 5.10, 4.69 km /hr respectively , and the highest values of dew temperature . the extracted weighted map showing a higher values of potential wind speed in limassol, Kyerina, Dipkarpaz, paphos compared to actual data while famgusta, lefke, Nicosia showing lower values.

The proposed study will assist planer and decision maker to establish a shared web platform of proposed strategies, mitigations, protection measures, thematic maps, and policies to tackle the supply needs considering environmental and mitigate greenhouse emissions by eliminate fossil fuels use. It can also be used to improve models for predicting climate change patterns and impacts in the future. Furthermore, understanding the pattern of wind speed and solar radiation will be important in a variety of fields, including the environment, agriculture, construction, and constructing structures.

CHAPTER VI

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Appendix A

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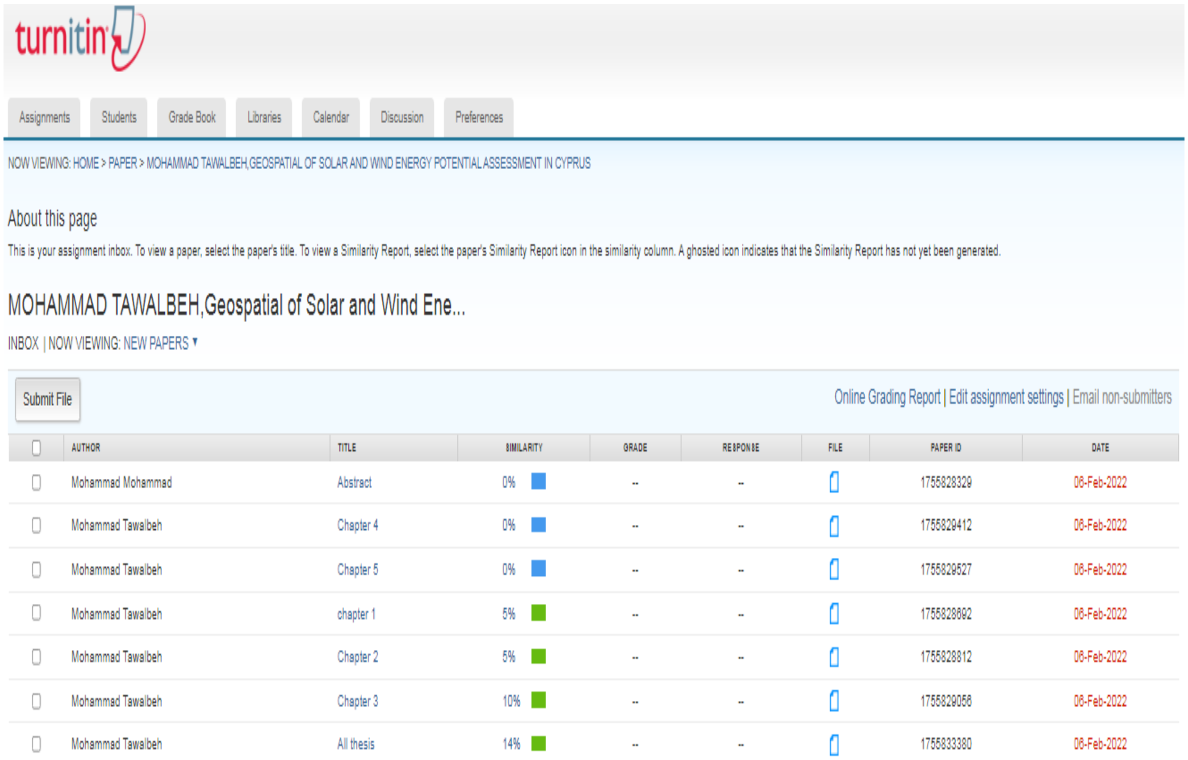

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Appendix B
Ethical Confirmation

Date: 24/1/2022

To the Institute of Graduate Studies

My name is Mohammad Ali Ahmad Tawalbeh with student number 20193957. The research project titled "**Geospatial of Solar and Wind Energy Potential Assessment in Cyprus"** has been evaluated. Since the researcher will not collect primary data from humans, animals, plants, or earth, this project does not need to go through the ethics committee.

Signatures

Title: Professor
Name: PROF. DR. HUSEYIN GOKCEKUS
Role in the Research Project: Supervisor