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Graduation Project Report II

A site selection study for Renewable Energy in Palestine – West Bank

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Dedication

To those who inspired it,

To Hadeel Al-Hashlamoun's free soul who never died,

To that extra chromosome,

To the sleepless nights,

To the bad internet and electricity,

We dedicate this work.

Acknowledgment

In the name of Allah SWT The Most Beneficent. All praises are to Allah SWT for all blesses so that we can accomplish this graduation project.

We have taken efforts in our graduation project. Nevertheless, without the kind assistance and support of many individuals, it would not have been possible. We would like to give all of them put heartfelt thanks.

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At last but not least gratitude goes to our beloved country Palestine.

Disclaimer statement

This report was written by Ahmad Omar Mohammed Shehada and Buthayna Fuad Faisal Qutaina at the Energy and Environmental Engineering Department, Faculty of Engineering, An-Najah National University. It has not been altered or corrected, other than editorial corrections, as a result of the assessment and it may contain language as well as content errors. The views expressed in it together with any outcomes and recommendations are solely those of the students. An-Najah National University accepts no responsibility or liability for the consequences of this report being used for a purpose other than the purpose for which it was commissioned.

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Nomenclature

AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
CI	Consistency Index
CR	Consistency Ratio
CSP	Concentrated Solar Power
DNI	Direct Normal Irradiance
DSS	Decision Support System
GDP	Gross Domestic Product
GEDCO	Gaza Electricity Distribution Company
GHI	Global Horizontal Irradiation
GIS	Geographical Information Systems
GPC	General Petroleum Corporation
GPP	Gaza Power Plant
GW	Giga Watt
HEPCO	Hebron Electric Power Company
IEC	Israel Electric Corporation
JDECO	Jerusalem District Electricity Company
kWh	kilo Watt Hour
LPG	Liquefied Petroleum Gas
MABAC	Multi-Attributive Border Approximation area Comparison
MCDM	Multi-Criteria Decision Making
MW	Mega Watt
MWh	Mega Watt-hour
NEDCO	Northern Electric Distribution Company
OCHA	The United Nations Office of Coordination of Humanitarian Affairs

OMSW	Olive Mill Solid Waste
PA	the Palestinian Authority
PCBS	the Palestinian Central Bureau of Statistics
PEC	Palestinian Energy and Environmental Research Center
PENRA	Palestinian Energy and Natural Resources Authority
PERC	Palestinian Energy Regulatory Council
PETL	Palestine Energy Transmission Company Ltd
PLC	Palestine Electricity Company
PSI	Palestinian Solar Initiative
PV	Photovoltaic
RE	Renewable Energy
SELCO	South Electricity Company
SWH	Solar Water Heaters
TEDCO	Tubas Electricity Distribution Company

Abstract

Renewable energy is the key term for the energy industry sector in the world recently. Palestine has good potential for multiple renewable energy applications at different locations, with acceptable climate conditions. The purpose of this study was to assess potential sites for solar photovoltaic systems, concentrated solar power systems, and wind farms in the West Bank.

The study was based on Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM). Various datasets from Geomolg, Global Solar Atlas, Global Wind Atlas, and Palestine Energy Transmission Company Ltd (PETL) have been used for the analysis.

Firstly, the criteria for each application were identified and weighted according to the Analytical Hierarchy Process (AHP). Then, different data were excluded from the study area as they are unsuitable locations**.** The most critical layers for photoelectric systems, concentrated solar systems, and wind turbines were the proximity to the electrical connection points, the land's slope, and the average annual wind speed, respectively.

Finally, all the layers resulted from steps one and two were multiplied together to produce the final suitability map for each application in the study area.

The results of the study depend on two scenarios, the first scenario if the area C is considered in the study area, the areas classified as highly suitable for PV, CSP, and wind turbines were 14.27,13.63 and 7.56 km^2 respectively. The excluded areas accounted for 67% of the study area for PV and CSP systems, and 42% for Wind systems.

The Second scenario is excluding area C, the highly suitable areas were 2.47, 2.81, and 4.1 km^2, respectively, accounting to around 93% of the study area were excluded for PV and CSP systems, and 81% for Wind systems. each application had different suitable locations scattered across the West Bank, but only Hebron and Jenin have high suitability locations for the three applications located in areas A and B.

Using only 30% of the suitable lands for PV or CSP in each governorate will cover its total energy purchases per year, which is a promising percentage since the numbers are related to high and moderate suitable lands and so they have the highest ranks in the scale.

the top-ranked locations according to our scale are a piece of land in Tulkarem, Ramin for PV system with a total annual production of 47.87 GWh, in Hebron, Al-Samu' for CSP system with a total production of 26.92 GWh per year, and finally in Nablus, Aqarba for Wind systems with a total annual production of 0.00039 GWh/m^2.

Introduction

Over 5 years of studying Energy, we learned that energy is described in various ways, even though we can't see it most of the time, but it is all there, everything is using it. Energy plays a main role in everyone's life, and it's a driving force to communities to improve the community economically and socially, people always tend to improve the quality of their lives and the standards of living by using different forms of energy[1,2].

During the last centuries, the world has depended on conventional sources of energy, because of their vast availability and the low cost of mining and extraction[1], but the extensive overuse of fossil fuels has resulted in severe impacts on the climate and the ecological system[1,3], tremendous amounts of harmful gases were released like CO_2, SO_2, NO_x, CO and other, which caused negative impacts on health, environment, and climate[1]. Global and international efforts were accelerated during the last years to reduce the harmful effects of these gases[4].

The demand for energy increase with the population and industry growth, which is increasing with time[3], and with limited reserves of fossil fuels[2], increasing in prices due to depletion rates and conflicts[1], the world is heading towards Renewable Energy (RE) sources.

Having adequate energy supply secures the country's political and economic stability will enhance life quality [1] which is the goal that nations are seeking to achieve to gain the trust of their citizens.

Renewable energies showed immunes growth in the last couple of years, as the reliance on renewable energies is related to effective approaches to sustainable developments, with its high potential of being cost-effective, can serve the rural areas, cause less harm to the environment comparing to conventional sources, and be specifically designed to match the desired local communities.

Palestine is distinguished by promising capabilities of solar, wind and biomass resources, numbers demonstrate better exploitation potential than other areas on the planet, such a Madrid-Spain, and Sydney-Australia[1].

Despite the unpleasant circumstances it is currently undergoing, Palestine is trying to improve the quality of life of its inhabitants, and that cannot be done without having secure, reliable, and resilient energy. In terms of its energy sector, Palestine seems to be in a volatile and critical situation due to its semi-complete dependence on imported energy, nearly all of which comes from Israel for political reasons and Palestine's undeveloped domestic resources[5].

Geared towards having secure energy, the Palestinian Authority (PA) intends to enhance the sector by setting future goals which include investments in Renewable Energy (RE). For the sake of making the achievement of these goals easier and simpler, this study was conducted.

Palestine is a developing occupied country, divided into two geographic areas: West Bank (including East Jerusalem) and Gaza Strip. According to the Palestinian Central Bureau of Statistics (PCBS), the population of Palestine is 4,976,684 inhabitants on an area of 6,025 km^2, being the population density 794 people/km^2, distributed as follows: West Bank 509 people/km^2, and Gaza Strip 5204 people/km^2, one of the highest population densities in the world.

West Bank and Gaza Strip are geographically disconnected, with a distance of 75 km from Gaza to the nearest West Bank city of Hebron. administrative divisions had been made by Oslo II in 1995, that divided West Bank into three administrative divisions: Areas A, B, and C as shown in Figure 1.

Area A is only 18% of the total area, and it indicates that full civil and security control is under the Palestinian Authority, and represents the major cities. Area B is 21% of the total land, it has civil Palestinian control and joint Palestinian-Israeli security control, which means that any Palestinian police action in is B needs prior approval from the Israeli security forces, and it mostly includes the Palestinian villages. Finally, area C is under the sole sovereignty of Israel, security, planning, and construction and represents 60% of the total area. The United Nations Office of Coordination of Humanitarian Affairs (OCHA) has noted that nearly 30% of Area C is prohibited and only 1% has been planned for Palestinian development by the Israeli Civil Administration. In a 2013 World Bank survey, Palestinians would have an estimated 35% of GDP if they had been able to enter and develop Area C without the present limitations on area [4].

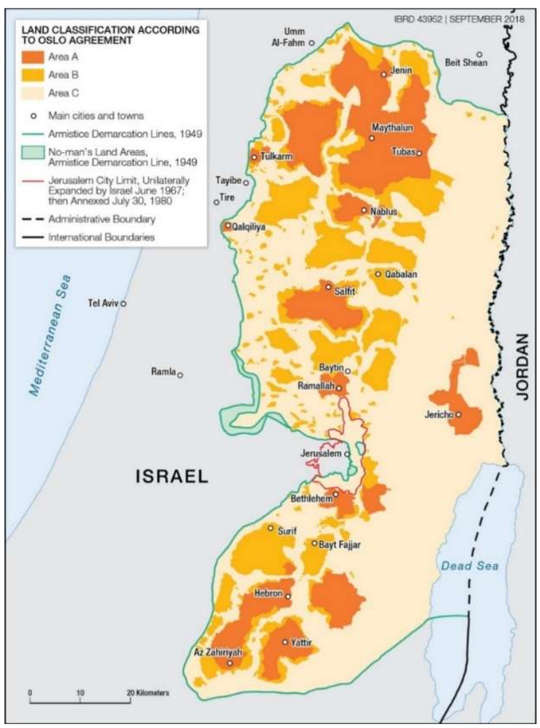


Figure 1: Land Classification According to the Oslo Agreement

With a very complex energy sector which is among several other issues that concern the Palestinian People's social, political, and economic situations[6]. One of the main characteristics of the Palestinian situation is the unstable political conditions with direct and indirect consequences for the energy sector and the local economy[2], adding to that the restrictions and lack of infrastructure, scarcity of conventional energy resources has created unrealistic price control, energy shortage, and coming energy crisis[7].

According to what is mentioned before, Palestine depends on Israel to import its need of petroleum products, and around 92% of electrical energy from the Israeli Electric Corporation, a total energy bill of more than 385 M€ per year[7]. It was found that the costs of energy in Palestine are considered the most expensive in the region[2]. The only power generation in Palestine exists in Gaza; Gaza Power Plant (GPP) using fossil fuels, which used to generate about 100 MW out of 242 MW of its needs, but due to repeated bombarding attack on the power station by Israel and fully controlling on the fuel supply the produced quantity has decreased, meanwhile 13% of West Bank population either lack the reliable power supply or have no power supply at all.

According to the PCBS 94% of the electricity imported from Israel Electric Corporation (IEC), 0.6% from Egypt, 1.4% from Jordan, and 4% from Palestine Electricity Company (PLC) to fulfill the demand with the increasing growth in population and the annual consumption is expected to reach 8,400 GW/hour by 2020 assuming that 6% of annual growth rate[8].

As it is mentioned before, the IEC supplies electricity to the Palestinians loads next to its overhead distribution lines[5], which is over 250 low and medium-voltage connection points with Israel in the West Bank as shown in Figure 2, and 1 connection point with Jordan, which provide 99% and 1% of total energy supply to the West Bank, respectively. Most of the connection points are fully saturated, which causes electricity cuts during winter and summer peaks, as the demand grows and the capacity of the lines and supplying is fixed[9].

Figure 2: Existing Transmission Infrastructure in the West Bank and Gaza

Regarding the discussed situation and because of the high growth in population The Palestinian Authority is considering Renewable Energy (RE) resources to mitigate the energy crisis which will increase the contribution to sustainable development. The reliance on domestic renewables can maximum reaches 19% in the production is limited to areas A&B and up to 30% with area C[9].

To indicate the reliability of the energy source, three main factors are considered; availability, affordability, and sustainability of the energy source supply. Palestine is distinguished by its promising potential of solar, wind, and biomass resources, most of Palestine receives solar radiation about 3000 hours annually, with an average solar radiation values range from 5.4 kWh/m^2.day to 6.0 kWh/m^2.day[1]. So RE can play a key role in the transition to the sustainable development sector in the long term[2].

Solar energy seems to be the most viable and reasonable choice for RE as most of Palestine receives plenty of sunrays in terms of duration and radiation intensity. Biomass has potential also through gasification, combustion, and other methods. Regarding wind energy, although it has a good potential in Palestine, it has its drawbacks since Israel rejected Al-Ahli hospital in Hebron project, claiming that the wind turbine interferes with Israeli military air paths [1].

In 2015 the Palestinian Authority declared a decision related to RE and energy efficiency, which basically amid to encourage the utilizing and developing RE resources, to achieve a secure supply of energy [10]. To achieve these goals, the Palestinian Energy and Natural Resources Authority (PENRA) has prepared a strategic plan for RE with clear goals to 2020, by gradually getting 240 GWh at least, which is equal to 10% of the total local power production. With an estimated of 130 MW of RE to be installed by 2020 divided into 7 applications; photovoltaic (PV) solar power ground station, PV solar roof systems following to the Palestinian Solar Initiative (PSI), Concentrated Solar Power systems (CSP), Biogas from dumps, biogas from animal wastes, small wind power stations, wind farms with capacities of 25, 20, 20, 18, 3, 4, 40 MW respectively, and a full capacity of 130 MW, which will be implemented at two stages over the periods of 2012-2015 and 2016-2020 [11].

This study aims to investigate, assess and highlight the Renewable Energy Potential in the West Bank by preparing a database for four applications: Solar Photovoltaic (PV) Mounted system, Concentrated Solar Thermal Power (CSP), Wind Farms, and Bioenergy. This will be set by applying a specific criterion for each application relying on previous studies in the same area, taking into consideration the unique state of the West Bank. Thereafter, the data will be shaped into maps using ArcGIS 10.7.1 illustrating the land suitability for each application and estimating the productivity of the application depending on the data, and using Excel to analyze the data into understandable numbers and percentages.

The resulting maps will yield significant advantages for the benefit of the Palestinian Energy and Natural Resources Authority (PENRA) and anyone interested to invest in RE, as it can be considered a decision support system and a pre-feasibility study, as we hypothesis.

As the market of RE in Palestine is growing and with little experience in the field, this study is important to conduct to fill the gap.

The report starts with a brief introduction to the energy situation in the world and Palestine in particular, following that description for the energy sector framework in Palestine, then talking about the different renewable energy resources in Palestine. The study's importance and the working process were emphasized by previous literature in the same field. The description of the used method and background of the process was mentioned in the Theory section. Data collection, preparations, and finalizations for each application were mentioned in the Method and Data section. Lastly, the results' discussions and the conclusion has been discussed and mentioned in the last section in this report.

Energy Sector Framework

To understand the situation of the energy sector in Palestine, we have to know the institutional framework of the energy sector, which will be described below:

Palestinian Energy and Natural Resources Authority (PENRA): which is the policymaker in the electricity sector in Palestine, some of its responsibility is summarized in as follows:

- Supervising the sector including planning, elaboration, and implementation of its strategy and policies, all the laws and legislation related to the electricity, and RE.
- Establishing and adopting mandatory specifications, standards, and technical instructions related to renewable energy systems and energy rationalization systems.
- Setting electrical tariffs, incentive terms, participation fees, and the costs of connection costs, extensions, insurance, and other services related to renewable energy projects, and submitting them for approval.

Palestinian Energy Regulatory Council (PERC): it is the electricity sector regulator. It was established by the Electricity Law, started to operate in 2011. The law stipulates that its objectives are:

- Monitoring the electricity sector, the generation, the transmission, the distribution, and usage, to ensure its efficiency, availability, and consistency to achieve the most appropriate value of various uses of electricity at the most reasonable costs and protect the environment and the interest of the consumers.
- Encouraging competition and reducing monopoly practices in the electricity generation and distribution market.

General Petroleum Corporation (GPC): work at the Ministry of Finance a Directorate. It is the only official governmental entity operating in the hydrocarbon sector. Its mandate to:

- Import petroleum products.
- Manage and monitor the fuel industry downstream (liquid and liquefied petroleum gas-LPG).
- Purchase petroleum products from Israel and distributing them through the Palestinian distribution chain.
- Giving license to the station of petroleum liquid fuel and LPG distribution stations.

Palestine Energy Transmission Company Ltd. (PETL): PETL was established in 2013. It is a public governmental company. The role of the PETL is described in the Law as the following:

- Regulating the technical and financial relationship between generation companies, distribution companies, and large consumers and transmit the power between them.
- Purchase electric power from various sources.
- Own, operate, maintain, and develop a high voltage national transmission system and the substations.
- Meet the growing needs through different sources.

Figure 3 below shows the service area of PETL.

Figure 3: Location and Service Area of New Palestinian Electricity Transmission Company High-Voltage Substation

Palestinian Energy and Environmental Research Center (PEC): resides under the responsibility of the PENRA and is funded by it. The mandate of PEC includes:

- The enhancement of the application of RE and EE.
- Acts as the technical arm of PENRA for the implementation of RE and EE projects.

According to the 1997 issue "letters of Sector Policy"[12], the PA has established the electricity distribution companies as shown in

Figure 4:

- **Jerusalem District Electricity Company (JDECO)**: Responsible for power distribution at Jerusalem, Ramallah, Al-Bireh, Bethlehem, and Jericho. 72% of JDECO is owned by the Private Sector, while 28% is owned by some of the local authorities situated within the Concession Area.
- **Northern Electric Distribution Company (NEDCO)**: Responsible for power distribution in the northern part of the West Bank.

- **Hebron Electric Power Company (HEPCO)**: Responsible for power distribution in the city of Hebron and it is wholly owned by Hebron Municipality.
- **South Electricity Company (SELCO)**: Responsible for power distribution at different Governorates in Hebron except for Hebron City; it is solely owned by the Municipalities and Rural Councils situated within the Concession Area.
- **Tubas Electricity Distribution Company (TEDCO)**: Responsible for Tubas region.
- **Gaza Electricity Distribution Company (GEDCO)**: Responsible for power distribution to the whole Strip and it is owned equally by the PA and the Gaza Strip Municipalities.
- **Municipalities and village councils**: Around 150 municipalities and village councils in the northern and southern regions of West Palestinian distribution companies Bank have not transferred their electricity services to utilities and are still providing electricity to the customers on their area.

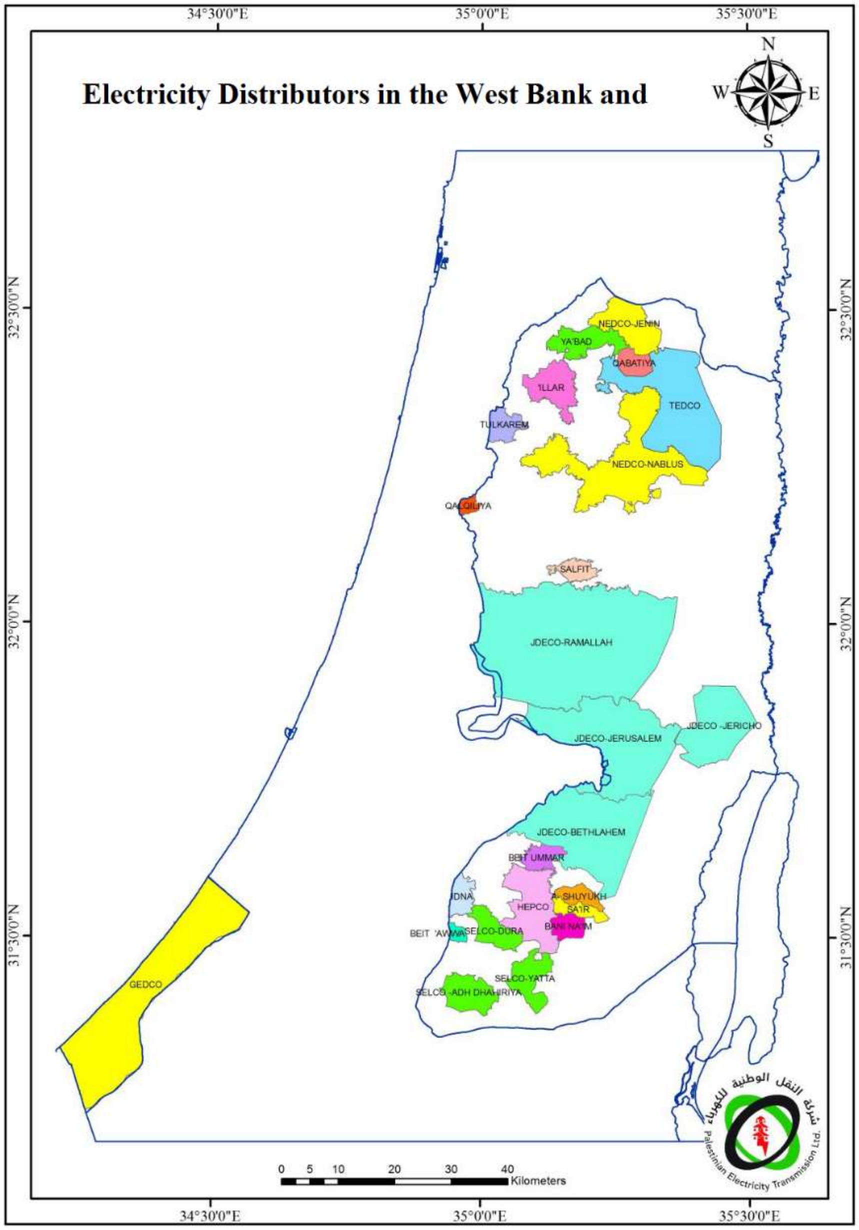


Figure 4: Electricity Distribution Companies in West Bank and Gaza

Renewable Energy Resources in Palestine

As mentioned before, Palestine depends on imported energy which makes RE is the only truly independent form of power supply and does not rely on imported electricity or fuel, which will give flexibility to the system power supply.

Solar Energy

The West Bank is located in an ideal location for solar investments and developments. Having more than 3000 sunshine hours over the year with its meteorological conditions and landscape suit the conditions needed to install PV systems.

The average Global Horizontal Irradiation (GHI) values are high, around 5.2 kWh/m^2.day or over 1,900 kWh/m^2 annually, many areas surpassing 2,000 kWh/m^2, which is over twice as high as in Germany, the world leader; similar to many solar power world leaders (e.g. Spain, USA)[13].

Palestine can be divided into three solar zones according to Global Solar Irradiance (GHI) [1]:

- High Irradiance zones: which is areas have more than 2300 kWh/m^2/ year, they are colored in brown in Figure 5 from SolarGIS, and mainly are the hilly regions in Jerusalem, Ramallah, Bethlehem, and Hebron. In addition to the coastal areas of Gaza.
- Medium Irradiance zones: those areas have GHI values from 2200 – 2300 kWh/m^2/year, they are colored in orange in Figure 5, and mainly are the Jordan Valley, Jericho, Tubas, and other areas in the middle north of West Bank.
- Low Irradiance zones: those areas have GHI values less than 2200 kWh/m^2/year, they are colored in light yellow in Figure 5, and mainly are Jenin, Qalqilya, Tulkarm, and other areas west of the West Bank.

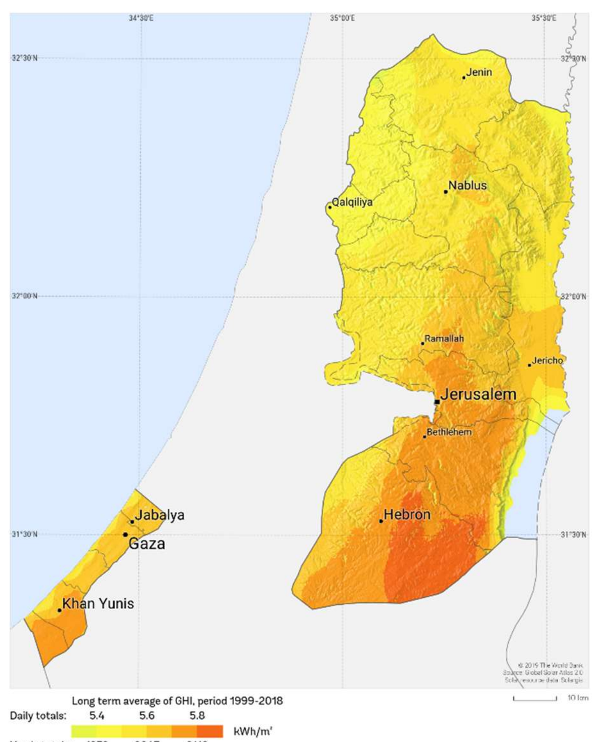


Figure 5: Long term (1999-2018) average of GHI

The numbers show that Photovoltaic electrification in isolated rural villages and communities in Palestine is considered feasible and effective compared with other alternatives like using diesel generators and extending the high-voltage electrical grid [2,7].

Going back to PENRA's strategic plan, the numbers show that reliance on solar energy accounts for 50% of total capacity, this policy to expand and encourage the use of clean solar energy technologies to generate electricity [11].

The energy sector has faced two main challenges; the inability to secure a power purchase agreement with a bankable off-taker, and the lack of available transmission infrastructure for power evacuation. Fixing these hurdles could go well beyond existing policy goals and the potential for renewable energy production across the West Bank and Gaza. Based on a survey of the available potential, the existing renewable energy target could be increased by more than 30 times, for a total of 4,246 MW [9].

The usage of solar energy in Palestine exists since a long time ago, by using Solar Water Heaters (SWH), around 58% of Palestinians homes use SWH, and it is estimated that a 5% increase of using SWH, will save 30,000 MWh, therefore, save 6 million dollars, and reduce 9000 ton of CO_2 emissions [14]. Adding to that, there are many existing PV projects in the West Bank with different capacities from 5 kW to 1.5 MW.

Wind Energy

Electricity generated from wind does not require an input fuel, and hence removes the risk of electricity interruptions due to political interference or unaffordable fuel price rises, also with no carbon emissions during the generation process[7].

According to the available data and topographical features of Palestine, wind investments can be only feasible in mountains with heights about 1000 m above sea level. This takes us to Hebron, Ramallah, and Nablus mountains as it is shown in Figure 6 where the speed reaches 5 m/s which is suitable to operate wind turbines with a potential of 600 kWh/m^2 [2,7].

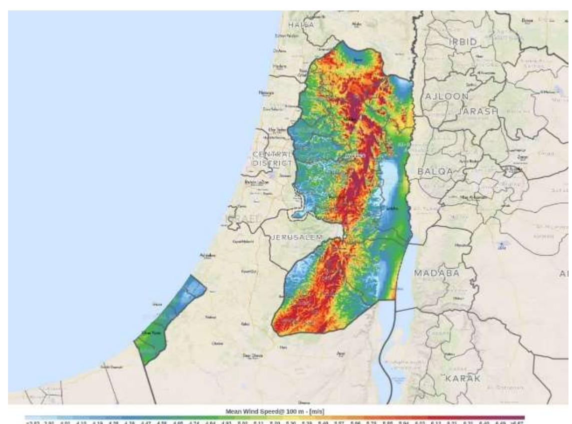


Figure 6: Mean Wind Speed in West Bank and Gaza

Bioenergy

In contract with solar and wind bioenergy plants are dispatchable and do not face land restrictions but are limited in terms of scalability [9]. There is a huge amount of solid waste produced by municipalities, causing them to spend a large amount of money to bury them in waste dumps, adding to that the huge quantities of animal manure from goats, chickens, and cows.

The Agricultural sector is a pillar of the Palestinian economy, and it is one of the many olive oil-producing countries in the region, the interest recently is directed to utilize the olive mill solid waste (OMSW) to be used as a clean source of energy. The olive harvest season is all year round and so the OMSW as a raw material is also constantly available. The annual average amount of OMSW is around 76,000 tons [7].

The organic waste produced in Palestine per year is Charcoal and Wood 27,917 tons, Organic municipal solid waste 73,257,415 tons, Olive peat 476,921 tons, Oils and lubricants 1,083 tons, Animal manure 628,660 tons, leading to a total of 74,391,996 ton. The amount of energy produced depends on the type of bioenergy used. One cow can produce enough compost in one day to generate 3 kWh of electricity [15].

Nearly half of West Bank household waste is in 156 dumps and the other half in o streets or burned, the available solid waste can produce 2.1% of the energy consumed in 2013 [15].

Numbers show that 400 tons of waste per day from the cupflower dump can produce 4,000 to 5,000 kWh of electricity, enough to supply electricity for 800 to 1,000 homes in Jenin [15].

Literature Review

Selecting the potential sites for renewable energy applications is one of the major technical challenges since the selection of the site is related to future demand, environmental impacts at local levels [16].

It is not a fully inclusive decision to take into account only the viability of the resource since several other important factors affect the site selection decision. Therefore, we need to evaluate the suitability of the sites based on environmental, technical, social, and economic factors [17].

With all of these spatially dependent factors, it seems evident to adopt a multi-criteria decision making (MCDM) method. MCDM method is a vital tool for site selection as it gives adequate solutions. The evaluation of the method is by comparing different factors according to their characteristics properties to select to a suitable location for RE application. Many studies have conducted this method in RE site selection [18] [19].

For this research, the MCDM methods were analyzed using geographical information systems (GIS). Recently, GIS has emerged as a decision support system (DSS) to help with spatial planning and management [16] as it combines unrelated data in a meaningful manner. GIS enables the organization, storage manipulation, analysis, and modeling of a large amount of data from the real world that are linked to a spatial reference shaped grid [18].

Literature has shown successful attempts to use GIS in wind site selection and various efforts have been made to combine GIS with different multi-criteria decision-making applications. For example, Al-Garni and Awasthi [20] have evaluated the most suitable location for utility-scale solar PV projects for Saudi Arabia using GIS and a MCDM technique. The model took into account different variables, like economic and technical factors, to ensure maximum efficiency while reducing project expenses.

Gigovic et al.[21] have developed a model for the identification of locations for the installation of wind farms based on combining applications of GIS and Multi-MCDA using the multi-criteria technique of Decision Making Trial and Evaluation Laboratory (DEMATEL), the Analytic Network Process (ANP), and Multi-Attributive Border Approximation area Comparison (MABAC) [19].

Jangid J et al. conducted a study for India that focused on combining geographic information systems (GIS) and spatial multi-criteria decision analysis for selecting the appropriate locations for wind farm projects. The study used wind speed data over a 20 years interval from 1991 to 2010 collected from different stations to assess the potential wind sites. The study divided the wind potential zones into four classifications as high, moderate, low, and not suitable zones [16].

Van Haaren R. and Fthenakis V performed a method for site selection for wind turbine farms in New York State according to a spatial cost-revenue optimization. They used ERSI ArcGIS Desktop 9.3.1 software to build an algorithm in three stages, starting with excluding the infeasible sites based on geological constraints in the first stage, then they identified the best feasible sites for the application based on the predicted net present value based on four main cost and revenue categories which are revenue from generated electricity, costs from access roads, power lines, and land clearing that all are spatially dependent. Then finally, assessing the ecological impacts on birds and their habitats [22].

Silva S et al developed a multicriteria decision-making support system to determine the most suitable locations for biogas plants which involved different environmental, economic, safety, and social factors. They used GIS to manage and process spatial information with flexibility [23].

Theory

GIS as a planning tool

GIS handles spatial data and the related application, it is used in fields such as environmental applications, transportation systems, emergency response, and other different areas [24]. It has been a very common tool for site selection studies [20], by arranging the data as a set of maps, with each layer showing certain features of area [25].

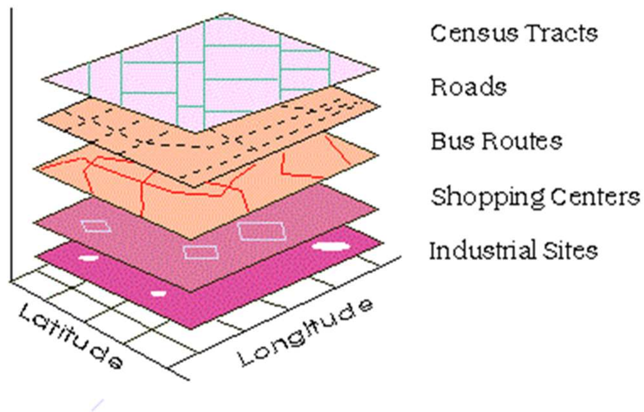


Figure 7: Overlay of different map layers

Each of these separate thematic maps is referred to as a layer, coverage, or level, each layer has been superimposed carefully on each other so that every location on the other maps is precisely matched with its respective locations. The bottom layer of Figure 7 is the most important one as it depicts the grid of a local reference network to which all maps have been precisely recorded [24].

When these maps in a common position reference system have been carefully recorded, information from the different layers can be compared and analyzed in combination, additionally, through cutting from a bigger map, single areas can be separated from their surroundings [25] as shown in Figure 8.

And we can select the layers to create a new layer, the combination and transformation of information from different layers are referred to map algebra because it involves adding, subtracting, multiplying, or dividing information [24].

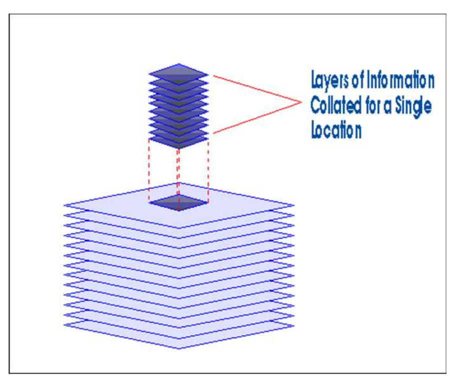


Figure 8: An example of separating single locations from the surroundings

Multi-Criteria Decision Making (MCDM)

Multi-Criteria Decision Making (MCDM) is a subdivision of operational research models and a well-known area of decision-making. These methods can tackle both quantitative and qualitative criteria and evaluate contradictions in decision-making criteria [26].

To assist with a solution for different options, we provide MCDM approaches with a range of techniques for spatial decision-making processes. Since GIS deals with the assessment of alternatives for locational choice depending on the suitability criteria, it has worked to incorporate with MCDM [25].

Since many factors can influence site selection, the use of several MCDM approaches can help promote site selection by considering key factors in the decision process [20]. For several energy-planning projects, MCDM methods were successfully applied, the literature on MCDM methods for RE planning by Pohekar and Ramachandran [27], Mateo [28], and Wang et al.[29] provide is excellent.

There are several classifications and categorizations, but these approaches can be usually divided into two categories: Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM) [26]. They include many different methods of which the most important are Analytic hierarchy process (AHP), Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE), ELimination Et Choix Traduisant la REalité (ELimination and Choice Expressing REality or more commonly—ELECTRE), and Multi-attribute utility theory (MAUT) [26].

Generally, MCDM methods have few essential steps to make rational, effective decisions [26]:

- Structure decision-making, alternative selection, restrictions, and formulation of criteria.
- Present a balance between requirements and model-based prioritization of selected potential sites.
- Sensitivity analysis to draw insights into the relevance of decision criteria.
- Apply value judgment concerning acceptable tradeoffs and evaluation.
- Calculate final aggregation and make decision

There is numerous literature about the best use of MCDM methods and controversy which is the ‘‘right’’ method applied to a real-life problem. Multi-criteria analysis is used to select the ‘‘best fitted’’ solution from different choices [26].

Analytical Hierarchy Process

AHP is one of the famous MCDM methods, developed by Saaty, the method has been applied in this study to weight the criteria and evaluate the suitable sites. Many studies had used the AHP method with GIS for siting.

AHP is a systematic pairwise comparison of alternatives concerning each criterion which is a distinctive feature comparing to direct weight or value functions [25]. By comparing pairs of criteria, a weight for each criterion is produced. A 1 value expresses “equal importance” and a value of 9 expresses “ extreme importance” against another factor in the matrix of comparisons[30].

Table 1 shows the scale that Saaty used in the pair-wise comparison process.

Table 1: Saaty`s scale in the pair-wise comparison process

Definition	Importance
Equal importance	1
Weak importance of one over another	3
Essential or strong importance	5
Demonstrated importance	7
Absolute importance	9
Intermediate values between two adjacent judgments	2,4,6,8

This method was applied to each application depending on the criteria using the help of experts to decide the importance value.

Method and Data

1- Study Area

West Bank, Palestine is or study area, boarded by Jordan to the east and the Green Line from the other directions separating it from Occupied Palestinian lands, encompasses the extent of 31.9466° N, 35.3027° E having a geographical area of 5,655 km^2 as shown in Figure 9.

The elevation span between the shoreline of the Dead Sea at −408 m to the highest point at Mount Nabi Yunis at 1,030 m above sea level. With the Mediterranean weather, slightly cooler at elevated areas.

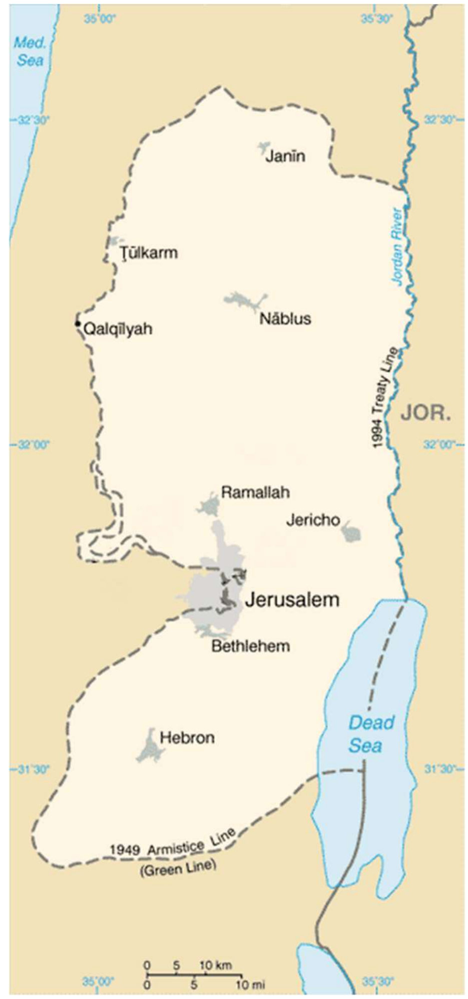


Figure 9: Location map of West Bank

2- Geographic Information Systems (GIS)

GIS can be used for different applications designed to store, gather, analyze, and map geographical data. GIS has two coverage representations; raster and vector. Raster is represented by a rectangular grid called pixels that contains specific information according to a specific geographic location. Vectors maintain geometric figures (points, lines, and polygons) that define limits that are associated with a reference system [18]. In this research data was processed in both ways depending on the data used and the final data were represented in Raster.

3- Determination of Criteria

The set of criteria and weights is based on experts' opinions and literature reviews that comply with national and international guidelines. Generally, all the RE sites should be economically viable and have no significant impact on the local environment. Each RE application has its criteria described as follows

I. **Site selection criteria for Solar Photovoltaic (PV) – mounted systems**

The siting of PV systems is vital to support decision-making to reduce the time, cost, and environmental impacts [3]. There are no clearly defined guidelines for choosing the site for the systems, based on literature reviews and personal judgments, we can infer the key constraints that needed to be addressed when selecting sites for PV systems as the following [13,31,32]:

- Solar Resource.
- Available Area.

- Local Climate.
- Topography.
- Grid Connection Proximity, Availability, and Capacity.
- Accessibility.
- Water Availability.

Because of Palestine's special circumstance, we should also take into account:

- Avoid Israeli military areas, settlements, and camps.

Site Selections Constraints

1- **Solar Resource**: As mentioned before in the report, West Bank has a high average of Global Horizontal Irradiance (GHI) with values varies from m 2.63 kW h/m2/day in December to 8.4 kW h/m2/day on June [2]. Insolation can affect the power generated from solar projects considerably [32]. Regarding Palestine, the solar resource across the West Bank varies slightly.

2- **Available Area**: The area per kW_p installed differs from one site to another depending on the technology used, the CdTe modules will take about 40 to 50% more space than the multi-crystalline modules for a plant with less efficiency. The distance required to avoid significant inter-row shading between rows of modules (the pitch) varies with the site latitude, studies show that 1 MW_p plant requires between 10,000 to 20,000 m^2 [31]. In this study, we considered available areas above 5,000 m^2.

3- **Local Climate**: In addition to the importance of solar resources, the climate should not be influenced by weather extremes which increase the risk of damage or downtime[31]. Considering that we rarely have floods, heavy snow, and very high wind speeds and temperatures, Palestinian weather is generally considered acceptable and varies slightly.

4- **Topography**: The site would preferably be flat or on a slight slope. Steep sites should be avoided to reduce the cost of technical modifications needed to adapt [3,31,32]. South-facing lands are preferable for PV systems, followed by south-western and then south-eastern lands[32], studies have a wide variety for suitable land slops, and prefer the low agricultural value lands.

5- **Grid Connection Proximity, Availability, and Capacity**: To ensure that the grid connection has no adverse impact on project economics site should be close to the grid connection, adding to that the percentage of time that the network will tolerate power from the solar PV system, rural areas usually struggle from significant downtime, and the grid should have enough capacity to accept the exported from the solar system[31].

6- **Accessibility**: Selected sites should be near the roads to minimize the adding cost to the system and the environmental impacts of building new roads [31,32].

7- **Water Availability**: For the cleaning of the PV modules, cold, low mineral water is used. Based on the module soiling, water supply, groundwater or stored water should be available to clean the system [3,31].

II. Site selection criteria for Concentrated Solar Thermal Power (CSP)

Site Selections Constraints

The selected CSP systems sites must meet certain requirements. These requirements can be divided into five groups [33]:

- Solar radiation requirements
- Land availability and use
- Land slope
- Water availability
- Infrastructure requirements
- Meteorological conditions.

1. **Solar Radiation potential:** Sufficiently high availability of solar radiation is a crucial criterion for the construction of a CSP plant at a given location. The direct normal irradiance (DNI) potential must be sufficient because CSP uses only the direct component of solar radiation, contrary to some other types of solar energy applications. DNI is defined as the density of radiant flux in the solar spectrum (0.3µm to 3µm) incident perpendicular to the direction of the Sun spread over a small cone tracing the Sun at the earth's surface. The usable DNI is influenced by solar radiation absorption and scattering at air molecules, ozone, water vapor, and aerosols. The unit used is the power per square meter: W/m^2. Yet, generally speaking, the annual quantities are taken as the criterion for determining the availability of direct radiation at a given site. In this instance, the unit is energy per square meter and year: $kWh/m^2/y$ [34.]
   The CSP technology needs ample DNI potential ranging from 1900 to 2100 kWh/m^2-y to deliver more competitive levelized prices of electricity. Such values are obtained in the Sun Belt areas, located between 15 ° and 40 ° latitudes on both hemispheres, including Palestine [33].

2. **Land Cover, Use, and Slope:** CSP plants need a large area compared to conventional power plants and the actual surface area of the CSP plant is on average around 25,000 m^2/MW [35]. Exclusion criteria are used to adopt the best location for the installation of the CSP project.

The exclusion criteria are to exclude all unsuitable land areas due to inhabited areas, soil composition, water bodies, land slope, dunes, protected or confined areas, forests, mountains, agriculture [33].

The chosen site should have an appropriate slope, depending on the type of CSP technology, varying from around 1-2% for linear focus and up to 3-4% for point focus technologies [34,35].

3. **Water Availability:** Water availability is one of the significant parameters for CSP plants, particularly if they are operated with wet cooling systems.

   Wet cooling systems are useful for the operation of the CSP plant due to higher possible power output and lower investment costs compared to CSP plants with dry cooling systems[33].

   For wet cooling systems, all CSP technologies except Dish-Stirling require approximately 3 m^3 of water per MWh generated. For dry cooling systems, all CSP technology except Dish-Stirling requires about 0.3 m^3 of deionized water for each MWh generated, whereas Dish-Stirling needs about 0.075 m^3 of deionized water for each MWh produced [36].

4. **Transportation:** CSP plant is preferable to be proximate to highways since access roads are needed for transportation to deliver the heavy machinery such as turbines, generators, reflectors, pipes, etc. Having unqualified roads will increase the investment cost of the plant. To provide the plant with the workers and stuff it is proposed that the plant is fairly close to the populated areas [35].

5. **Power Transmission Lines:** A CSP plant site must be located near existing power transmission lines. Large CSP plants need high voltage lines to transmit the electrical power generated to consumers. To reduce the investment cost, the distance between the transmission lines and the plant is desirable to be short [33].

6. **Meteorological Conditions:** Both positive and negative meteorological conditions affect site selection. For example, rain and snow will wash the mirrors effectively and reduce plant costs. However, plant isolation can decrease if rainfall and snow can be found frequently [34].

   Solar field specifications limit the operation of the plant in high wind conditions. The ambient temperature and humidity impact the performance of the thermal cycle as in conventional power plants. Extreme weather conditions, such as hail, tornadoes, hurricanes, and flash flooding, may have a significant effect on plant operation [35].

   6.1 Wind: High winds affect the performance and the structural design of the solar field since the solar field is not designed to operate in winds more than 30 to 70 km/h (8.3 to 19.5 m/s) and it differs on the chosen CSP technology. The design of the collector structure is dictating by the wind forces.

Since the structure represents around 40% of the solar field cost, it is important to know both the frequency distribution curve of the wind velocities and to optimize the structure for these circumstances.
The solar field is designed to handle wind speeds from 120 to 130 km/h (33.3 to 36.1 m/s) with the collectors stowed in a non-operating face down position [35].

6.2 Ambient Temperature: The performance and efficiency of the solar power plant depend on the ambient temperature, which has two opposing effects on the efficiency of the solar field and of the solar block [37].
The efficiency of the solar field depends on the convective losses of the heat transfer fluid and the collectors to the ambient air. Such losses depend on the ambient temperature. The lower the ambient temperature, the higher the losses, and vice versa.
The power block efficiency is indirectly a function of the ambient temperature and depends on the condenser efficiency. In the case of wet cooling, the efficiency of the condensers increases with decreasing wet bulb temperature, which is a function of ambient temperature and relative humidity, and vice versa [33].

6.3 Humidity: The performance and efficiency of the power block also depend on the humidity of the air. The efficiency of the wet cooling system decreases with increasing relative humidity, which in turn reduces the efficiency of the power block. As a result, changes in relative humidity levels affect the overall energy production of CSP plants[37].

III. Site selection criteria for wind farms

In general, the wind farm's location should be economically viable and should have no major effect on the local environment in terms of visual and noise intrusion, electromagnetic interference, and potentially wildlife collisions [22].

Based on the availability of data and their economic and environmental importance, the considered criteria for wind farms site selection is as following [16,17] :

- Wind speed.
- Distance from residential areas.
- Land use and land cover of the surrounding area.
- The distance of the proposed site from roads.
- Proximity to gridlines.
- Slope.

1. **Wind speed:** The wind speed is a very crucial parameter in the criteria for assessing the suitable wind farm location. Areas with a wind speed of 4.4 m/s and above at 10 m anemometer height are good for wind farm investments. Meanwhile, areas with less 4.4 m/ wind speed are not good for siting wind farms according to National Renewable Energy Laboratory (NREL) classification [38].

2. **Distance from residential areas:** Siting wind farms in the vicinity of residential areas may cause negative environmental impacts, such as noise pollution, visual intrusion (shadow flicker, light reflections, landscape impacts), or massing effects. In consideration of noise nuisance and possible visual impacts, it is preferable to consider areas away from urban areas for wind farms. According to the literature review, the suitable threshold sites distance from residential areas to neglect the visual impacts range from 500 to 2500 [16], a 500 m buffer zone was obscured in this study.

3. **Land use and land cover:** Knowing the land use and the cover is important to evaluate the land suitability for energy investment. Taking into consideration the social acceptance, certain forms of land are more preferred than others [16].
   Among all the studies, it is preferable to have shorter vegetation to higher vegetation. High density and high vegetation decrease the wind speed and increase the intensity of the turbulence that may cause damages to the turbine which will increase the project cost [39].
   Protected areas such as nature, archeological and historic sites, tourist areas, wildlife, and cultural heritage areas are excluded from the study. These protected areas and areas within 500 m of a buffer from these areas are classified as unsuitable areas [40].
   As a result, bare land can generally be considered most suitable, agricultural land as moderate and thorn scrub forest and plantations as low suitable, while forest land is considered less suitable [22,39,41,42] but in this study, we are considering all type of lands since there is a little variety in land cover across the West Bank, and the design of the wind turbines will consider the nature of the location with minimum costs and best efficiency.

4. **Distance to roads:** To reduce the project cost, it is preferable to locate the wind farms close to the existing roads.
   This helps minimize construction costs by allowing vehicles to access the site for the delivery and maintenance of materials. In a variety of wind farm assessments, the areas closest to the roads are deemed acceptable than those further from the roads [22,43].
   It was proposed that acceptable sites should not exceed 10 km from the roads. On the other hand, we should avoid locating the site within 500 m distance from the road for safety consideration [44] and to reduce visual disturbance and ensure electrical safety [17]. A 100 m buffer zone from roads was taken in this study.

5. **Proximity to gridlines:** Wind farms as all the other renewable energy applications are preferable to be placed close to the grid lines to reduce the initial cost of the project by reducing the construction cost of new grid lines [18].

6. **Slope:** Areas with low slope values are ideally suited for siting wind farms because high slope means high turbulence that renders wind unusable for producing energy, increases construction costs. After all, it requires more grading and ground movement than a slight slope. This will also increase the mobility of cranes and trucks to install wind turbines on the construction site [16,17]. The recommended value for slope ranges from 10% [45] to 45%[46].

IV. Site Selection criteria for Bioenergy

The history of using biogas in Palestine goes back to 1998 in Jericho Station[15]. Same as the other renewable energy forms site selection, deciding the suitable location for biomass will be through a specific criterion depending on the following parameters:

- Resource availability
- Access roads
- Distance to the electricity grid
- Slope factor
- Water availability

1. **Resource availability:** It is challenging to ensure the right kind, the right price, the right amount, and the right channels of biomass procurement in the development of biomass power plants. Each of these is necessary for the efficient and economic functioning of biomass-based plants.[47] In this study, we are looking for animal farms and dumps

2. **Access to roads:** It is difficult to transport agricultural crop residues from the collection site to a bioenergy plant without proper roads. The physical characteristics of the road network are related to the geography of the study area and therefore good road access is required. [47]

3. **Distance to the electricity grid:** It should be as close as possible but, for safety reasons, exclude areas where the distance to very high voltage lines is less than 200 m, the distance to high voltage lines is less than 100 m and the distance to medium-voltage lines is less than 50 m.[23]

4. **Slope factor:** Topographic features play an important role in determining the viability of the collection of agricultural biomass, as they directly affect the selection and management tools and therefore the costs. Sharp slopes are expensive and more sophisticated machines. In this regard, several studies on harvesting systems for agricultural and wood biomass limit the use of these resources to a slope of less than 15%. [48,49].

5. **Water availability:** Water is important for farms and the growth of plants, so sites should be 150 m maximum away from the water line source [23].

4- Data

Freely available data from Geomolg prepared by the Ministry of Local Govronate, PETL, Global Solar Atlas, and Global Wind Atlas were used in this study as shown in Table 2 below.

Table 2: Datasets used in the study

Data	Source
Forests	Geomolg
Agricultural land classification	Geomolg
Natural Reserve	Geomolg
Colonies borders	Geomolg
Military base	Geomolg
Occupation industrial areas	Geomolg
Built-up areas	Geomolg
Road network	Geomolg
Administrative division: area A, B, and C	Geomolg
Slope	Geomolg
Aspect	Geomolg
Communities Census Boundaries	Geomolg
Direct Normal Irradiation (DNI)	Global Solar Atlas
Global Horizontal Irradiation (GHI)	Global Solar Atlas
Wind speed	Global Wind Atlas
Grid connection points	PETL

Due to the unavailability of water networks data, grid capacities data, bioenergy site selection data, and the meteorological data is almost the same across the West Bank, these criteria have not been considered or applied.

5- Data preparation

The data for PV, CSP, and Wind farms applications were prepared before getting the final output. First, the following layers have been excluded from the study area as none of these applications can be sited there as shown in Figure 10 and Figure 11, noting that all data have been projected using the Palestinian 1923 Grid coordinate system:

1- Forests.
2- Medium agricultural value lands.
3- High agricultural lands.
4- Natural Reserve.
5- Colonies borders.
6- Military base.
7- Occupation Industrial areas.
8- Built-up areas

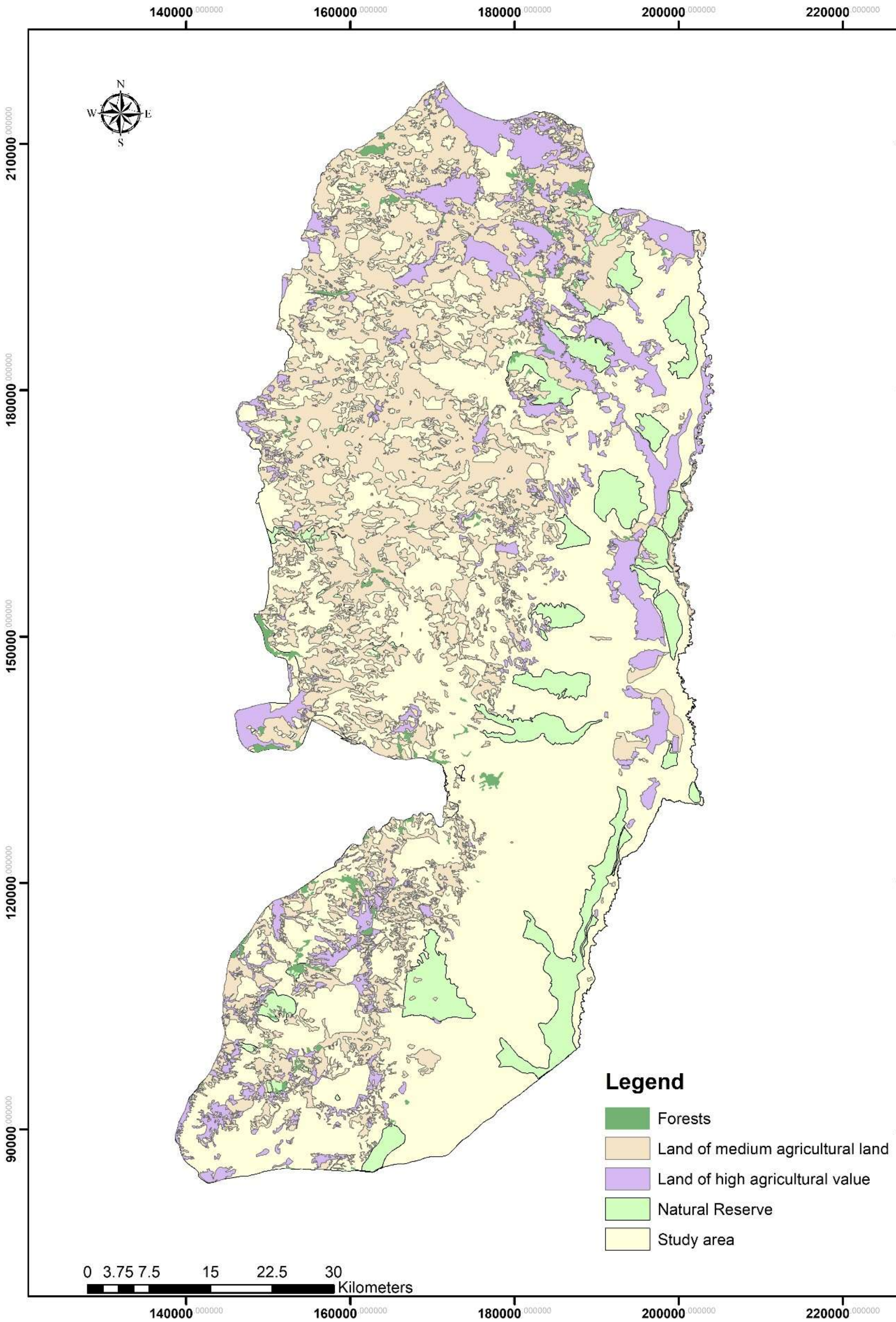


Figure 10: Forests, agricultural lands, and natural reserves in West Bank

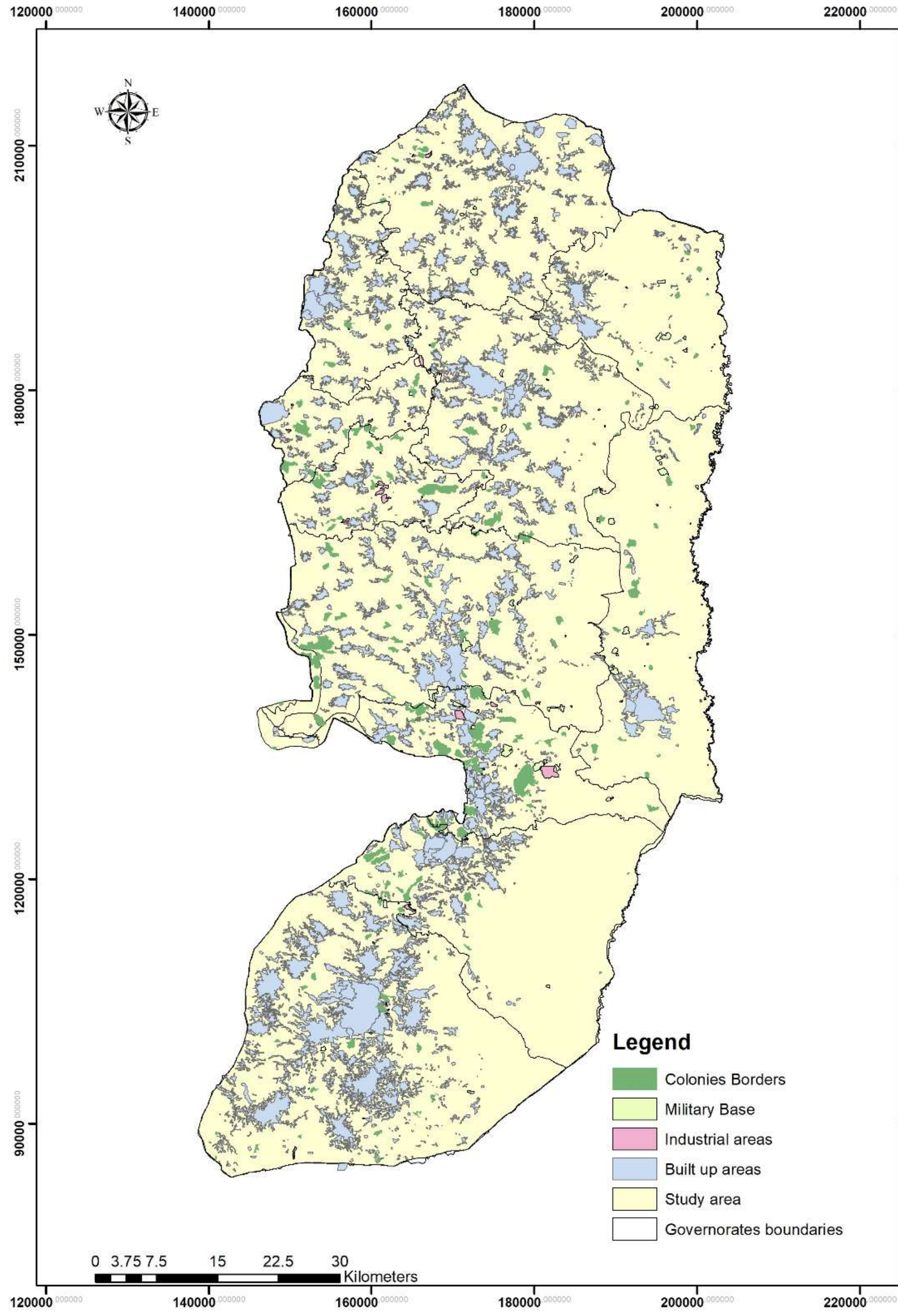


Figure 11: Colonies borders, military base, industrial areas, and built-up areas in West Bank

The next step for each application is applying each criterion for each application as shown in Table 3 for PV, Table 4 for CSP, and in Table 5 for Wind in the

Methodology section. Using the following inputs.

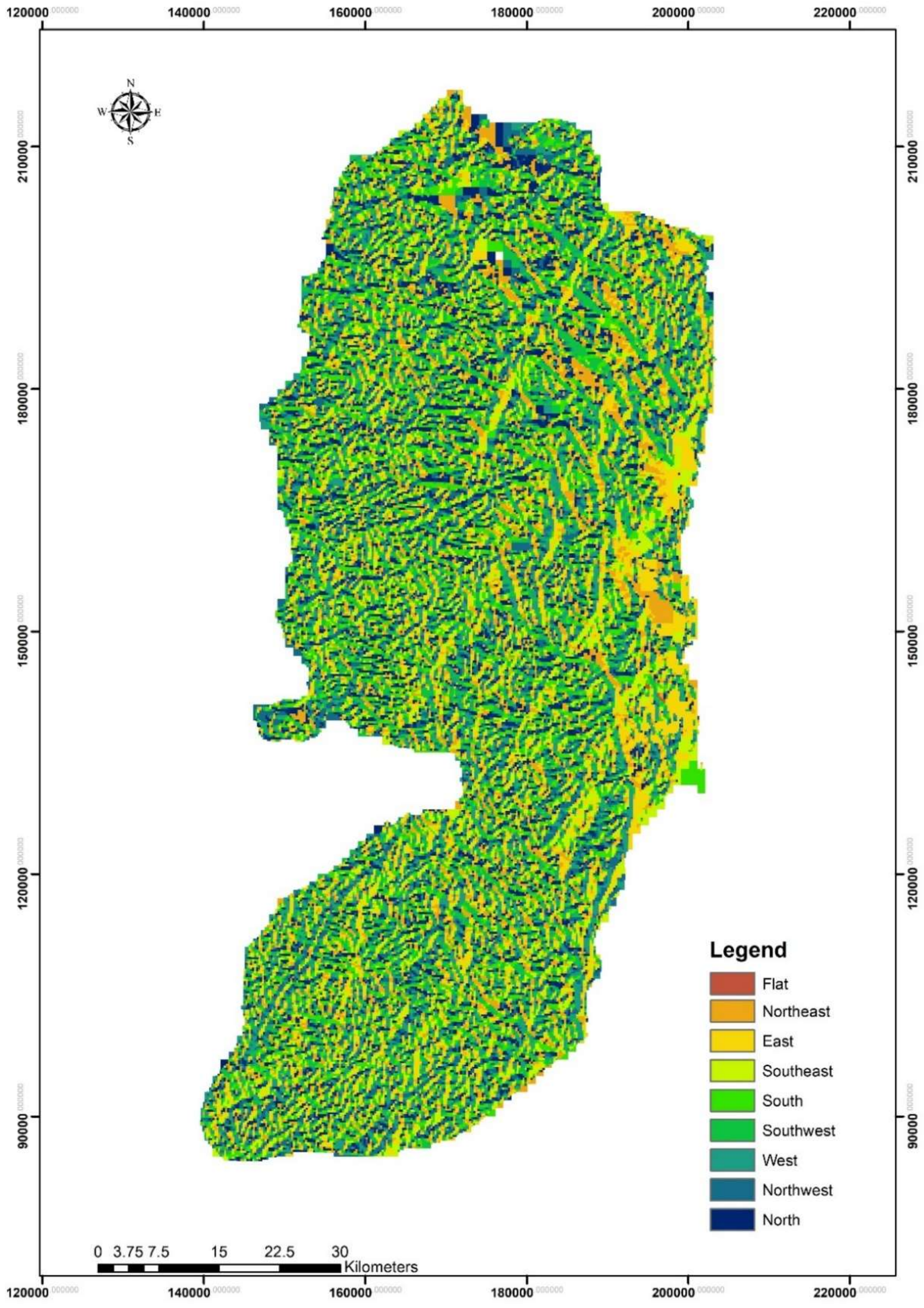


Figure 12: West Bank aspect layer

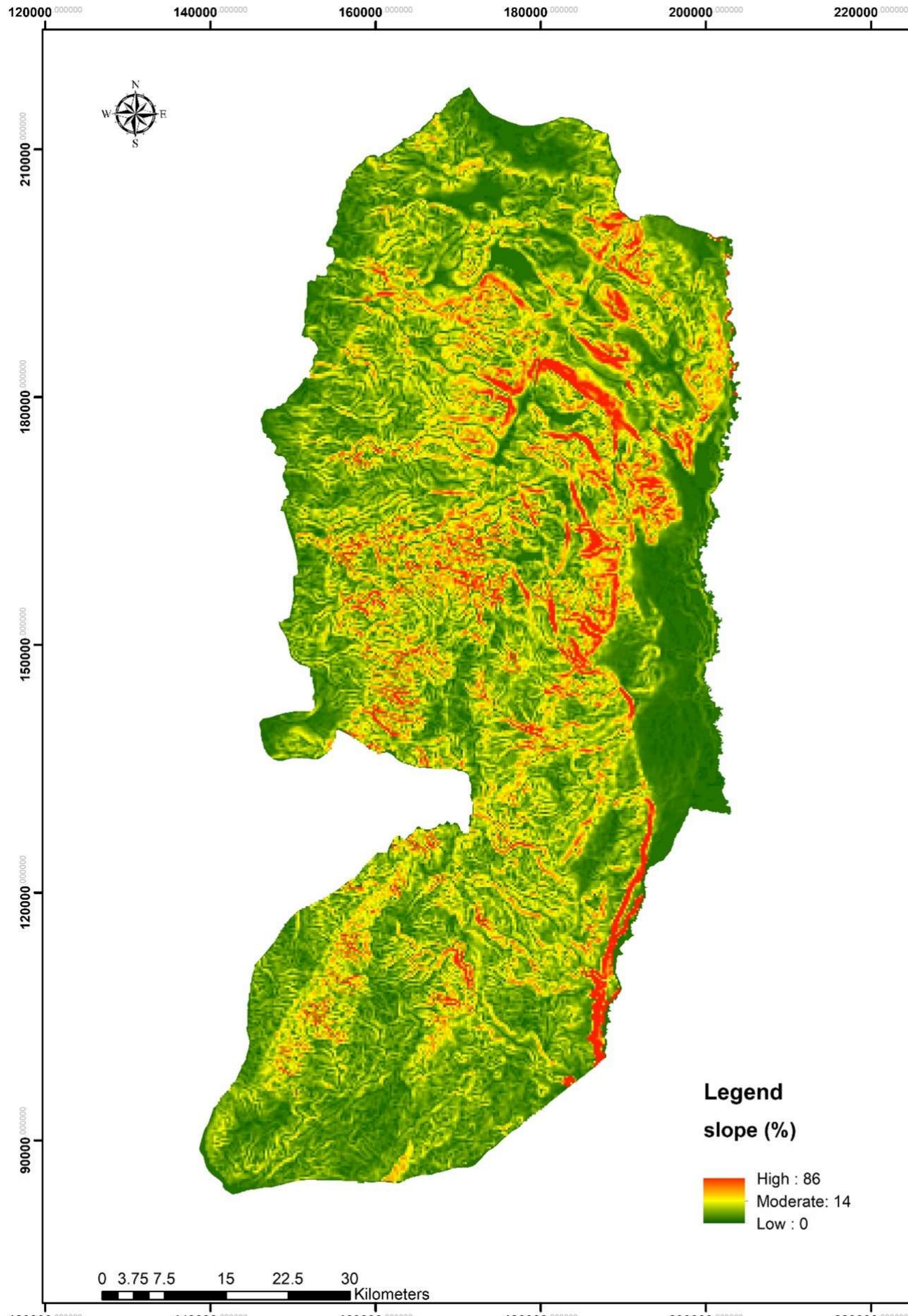


Figure 13: West Bank slope layer

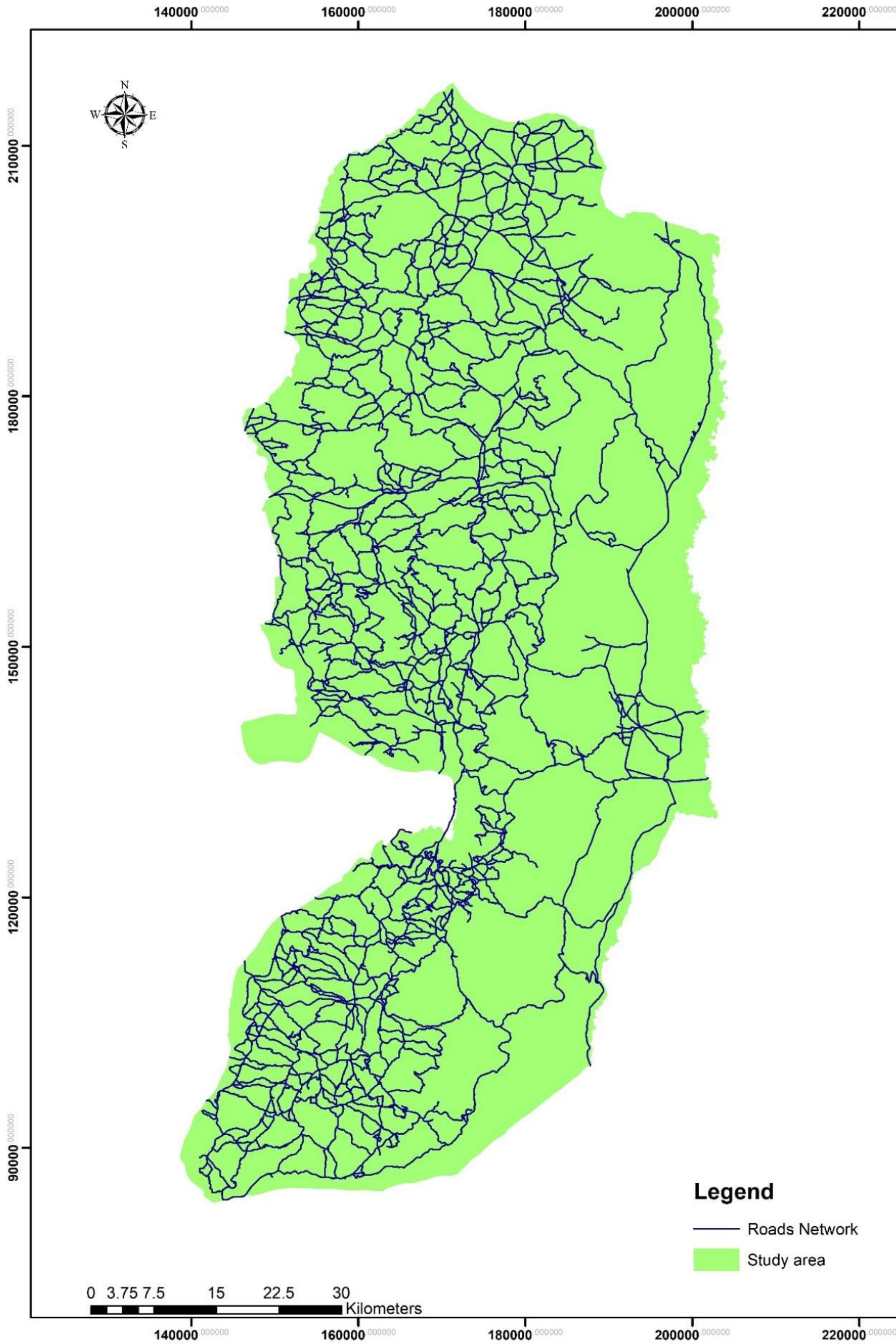


Figure 14: West Bank road network layer

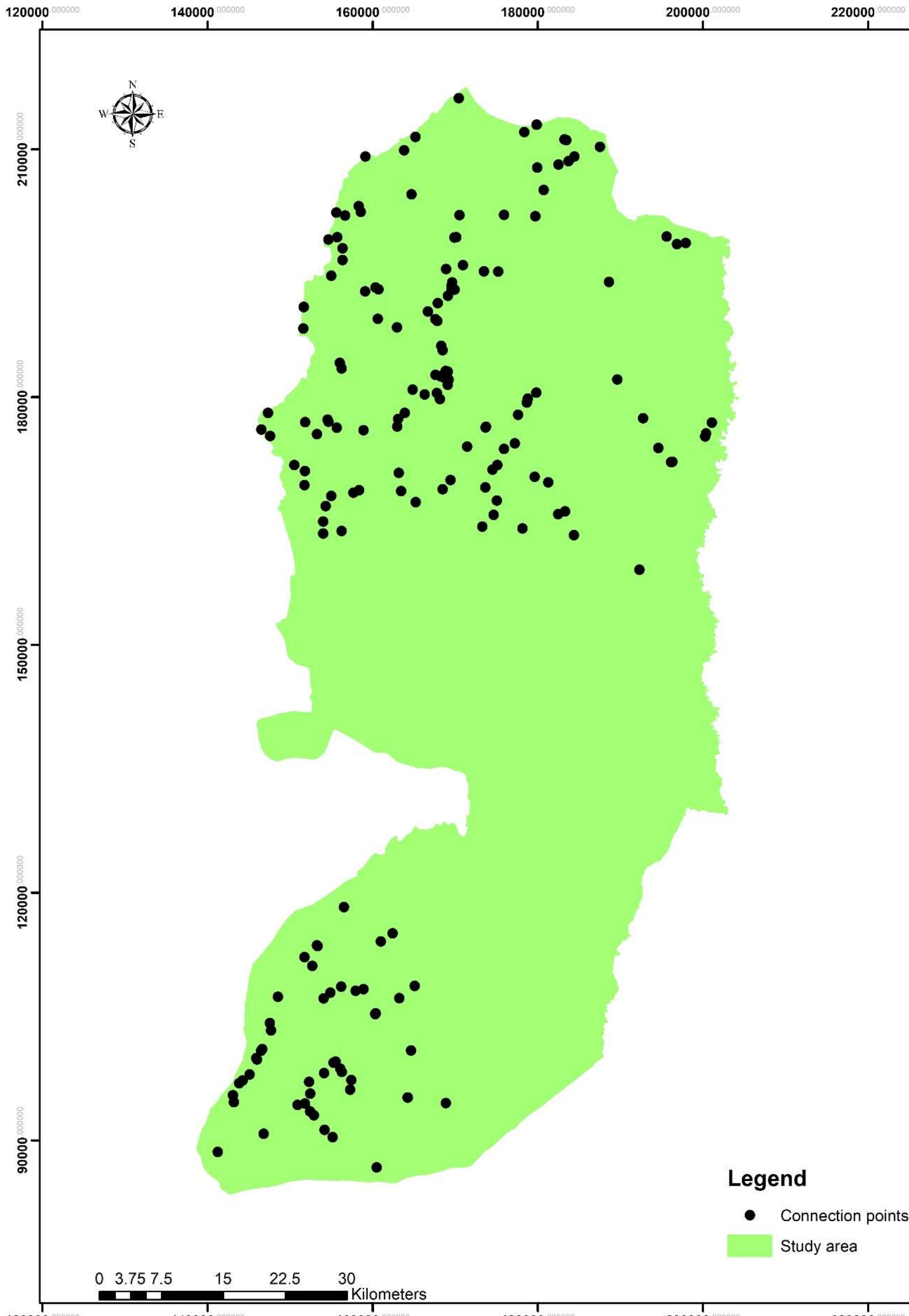


Figure 15: West Bank grid connection points layer

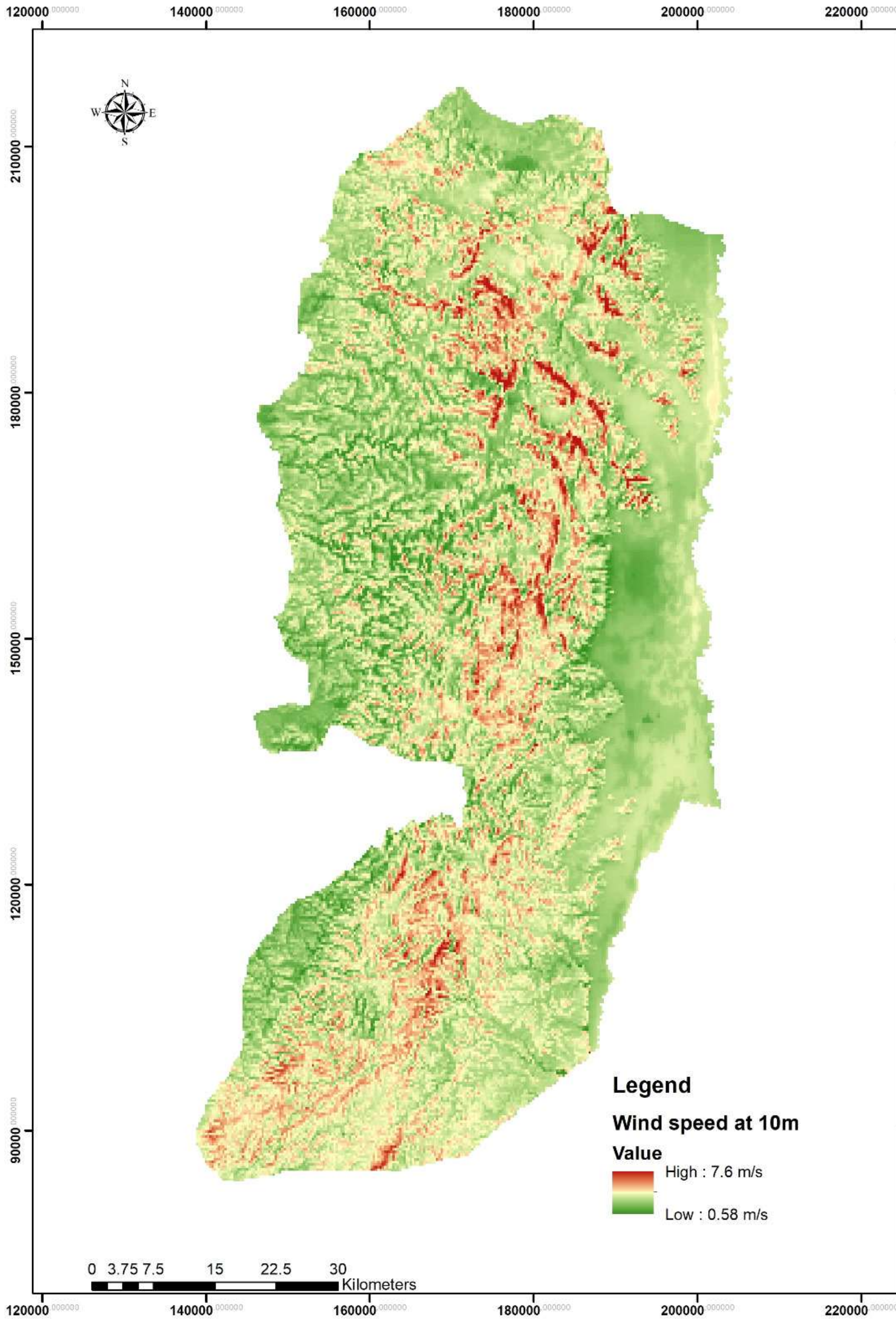


Figure 16: West Bank wind speed layer

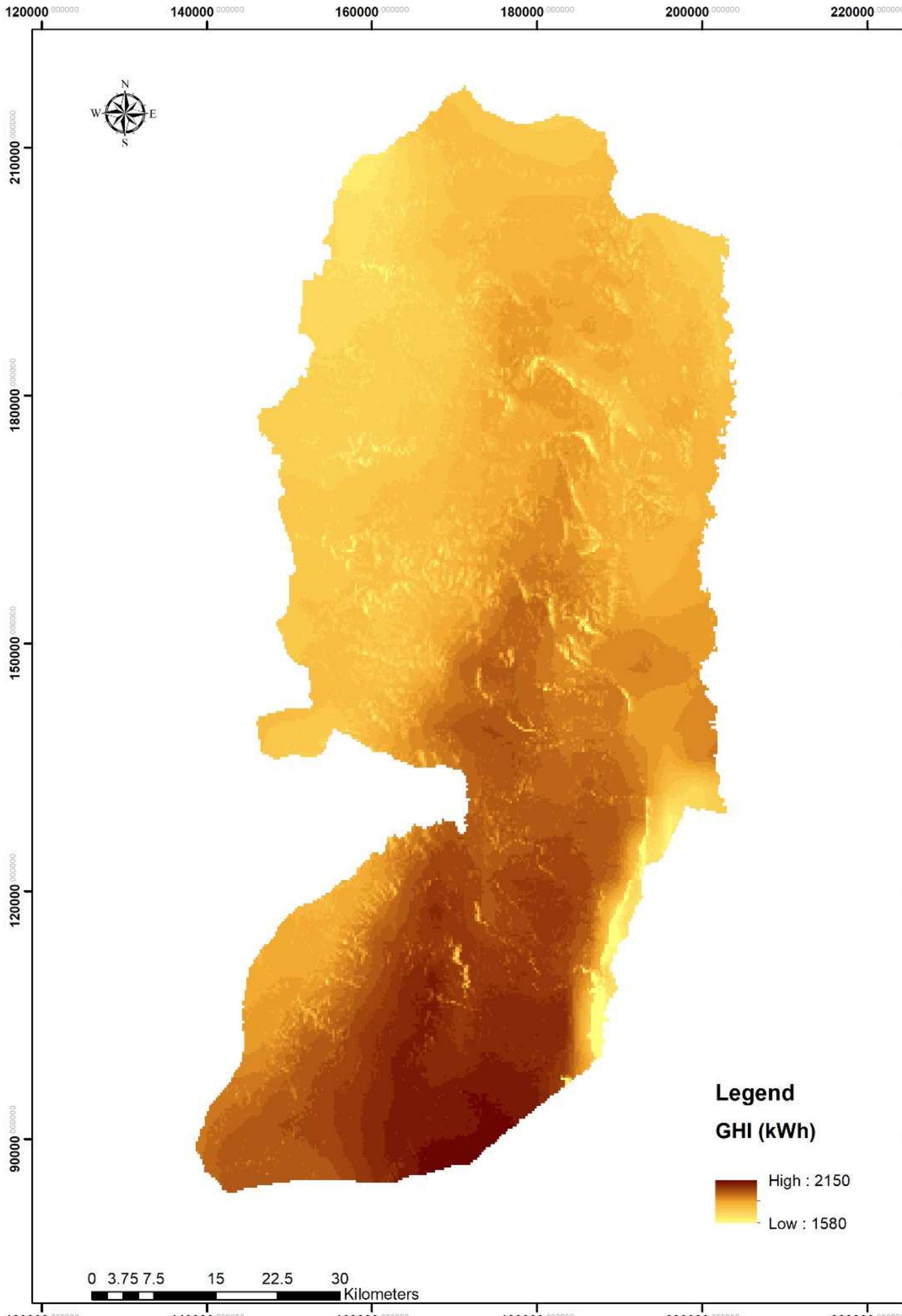


Figure 17: West Bank Global Horizontal Irradiance (GHI)

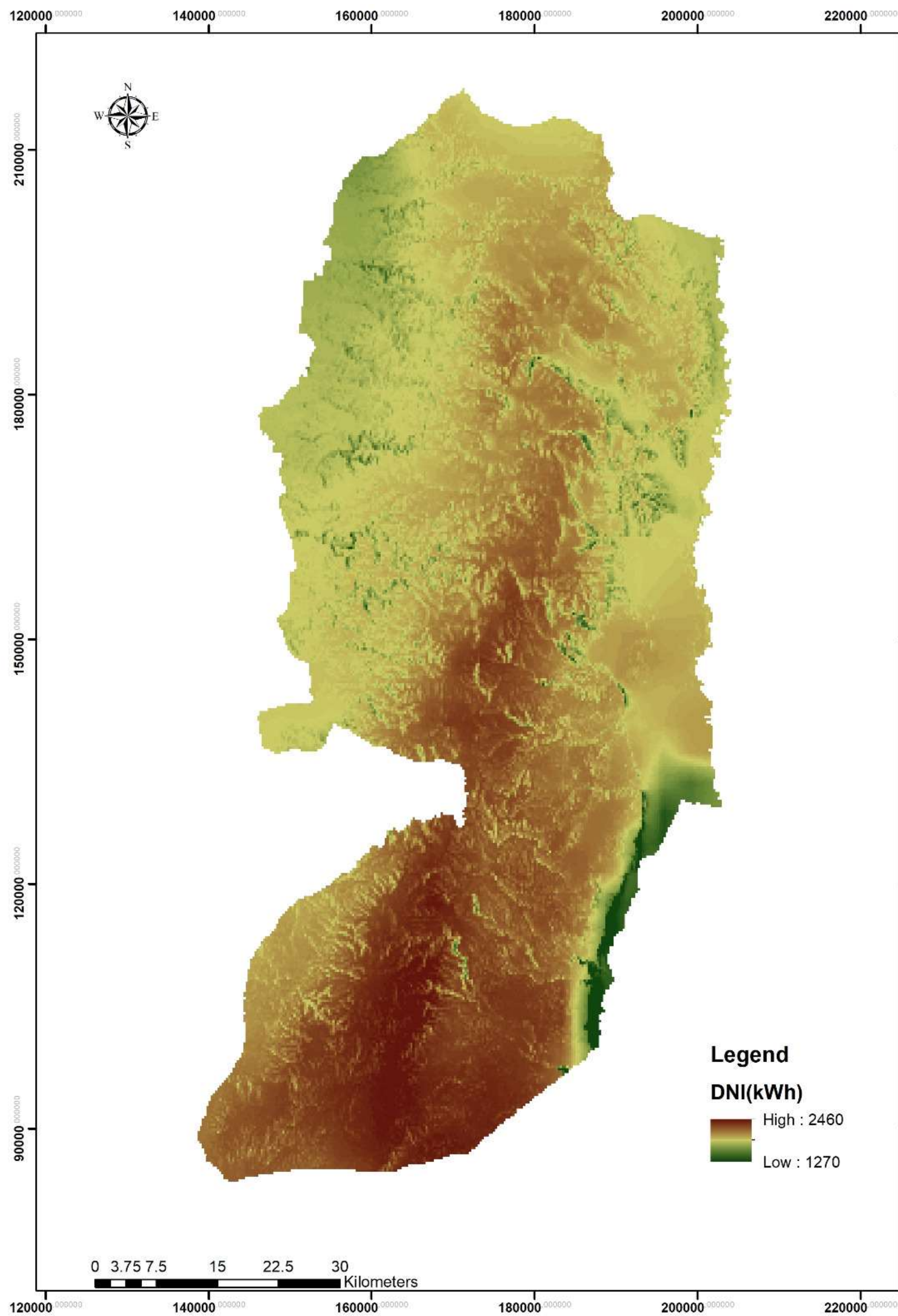


Figure 18: West Bank Direct Normal Irradiance (DNI)

6- Methodology

As mentioned before MCDM and AHP have been adopted in this study for each application. Because of the lack of planning policies and national guidelines in the West Bank for the development of Renewable energies, the criteria employed in this study are based on related researches and experts' opinions in the field of Renewable energy in Palestine.

A set of rules for the specified criteria has applied to each application according to the literature and experts' opinions as shown in the following tables.

Table 3: GIS used model for PV systems site selection

Criteria	Condition
Solar resource	No restrictions since there is a slightly varies in the radiation in the study area
Slope	Up to 15%
Aspect	South facing and the south-west facing site was given the highest values
Grid connection point proximity	Different scales were given, up to 2000 m
Road accessibility	Different scales were given, up to 1500 m

Table 4: GIS used model for CSP systems site selection

Criteria	Condition
Solar resource	No restrictions since there is a slightly varies in the radiation in the study area
Slope	Up to 3%
Grid connection point proximity	Different scales were given, up to 2000 m
Road accessibility	Different scales were given, up to 1500 m

Table 5: GIS used model for Wind farms site selection

Criteria	Condition
Wind speed	Values from 4 to 7.6 m/s were given the highest values at 10 m.
Slope	Up to 20%
Grid connection point proximity	Different scales were given, up to 2000 m
Road accessibility	Different scales were given, up to 1500 m

A hierarchical model shows how the criteria are designed for each application as the following graphs show.

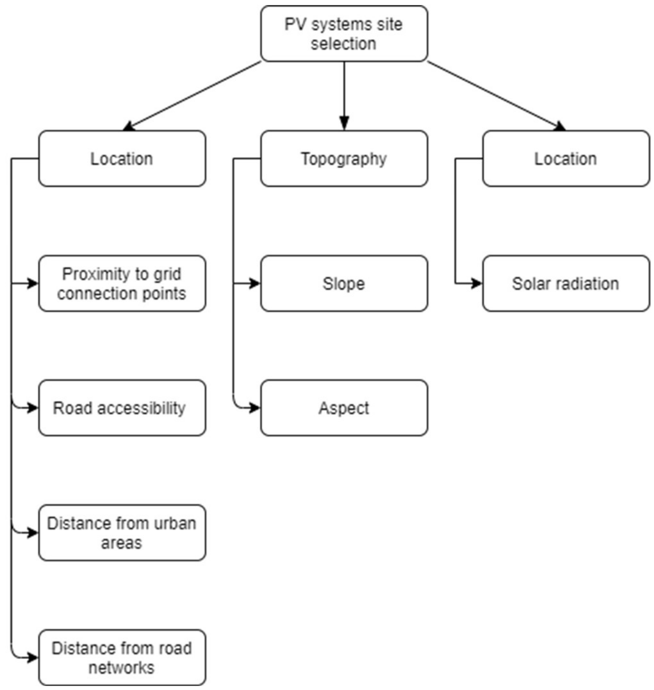


Figure 19:Hierarchy tree for the selection of PV systems

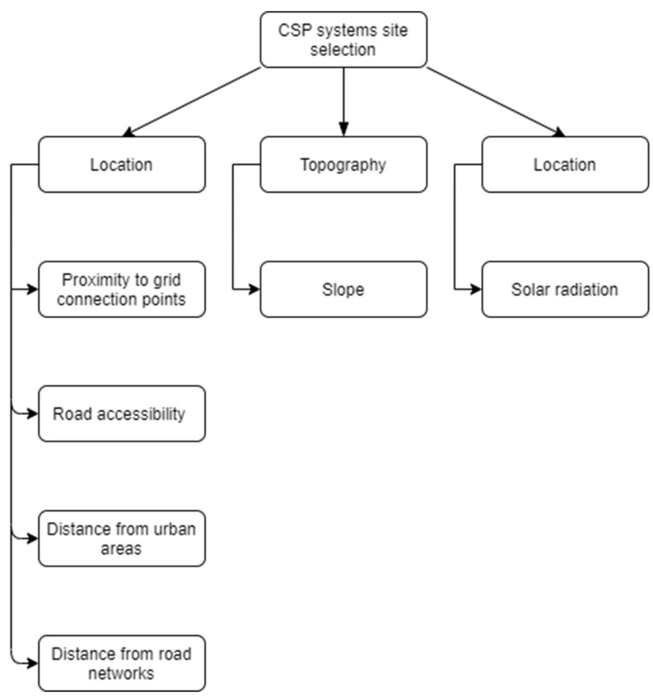


Figure 20:Hierarchy tree for the selection of CSP systems

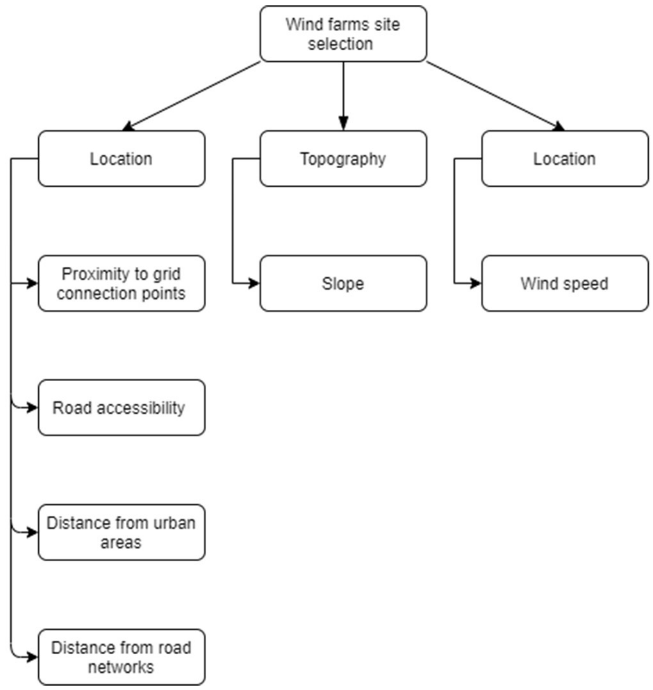


Figure 21:Hierarchy tree for the selection of Windfarms

One of the updates on the project is calculating the potential of each suitable location for each application as following.

- PV system

To find the annual energy output potential, we used :

$$EPV = GHI \times APV \times \eta\, PV$$

Where;

GHI is the yearly average of daily global irradiation in kWh/m^2, the data were taken for the solar atlas as mentioned before.

APV is the surface area of the PV modules in m^2, we assumed that 0.7 of the 1 m^2 of the area is for the PV surface area[50].

$\eta\, PV$ is the PV module efficiency, assumed 12%.

All the energy losses including connection losses, wiring losses, and other losses were assumed to be zero, also the effect of temperature on the PV cells is being ignored [51].

- CSP system

to find the annual electricity generation, we used :

$$AEG_{CSP} = (365 \times 24) \times CF_{CSP} \times P_{CSP}$$

Where;

P_{CSP} represents the capacity of the CSP system,

CF_{CSP} represents the capacity factor, which is assumed to be 0.36 [52].

Each CSP plant capacity in the project is 1 MW with about 25,000 m^2 of area.

- Wind system

For Wind systems, the amount of wind energy that can be generated from a particular location is proportional to the wind speed at the specific location and can be found from the following equation[53]

$$Pin = \frac{1}{2}\ \rho\ A\ v_m^3$$

$$Annual\ enery\ production =\ Pin \times C_p\ \times 8760$$

Where;

Cp is assumed to 25%

ρ is the air density in kg/m^3 = 1.225

A is the swept area in m^2 of the rotor blades.

V_m is the average wind speed in m/s.

The energy potential for the wind was calculated per m^2 of the swept area.

The following comparisons matrices of criteria for each application were filled in based on the scale values from Table 1 based o different experts' opinions who are professional and enrolled in multiple energy-related jobs.

Table 6: AHP comparison matrix of the PV criteria

	Solar Resource	Slope	Aspect	Grid Connection Point Proximity	Road Accessibility
Solar Resource	1	0.2	0.1667	0.1429	0.2
Slope	5	1	0.25	0.1667	5
Aspect	6	4	1	5	5
Grid Connection Point Proximity	7	6	0.2	1	6
Road Accessibility	5	0.2	0.2	0.1667	1

Table 7:AHP comparison matrix of CSP criteria

	Solar Resource	Slope	Grid Connection Point Proximity	Road Accessibility
Solar Resource	1	0.25	0.25	0.334
Slope	4	1	5	7
Grid Connection Point Proximity	4	0.2	1	5
Road Accessibility	3	0.1428	0.2	1

Table 8: AHP comparison matrix of Wind criteria

	Wind Speed	Slope	Grid Connection Point Proximity	Road Accessibility
Wind Speed	1	8	8	8
Slope	0.125	1	0.2	0.25
Grid Connection Point Proximity	0.125	5	1	7
Road Accessibility	0.112	4	0.1429	1

The next step is calculating the weights based on the previous pairwise comparisons using the AHP Online System - AHP-OS, and adjusted based on experts' recommendations. The higher the weight, the more important is the corresponding criterion. The weights are presented in Table 9, Table 10, and Table 11 below.

Table 9: PV criteria weights

Factor	Weight
Grid Connection Point Proximity	36%
Aspect	26%
Slope	22%
Solar Resource	9%
Road Accessibility	7%

Table 10: CSP criteria weights

Factor	Weight
Slope	60%
Grid Connection Point Proximity	24%
Road Accessibility	9%
Solar Resource	7%

Table 11: Wind farm criteria weights

Factor	Weight
Wind speed	68%
Grid Connection Point Proximity	21%
Road Accessibility	7%
Slope	4%

The Consistency Index (CI) is calculated to prevent inconsistencies in pairwise comparisons. Perfect comparisons should obtain CI=0, but small values are tolerable.

8- Final suitability maps

The weighted layers for each application and the excluded layer were multiplied together to produce the final suitability map.

- **PV systems suitability maps**

In this application, we are targeting empty land with an area above 5,000 m^2, after excluding all the mentioned layers before and applying the weights in Table 9. This process was applied twice one while including area C in the study area, and the other excluding area C. The data were ranked on a scale 1 to 4 considering 4 is the most suitable and 1 is the least suitable, each governorate was analyzed on its own for better-detailed resulted in locations and the equations mentioned before were applied to calculate the potential for each area.

The total high and moderately suitable areas for PV systems including area C is 444 km^2 with an approximate production of 76,825 GWh per year while excluding area C will result in a 90 km^2 with an approximate production of 15,632 GWh annually.

The following figures [22 to 32] represent suitable areas for PV systems in each governorate including and excluding area C in the same map for each. Table 12 shows the resulted data in numbers for each governorate including area C, as shown Qalqilya has the lowest potential with only 13 km^2 available for good investments for PV systems, and Hebron as the highest potential with about 110 km^2 of available area for PV systems investments with an annual potential of 19,508 GWh.

Table 12: Potential and available area for each Governorate for PV systems including area C

Governorate	Area (Km^2)	The annual potential of areas (GWh)
Qalqiliya	13	2,209
Jerusalem	19	3,264
Tulkarm	21	3,430
Jenin	21	3,543
Salfit	24	4,027
Tubas	26	4,360
Ramallah & Al Bireh	33	5,724
Nablus	40	6,800
Bethlehem	54	9,522
Jericho & Al Aghwar	84	14,438
Hebron	110	19,508

While Table 13 shows the resulted data for each governorate excluding area C, as shown, Tubas has the lowest potential for PV systems with only a 0.1 km^2 available for solar investments, and Hebron as the highest potential with about 33 km^2 and an annual potential of 5,851 GWh.

Table 13: Potential and available area for each Governorate for PV systems excluding area C

Governorate	Area (Km^2)	The annual potential of areas (GWh)
Tubas	0.10	17
Jerusalem	0.61	107
Salfit	0.86	146
Qalqiliya	3.19	536
Jericho & Al Aghwar	3.49	597
Ramallah & Al Bireh	4.30	740
Tulkarm	8.84	1,476
Nablus	9.44	1,619
Jenin	9.74	1,667
Bethlehem	16.28	2,876
Hebron	32.97	5,851

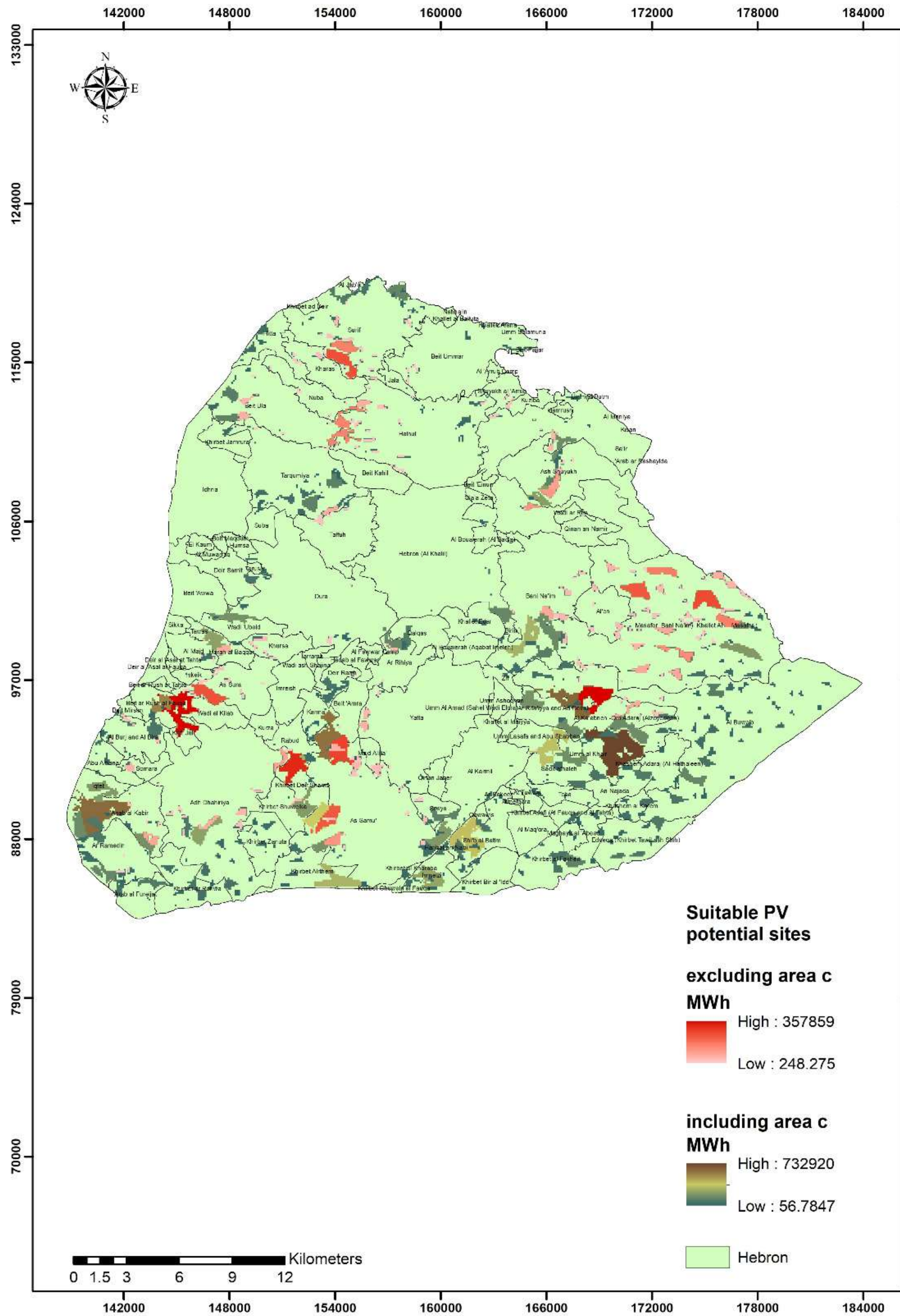


Figure 22: Suitable sites for PV systems in Hebron

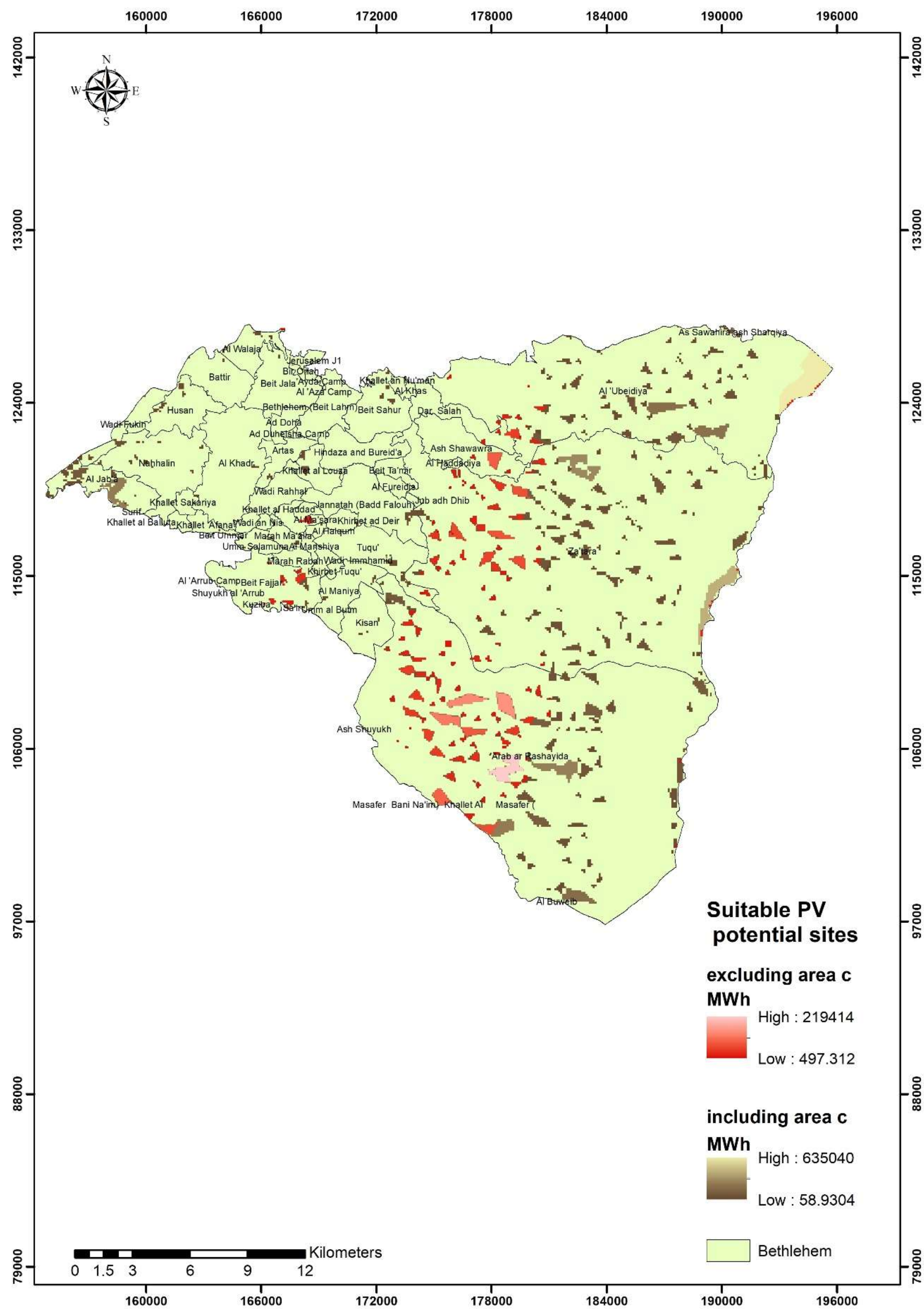


Figure 23: Suitable sites for PV systems in Bethlehem

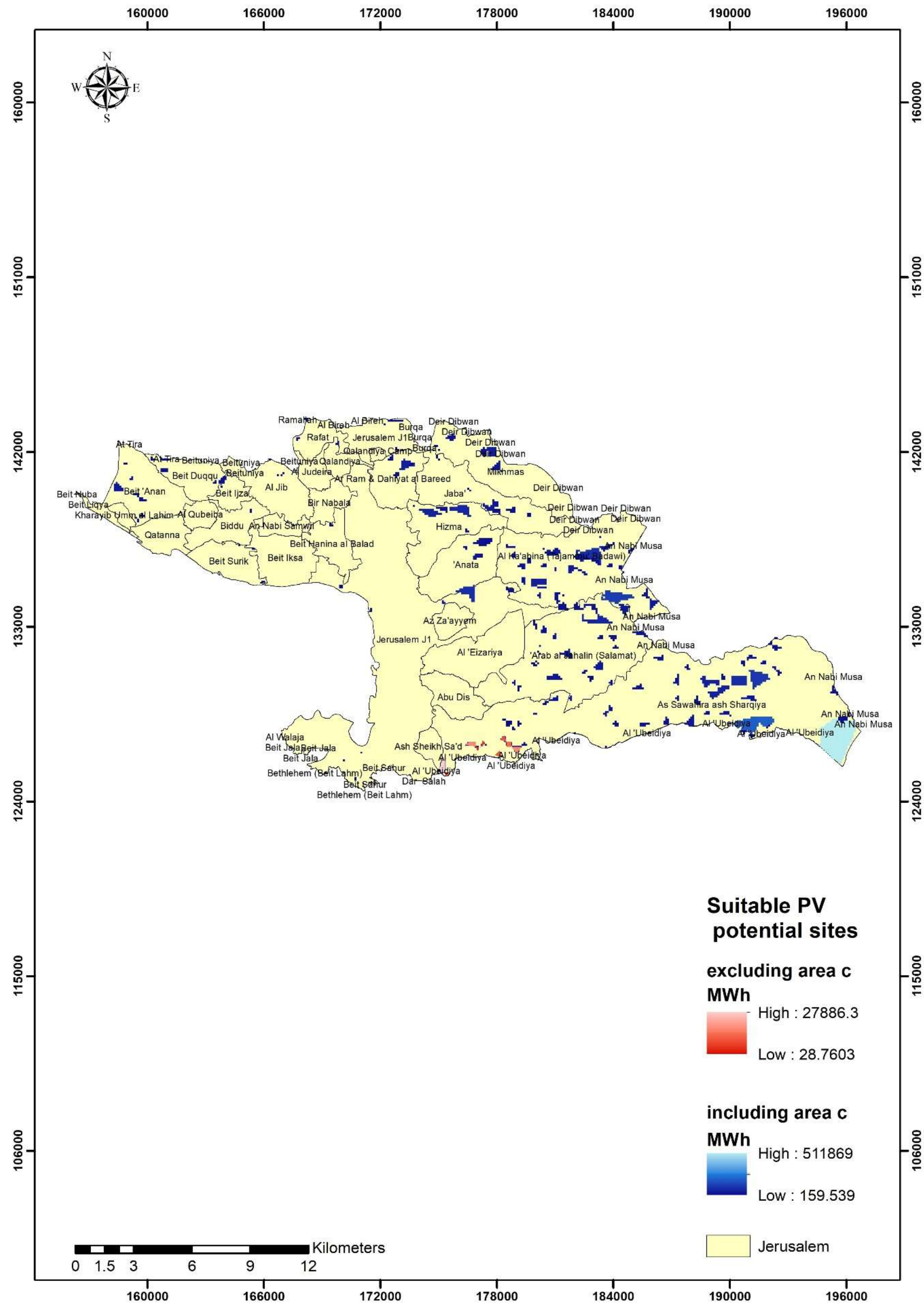


Figure 24: Suitable sites for PV systems in Jerusalem

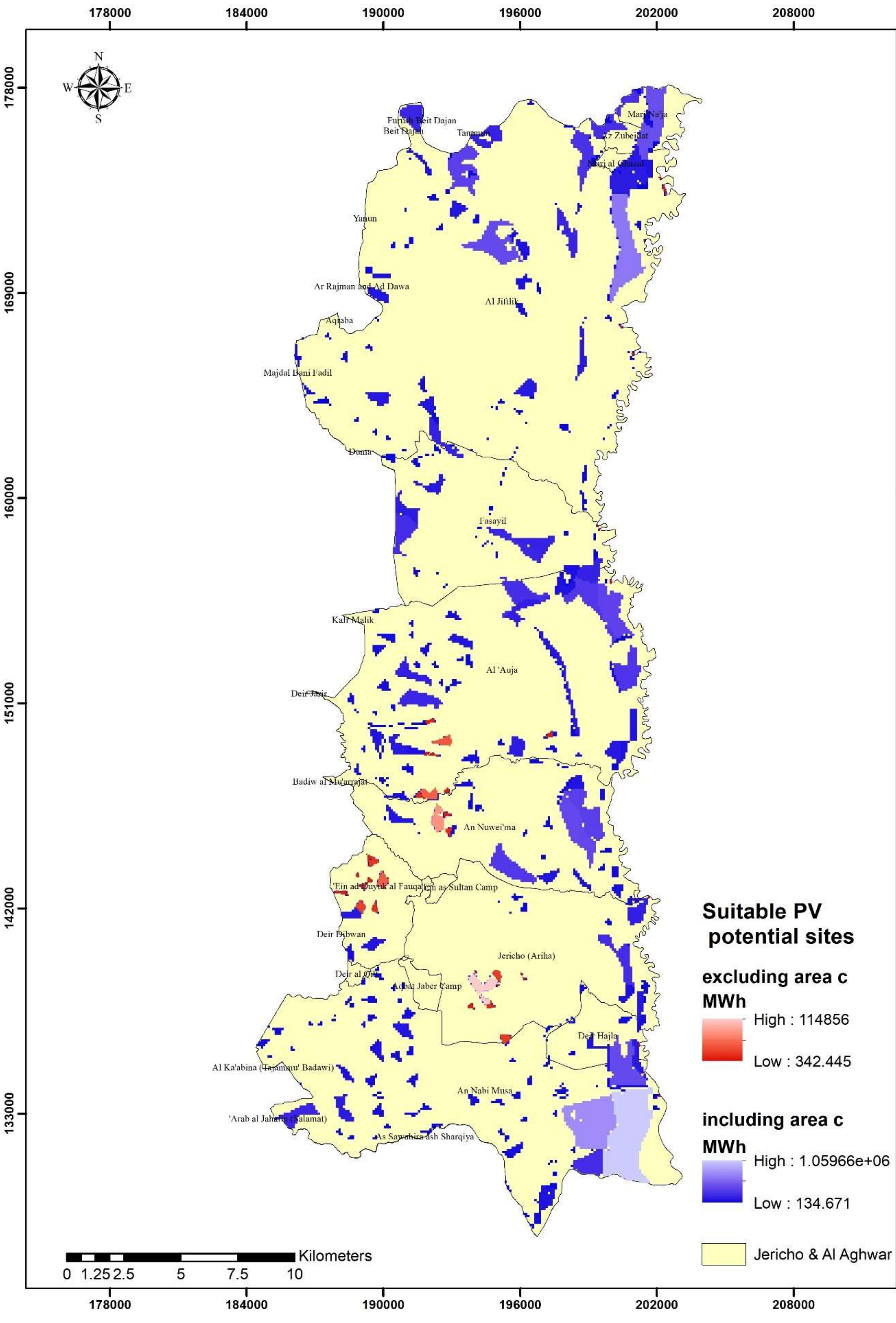


Figure 25: Suitable sites for PV systems in Jericho & Al-Aghwar

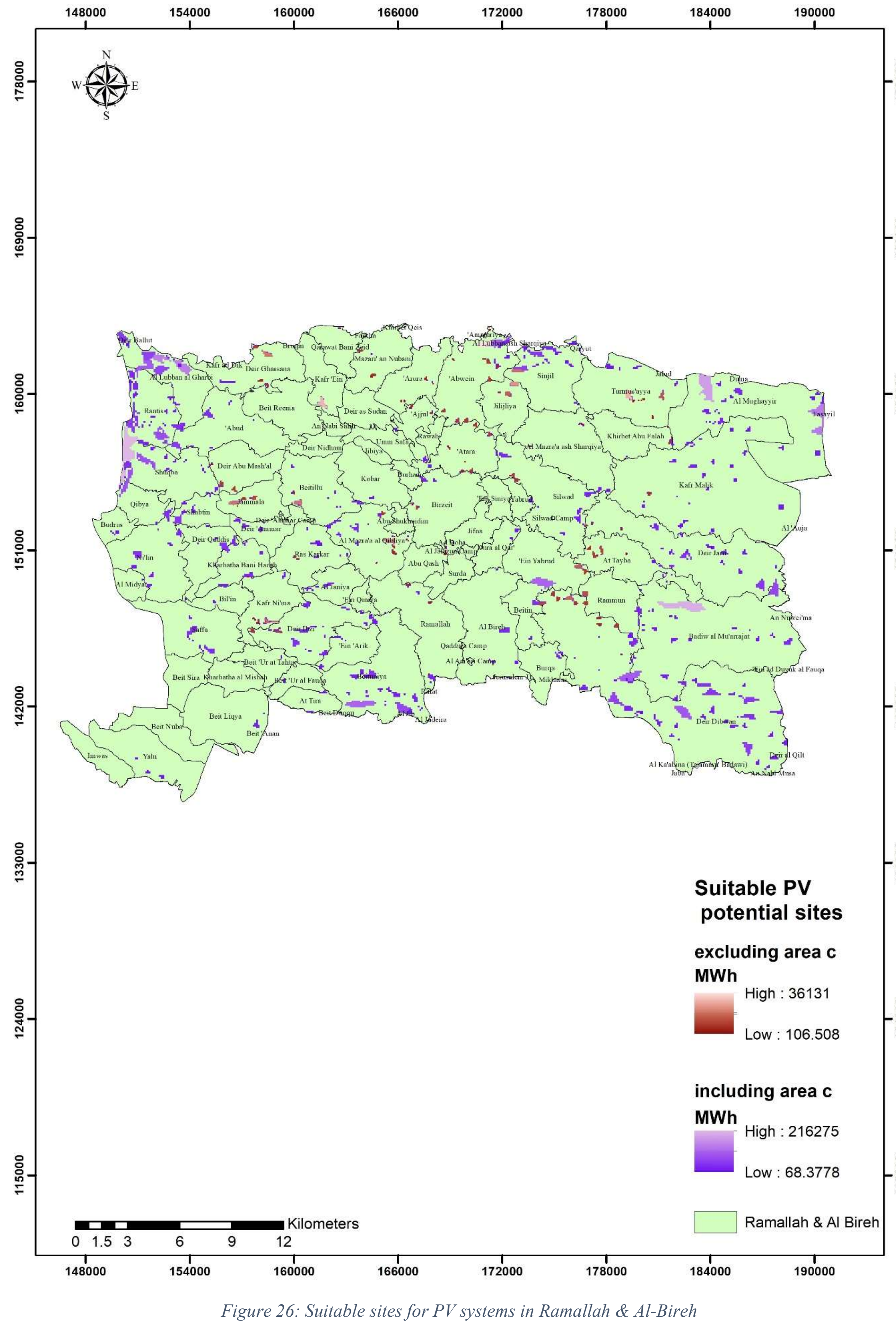


Figure 26: Suitable sites for PV systems in Ramallah & Al-Bireh

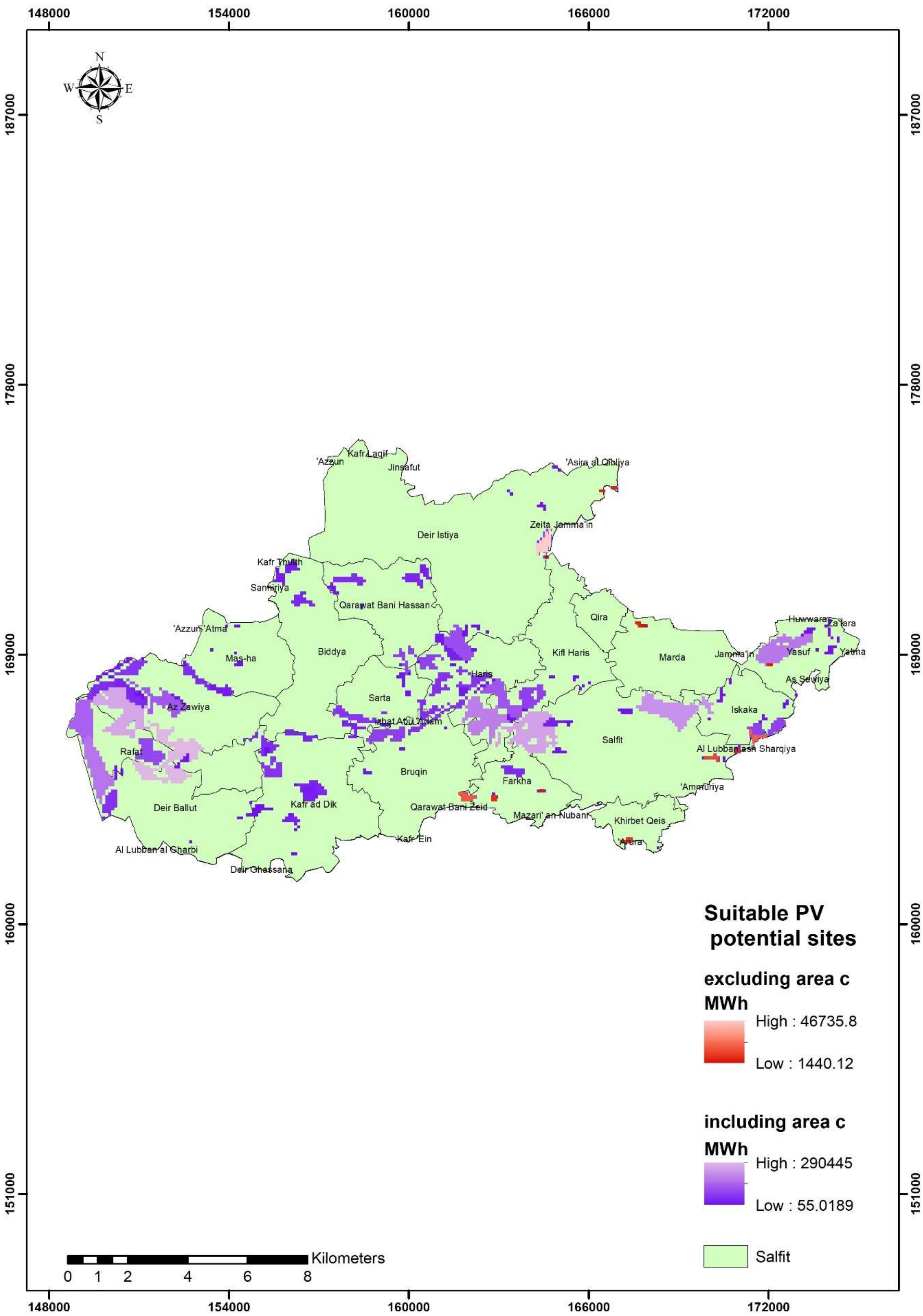


Figure 27: Suitable sites for PV systems in Salfit

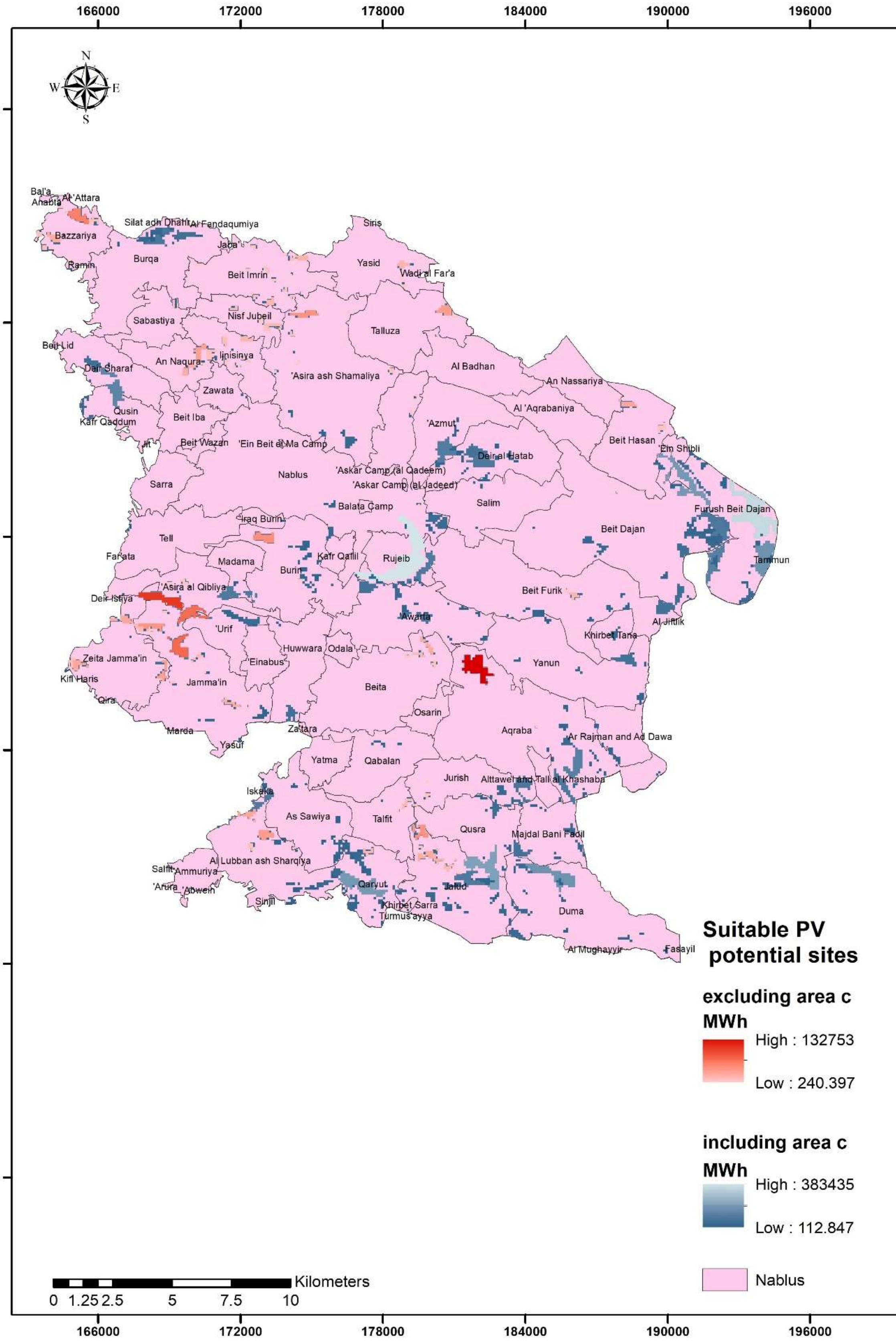


Figure 28: Suitable sites for PV systems in Nablus

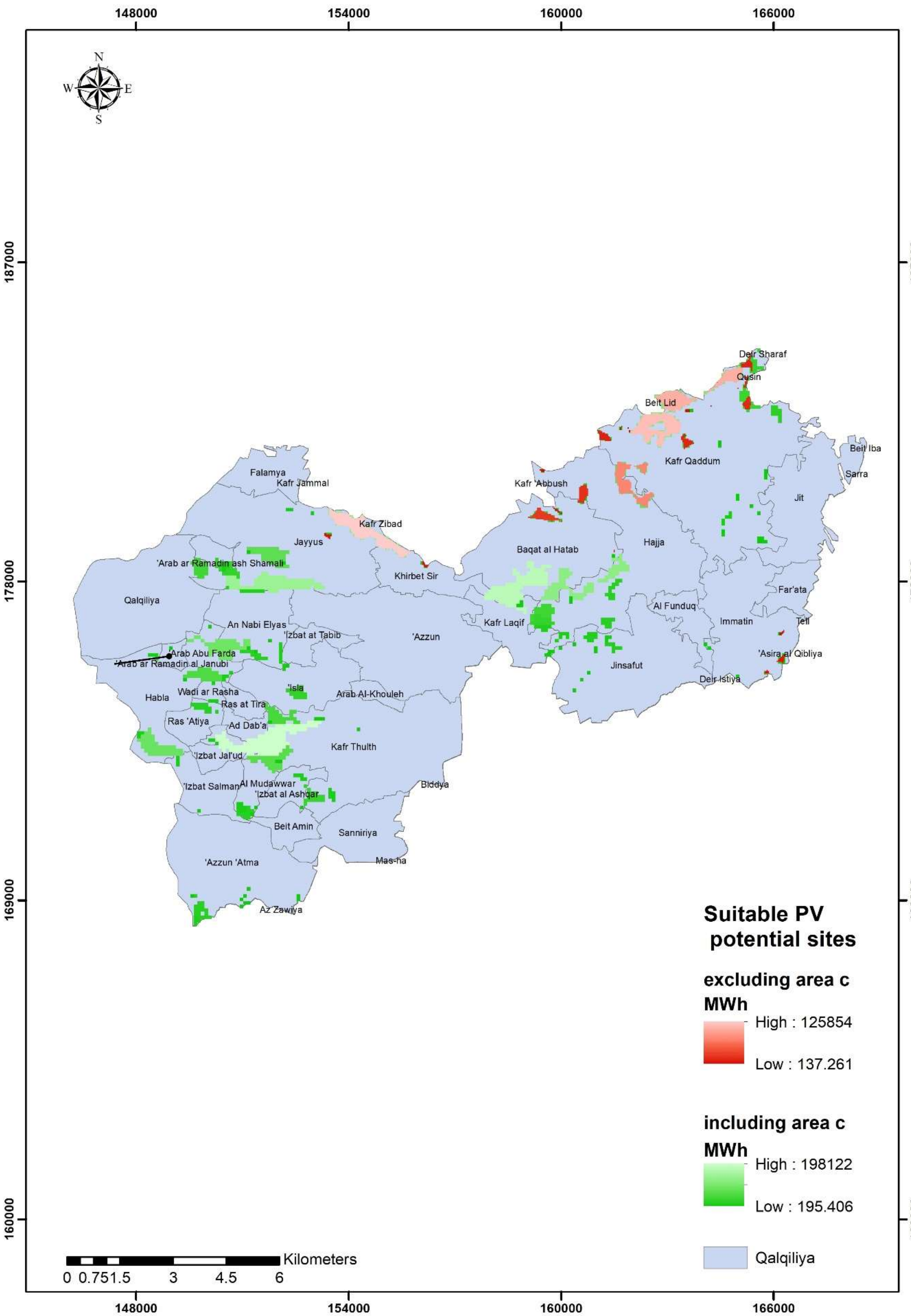


Figure 29: Suitable sites for PV systems in Qalqiliya

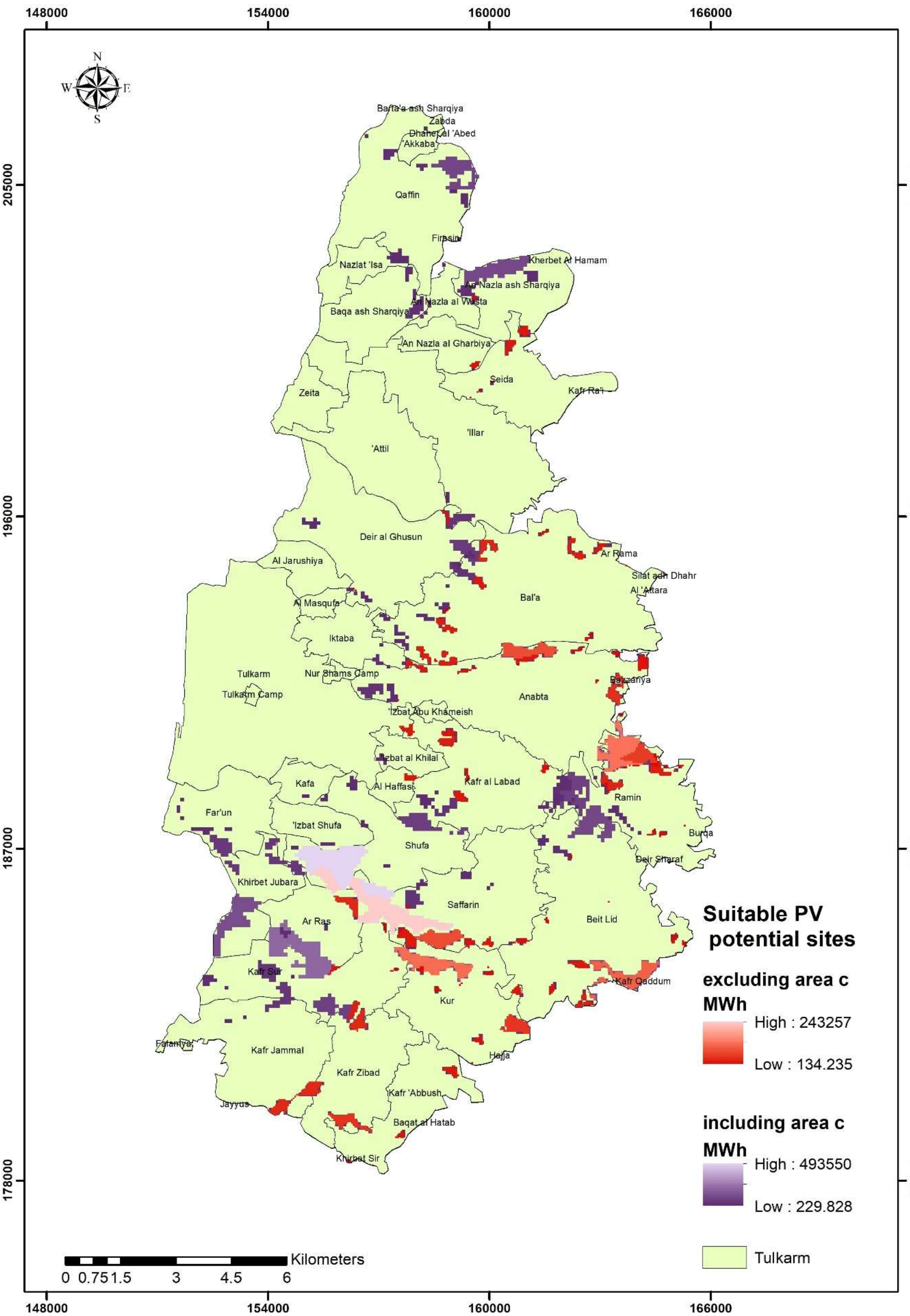


Figure 30: Suitable sites for PV systems in Tulkarm

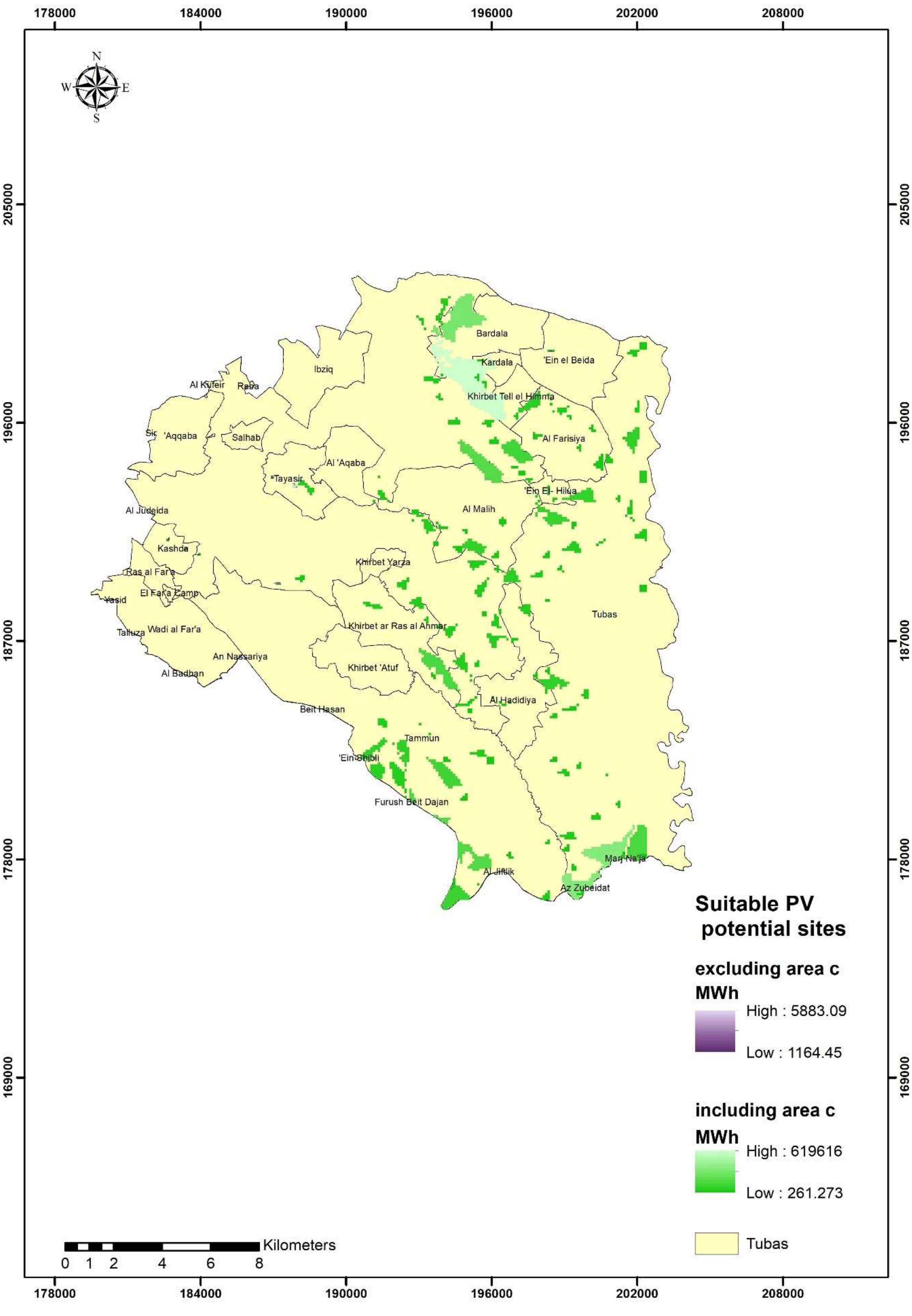


Figure 31: Suitable sites for PV systems in Tubas

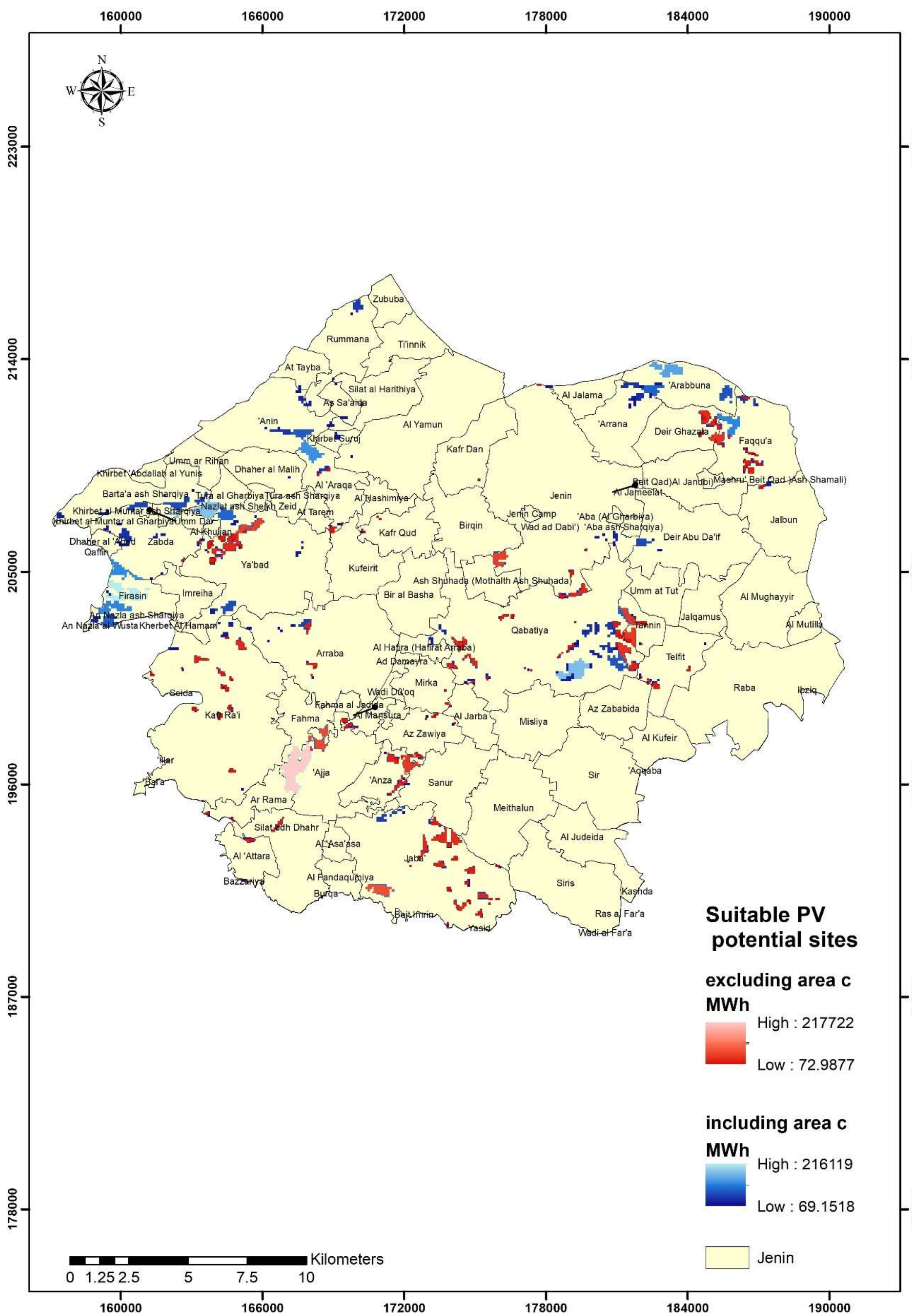


Figure 32:Suitable sites for PV systems in Jenin

- **CSP systems suitability maps**

In this application, we are targeting empty land with an area above 25,000 m^2, after excluding all the mentioned layers before and applying the weights in Table 10. This process was applied twice one while including area C in the study area, and the other excluding area C. The data were ranked on a scale 1 to 4 considering 4 is the most suitable and 1 is the least suitable, each governorate was analyzed on its own for better-detailed resulted in locations and the equations mentioned before were applied to calculate the potential for each area.

The total high suitable available areas for CSP systems including area C is 13.63 km^2 with an approximate production of 1,719 GWh per year while excluding area C will result in a 2.81 km^2 of an available area with an approximate production of 319 GWh annually.

The following figures [33 to 41] represent suitable areas for CSP systems in each governorate including and excluding area C in the same map for each. Table 14 shows the resulted data in numbers for each governorate including area C, as shown in Jerusalem, Ramallah & Al-Bireh have zero potential for CSP systems investments, and Hebron as the highest potential with about 3.65 km^2 of available area for CSP systems investments with an annual potential of 460 GWh.

Table 14: Potential and available area for each Governorate for CSP systems including area C

Governorate	Area (km^2)	The annual potential of areas (GWh)
Jerusalem	-	-
Ramallah & Al Bireh	-	-
Bethlehem	0.37	46
Tubas	0.43	55
Qalqiliya	0.51	65
Jenin	1.10	139
Tulkarm	1.23	155
Salfit	1.47	185
Nablus	1.47	185
Jericho & Al Aghwar	3.40	429
Hebron	3.65	460

While

Table 15 shows the resulted data for each governorate excluding area C, as shown, adding to Jerusalem, Ramallah & Al-Bireh, there is also Tubas, Salfit and Bethlehem were excluded with zero potential CSP systems, and Hebron as the highest potential with about 1.26 km^2 and an annual potential of 159 GWh.

Table 15: Potential and available area for each Governorate for CSP systems excluding area C

Governorate	Area (km^2)	The annual potential of areas (GWh)
Jerusalem	-	-
Tubas	-	-
Salfit	-	-
Ramallah & Al Bireh	-	-
Bethlehem	-	-
Nablus	0.06	8
Qalqiliya	0.07	9
Jericho & Al Aghwar	0.31	4
Tulkarm	0.51	65
Jenin	0.59	74
Hebron	1.26	159

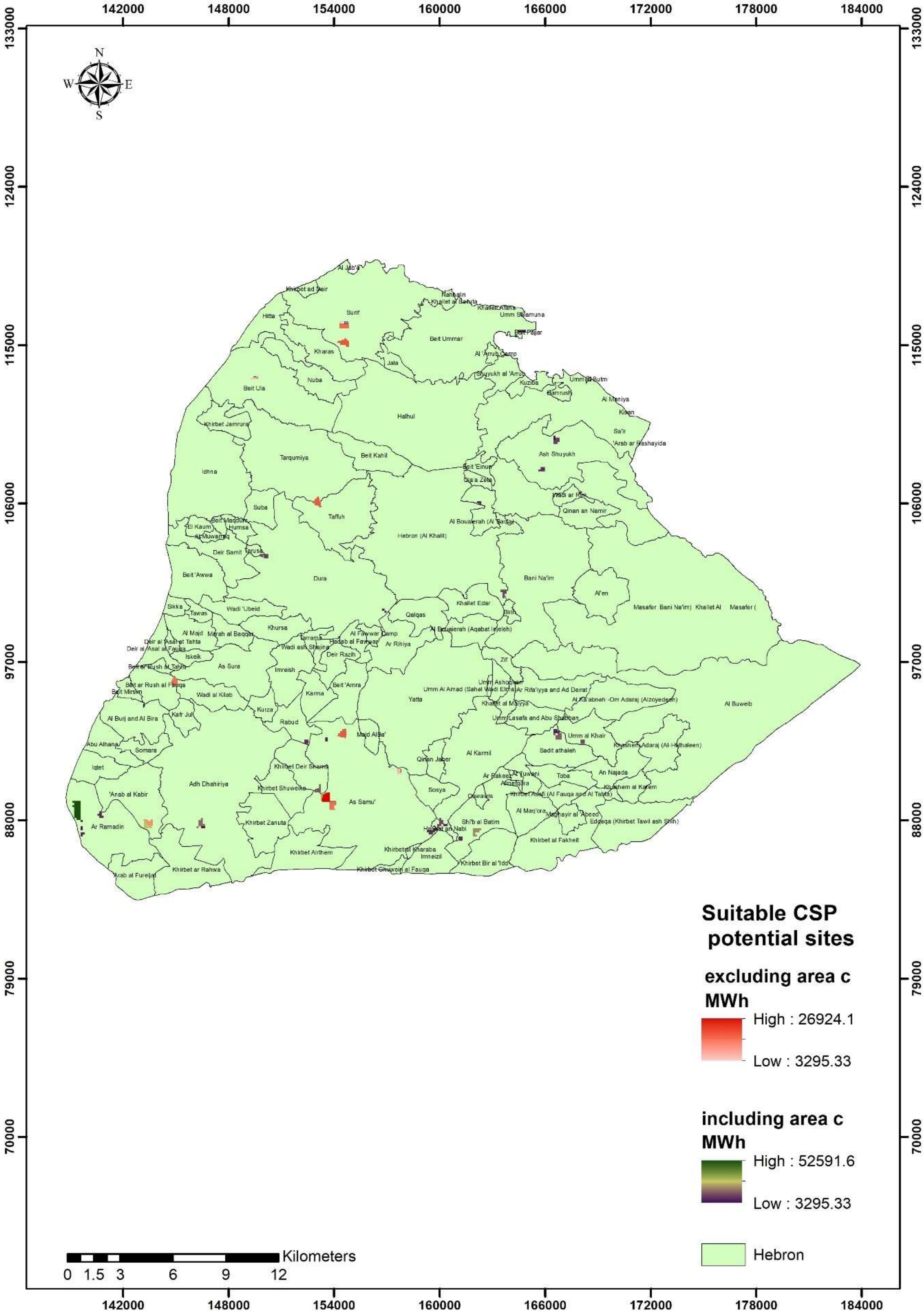


Figure 33: Suitable sites for CSP systems in Hebron

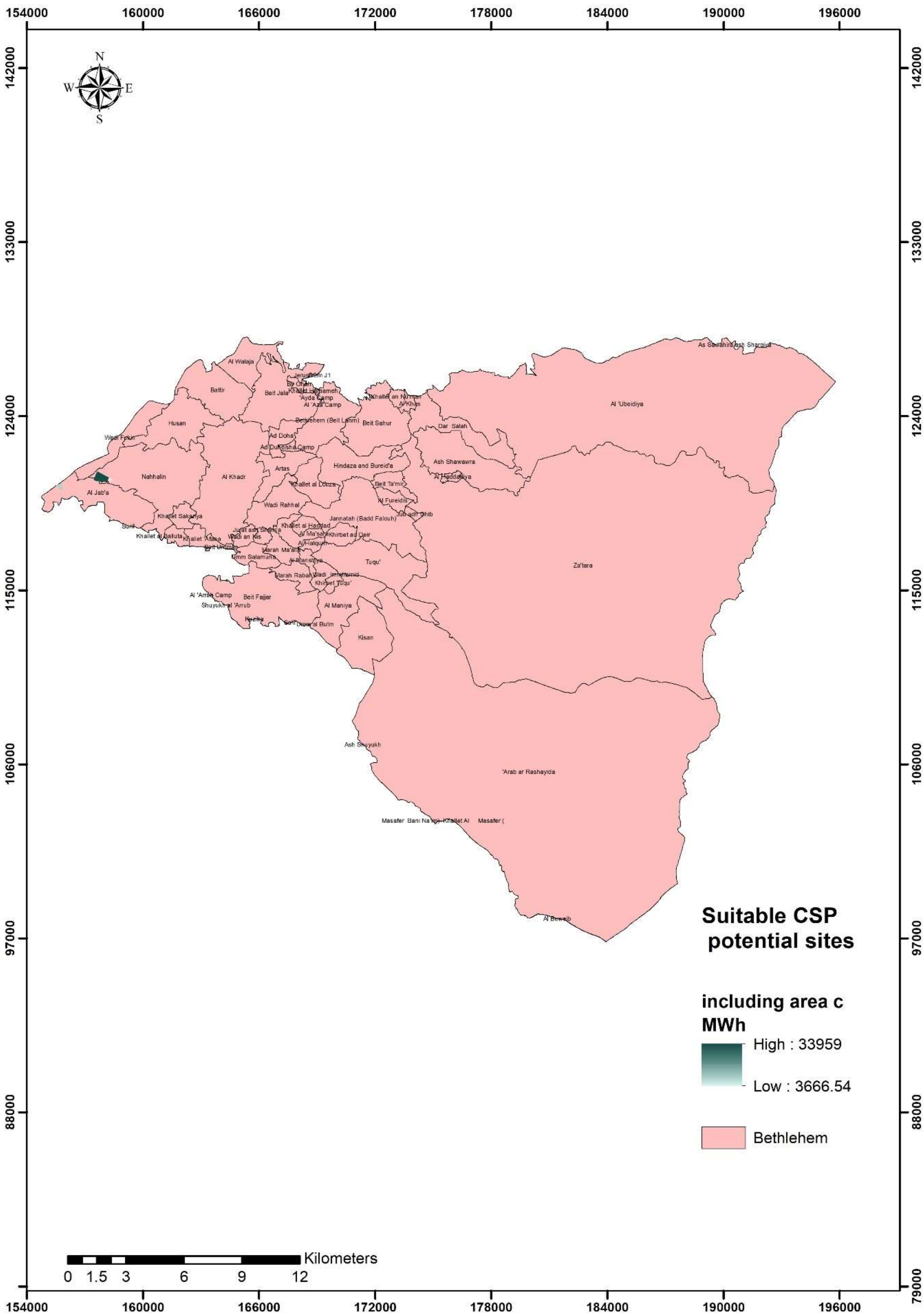


Figure 34: Suitable sites for CSP systems in Bethlehem

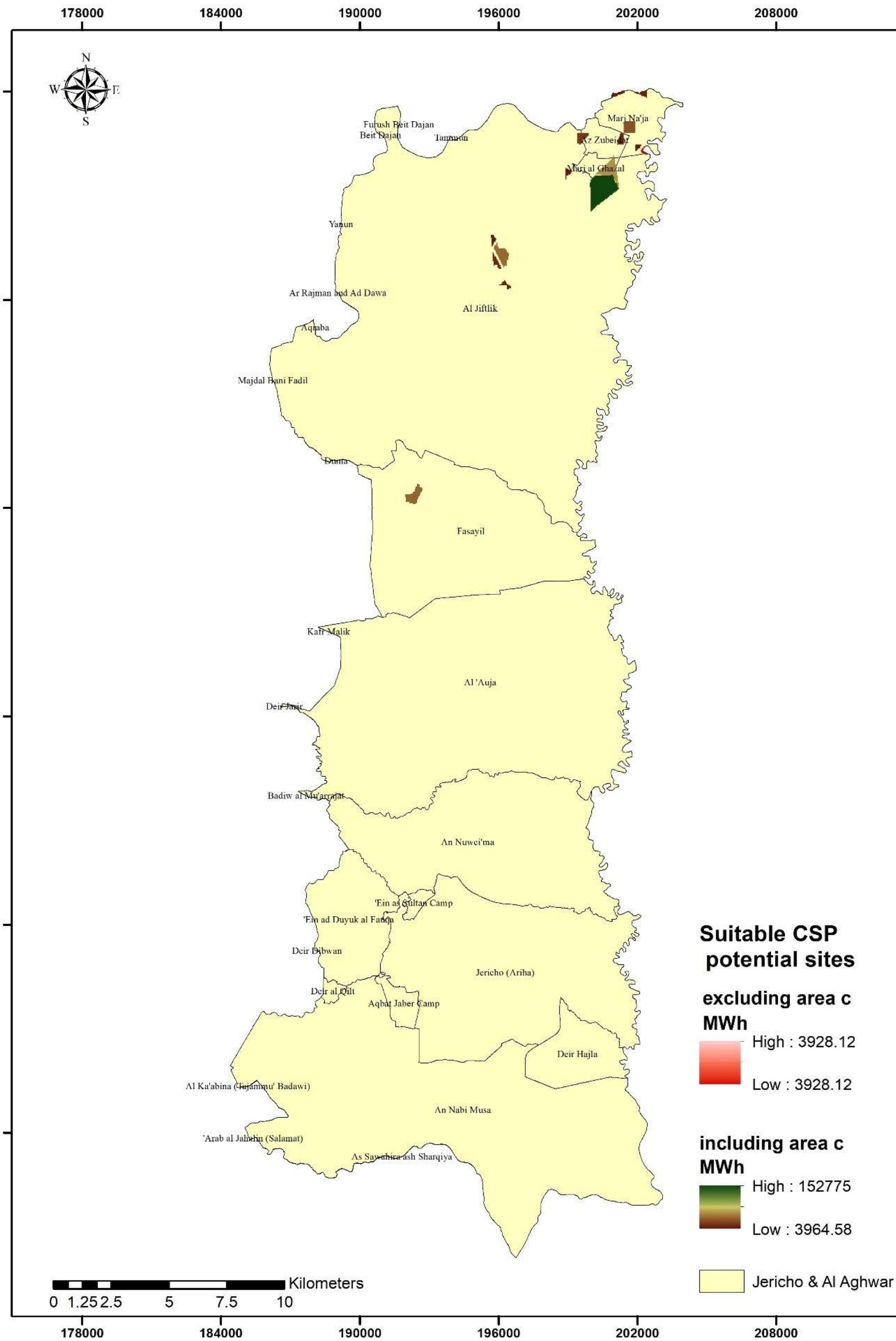


Figure 35: Suitable sites for CSP systems in Jericho & AL-Aghwar

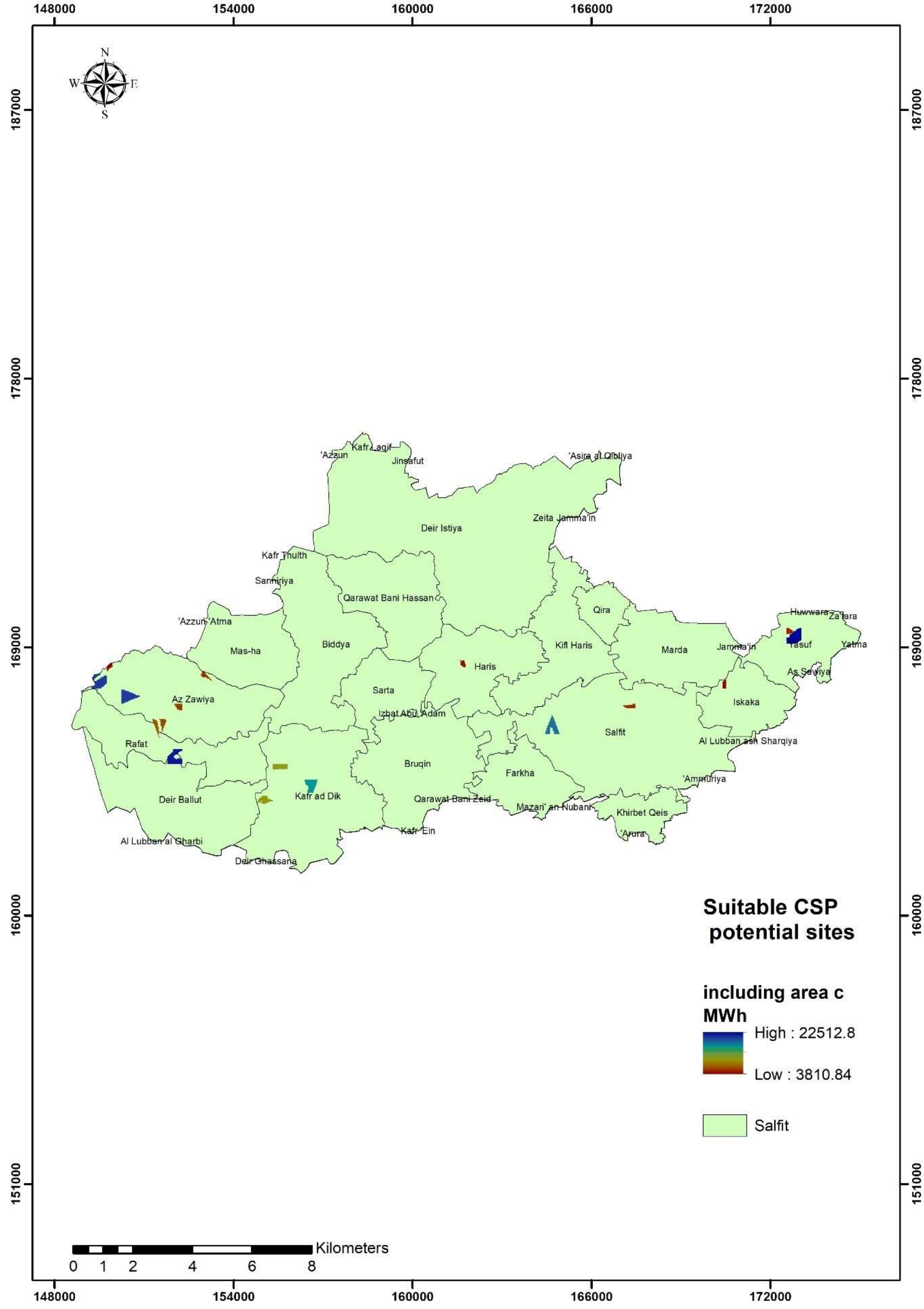


Figure 36: Suitable sites for CSP systems in Salfit

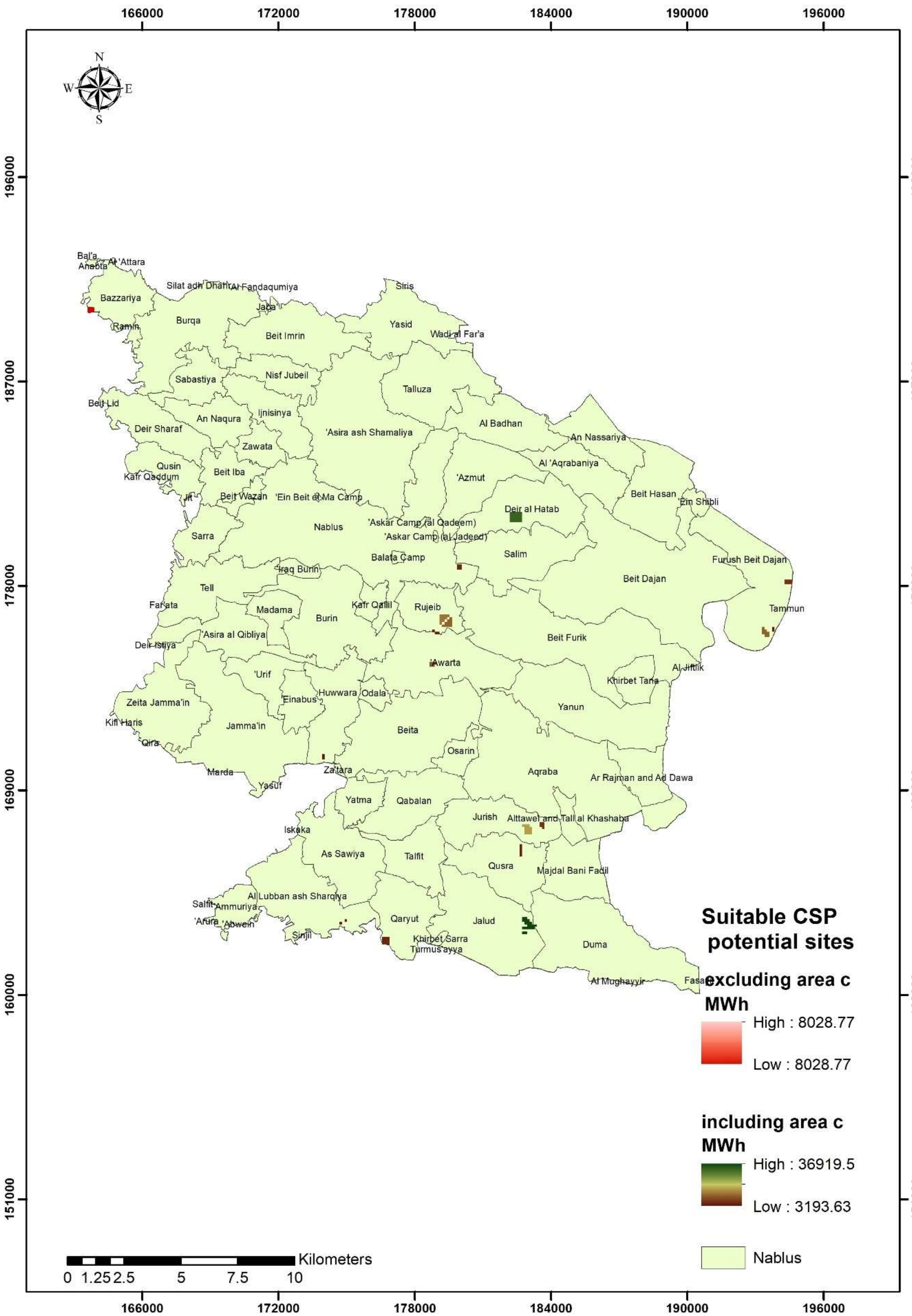


Figure 37: Suitable sites for CSP systems in Nablus

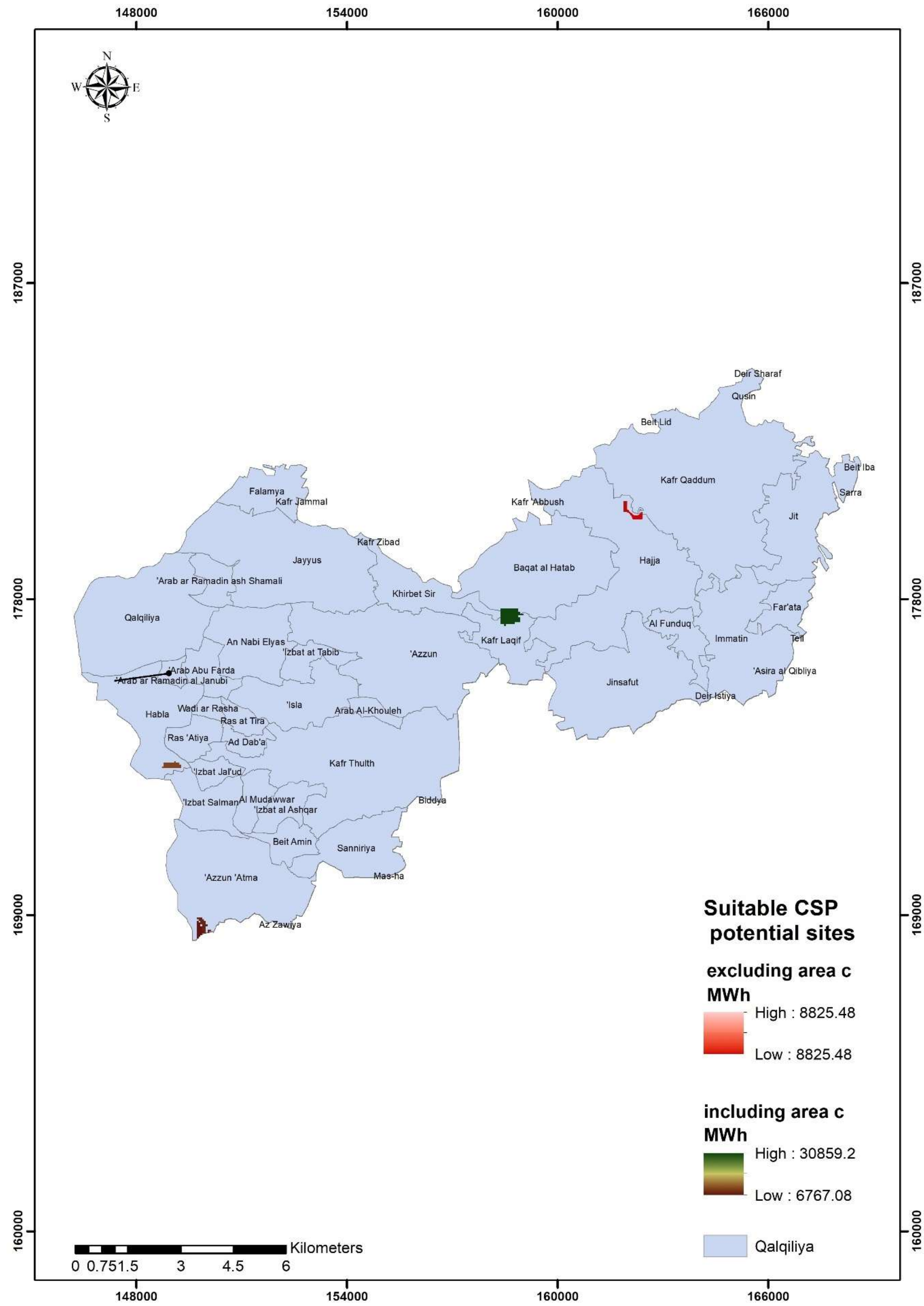


Figure 38: Suitable sites for CSP systems in Qalqiliya

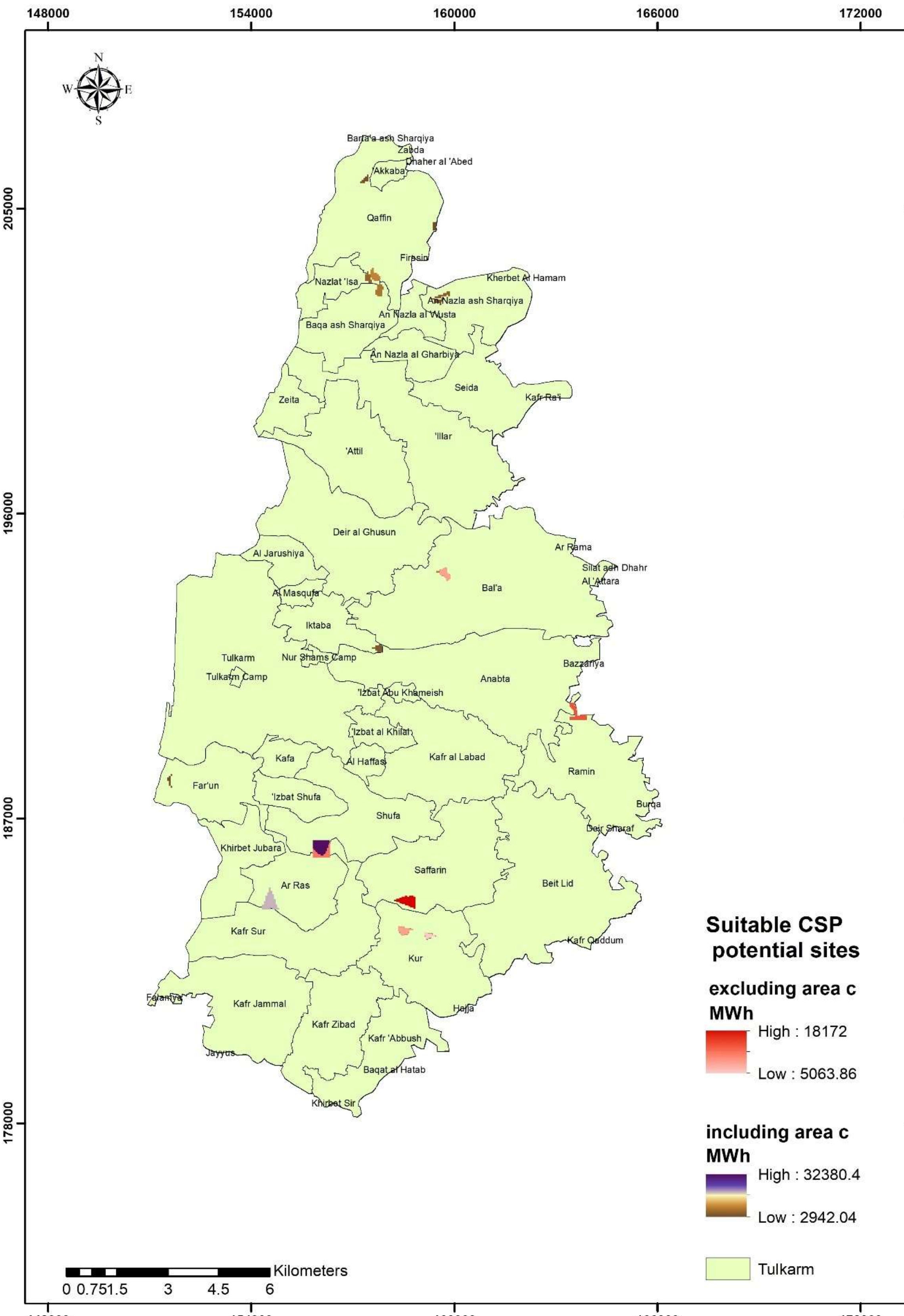


Figure 39: Suitable sites for CSP systems in Tulkarm

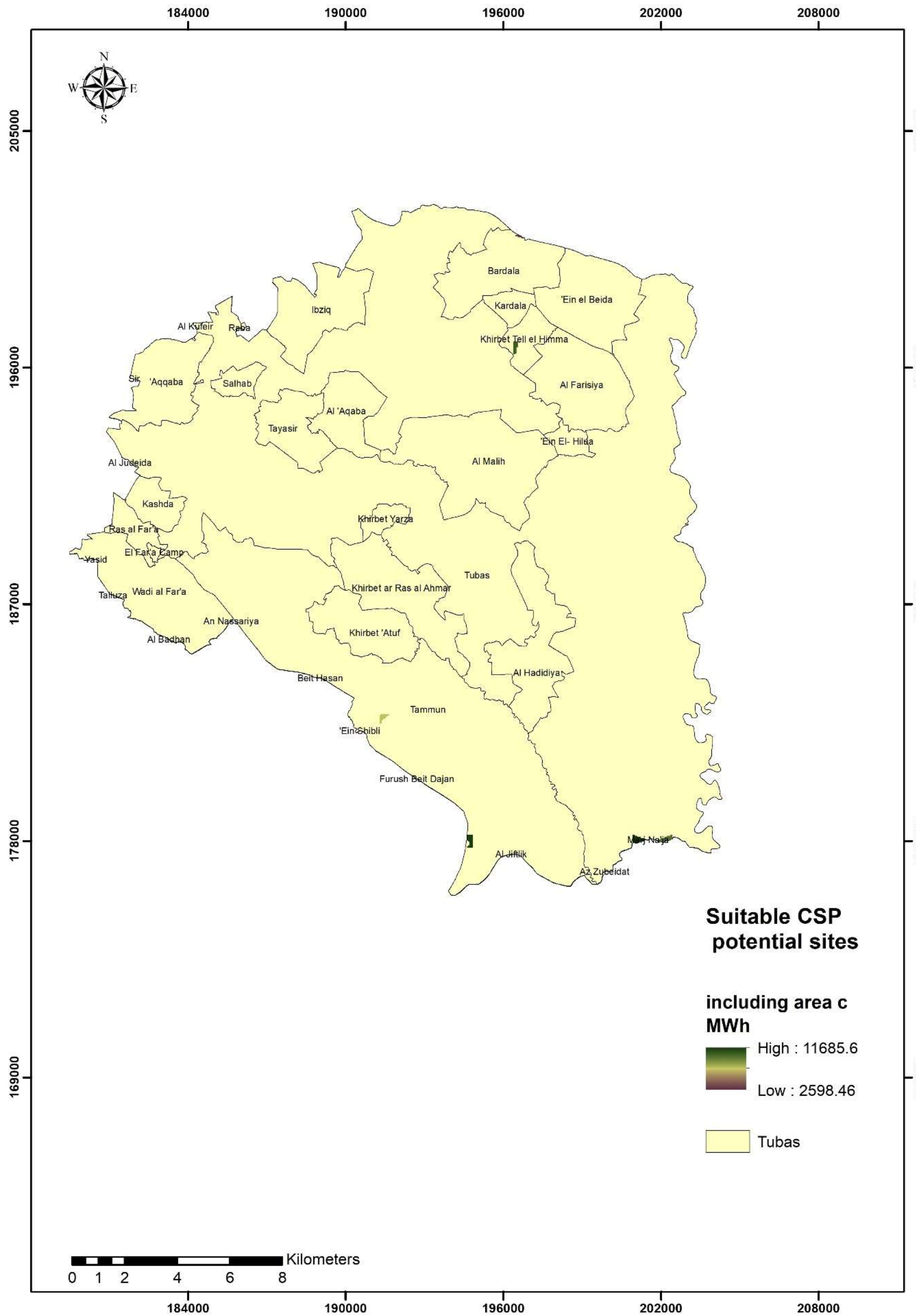


Figure 40: Suitable sites for CSP systems in Tubas

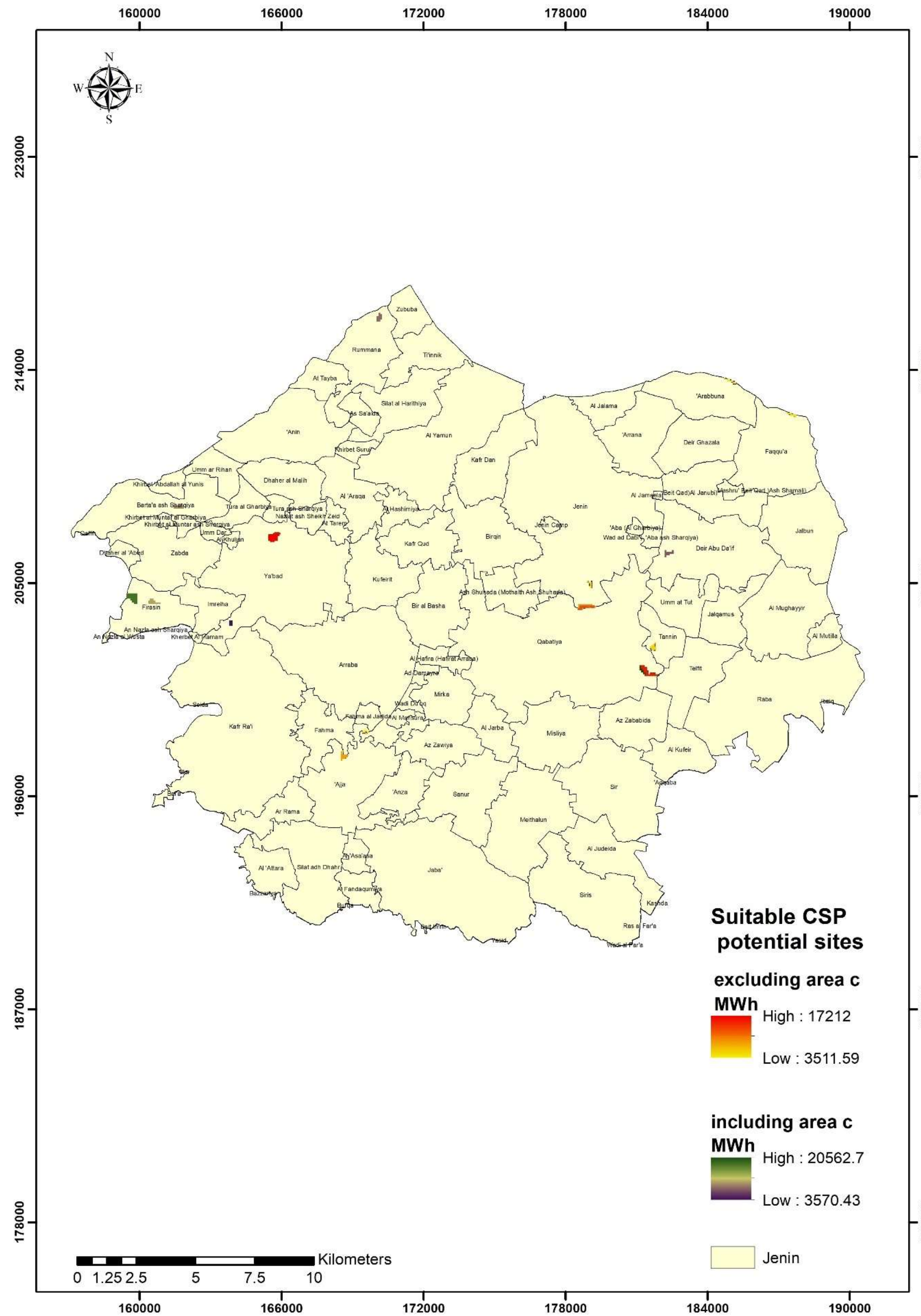


Figure 41:Suitable sites for CSP systems in Jenin

- **Wind systems suitability map**

In this application, we didn't target specific areas of empty land, since the spacing area between each wind turbine differs from one type to another depending on many factors, we are not interested to discuss it in this study now.

After excluding all the mentioned layers except the Agricultural land classification before and applying the weights in Table 11. This process was applied twice one while including area C in the study area, and the other excluding area C. The data were ranked on a scale 1 to 4 considering 4 is the most suitable and 1 is the least suitable, each governorate was analyzed on its own for better-detailed resulted in locations, and the equations mentioned before were applied to calculate the potential for each area.

The total high and moderately suitable available areas for Wind systems including area C is 267 km^2 with an approximate production of 0.13 GWh/m^2 per year while excluding area C will result in a 121 km^2 of an available area with an approximate production of 0.0719 GWh/m^2 annually.

The following figures [42 to 52] represent suitable areas for wind systems in each governorate including and excluding area C in the same map for each. Table 16 shows the resulted data in numbers for each governorate including area C, as shown Jericho & Al-Aghwar have the lowest potential with only 2.43 km^2 available for good investments for wind systems, and Nablus as the highest potential with about 83.84 km^2 of available area for wind systems investments with an annual potential of 0.029 GWh/m^2.

Table 16: Potential and available area for each Governorate for wind systems including area C

Governorate	Area (km^2)	The annual potential per area (GWh/m^2)
Jericho & Al Aghwar	2.43	0.002
Tulkarm	3.65	0.004
Qalqiliya	5.87	0.001
Salfit	6.80	0.001
Jerusalem	8.33	0.009
Bethlehem	16.33	0.015
Tubas	16.69	0.009
Ramallah & Al Bireh	29.59	0.017
Jenin	42.97	0.018
Hebron	50.51	0.023
Nablus	83.84	0.029

While

Table 17 shows the resulted data for each governorate excluding area C, as shown, Jericho and Al-Aghwar have zero potential for wind systems investments and Nablus has the highest potential with about 43 km^2 and an annual potential of 0.0202 GWh/m^2

Table 17: Potential and available area for each Governorate for wind systems excluding area C

Governorate	Area (km^2)	The annual potential per area (GWh/m^2)
Jericho & Al Aghwar	0.000	0.0000
Salfit	0.097	0.0004
Jerusalem	0.669	0.0013
Qalqiliya	1.760	0.0003
Tulkarm	2.703	0.0032
Tubas	5.291	0.0015
Bethlehem	6.082	0.0082
Ramallah & Al Bireh	14.330	0.0083
Hebron	22.274	0.0136
Jenin	24.558	0.0150
Nablus	43.327	0.0202

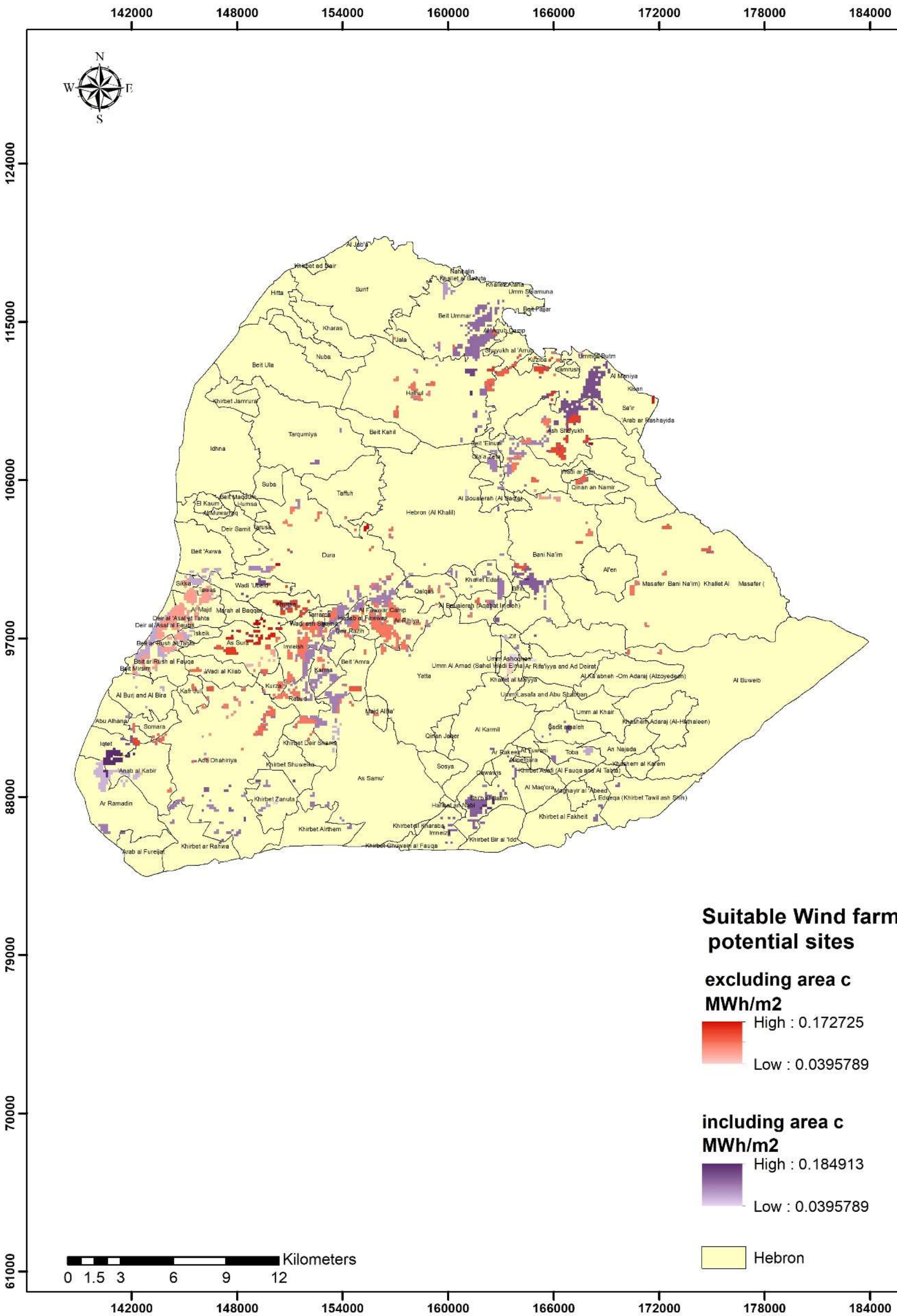


Figure 42: Suitable sites for Wind systems in Hebron

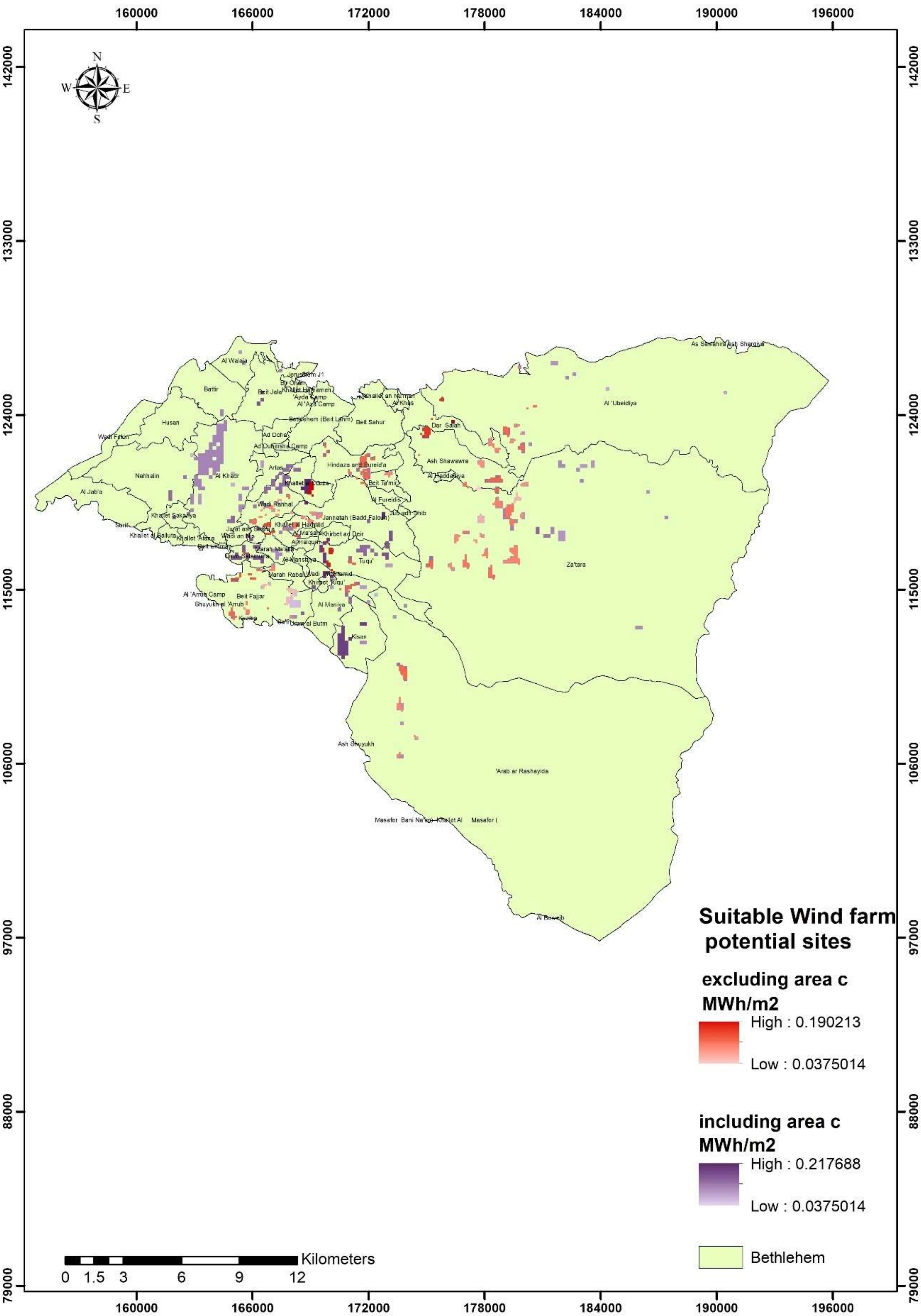


Figure 43: Suitable sites for Wind systems in Bethlehem

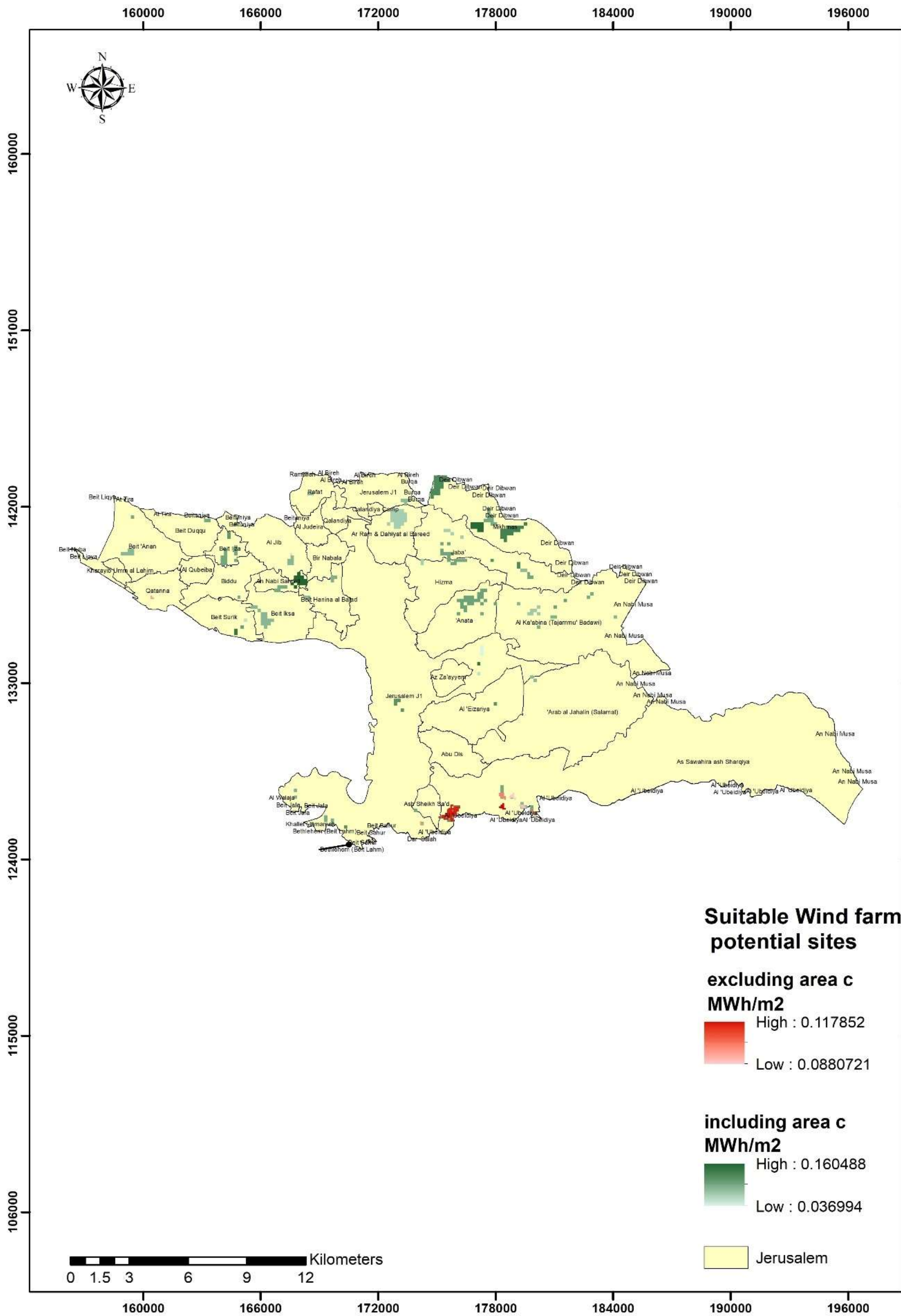


Figure 44: Suitable sites for Wind systems in Jerusalem

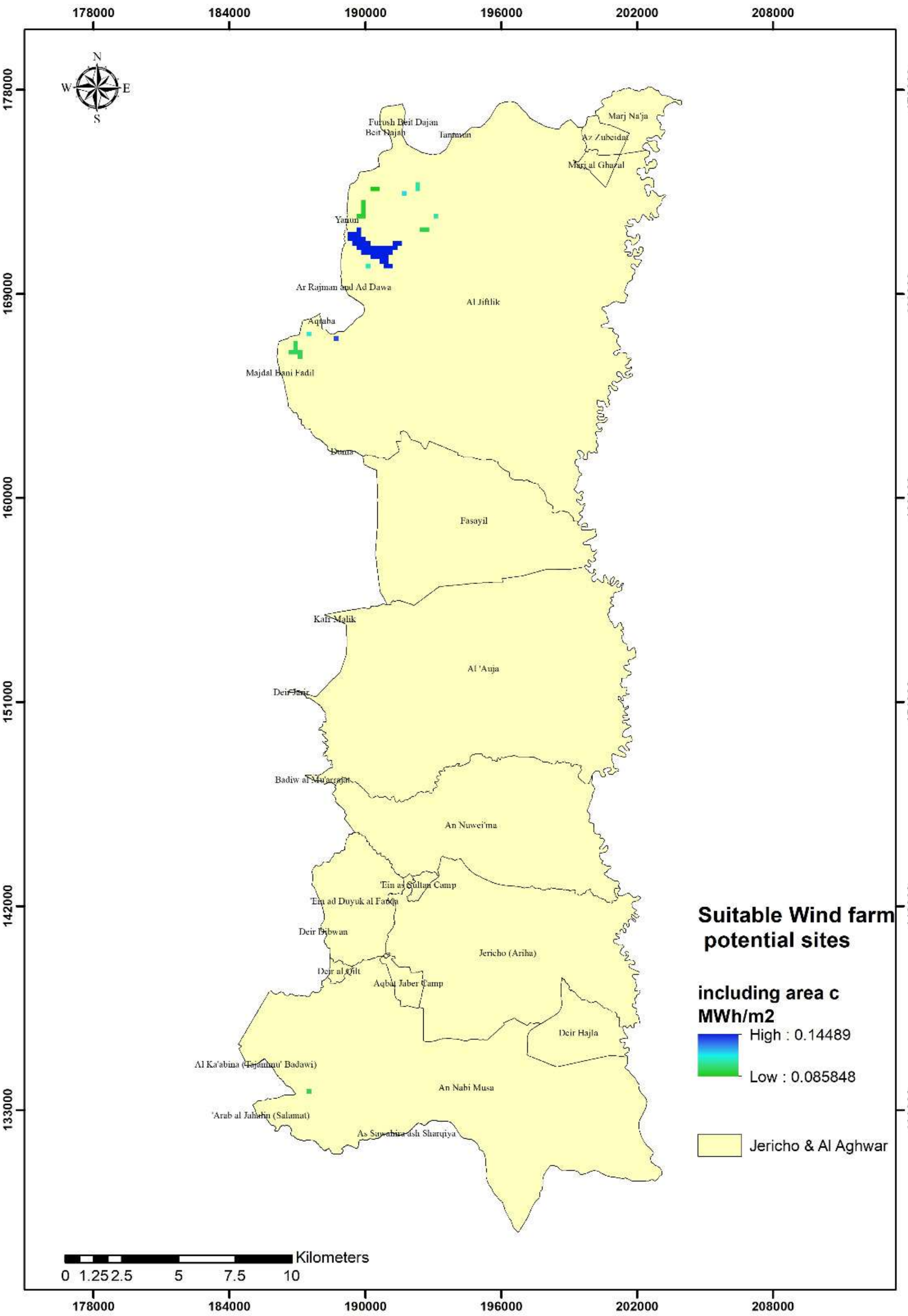


Figure 45: Suitable sites for Wind systems in Jericho & Al-Aghwar

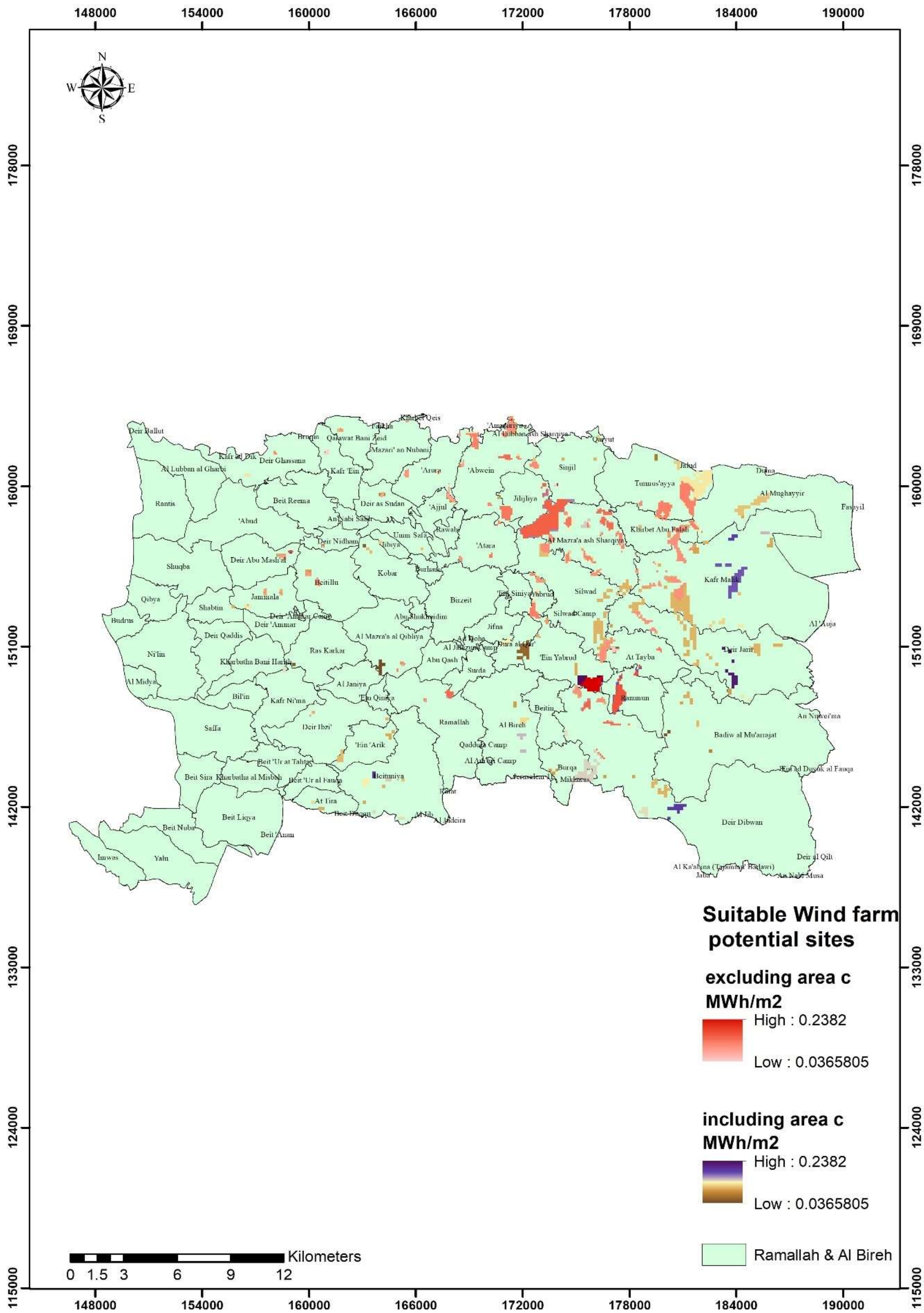


Figure 46: Suitable sites for Wind systems in Ramallah & Al-Bireh

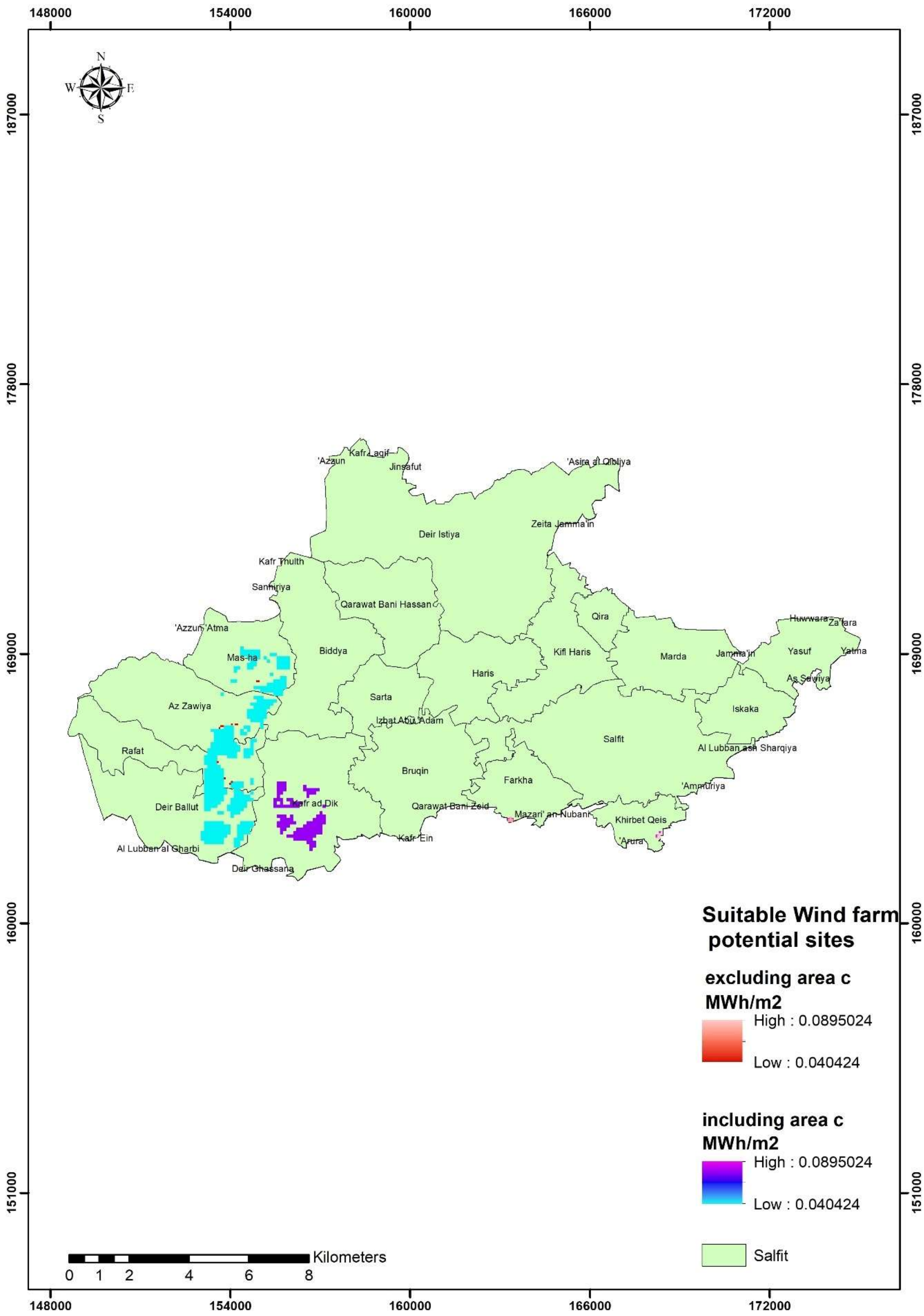


Figure 47: Suitable sites for Wind systems in Salfit

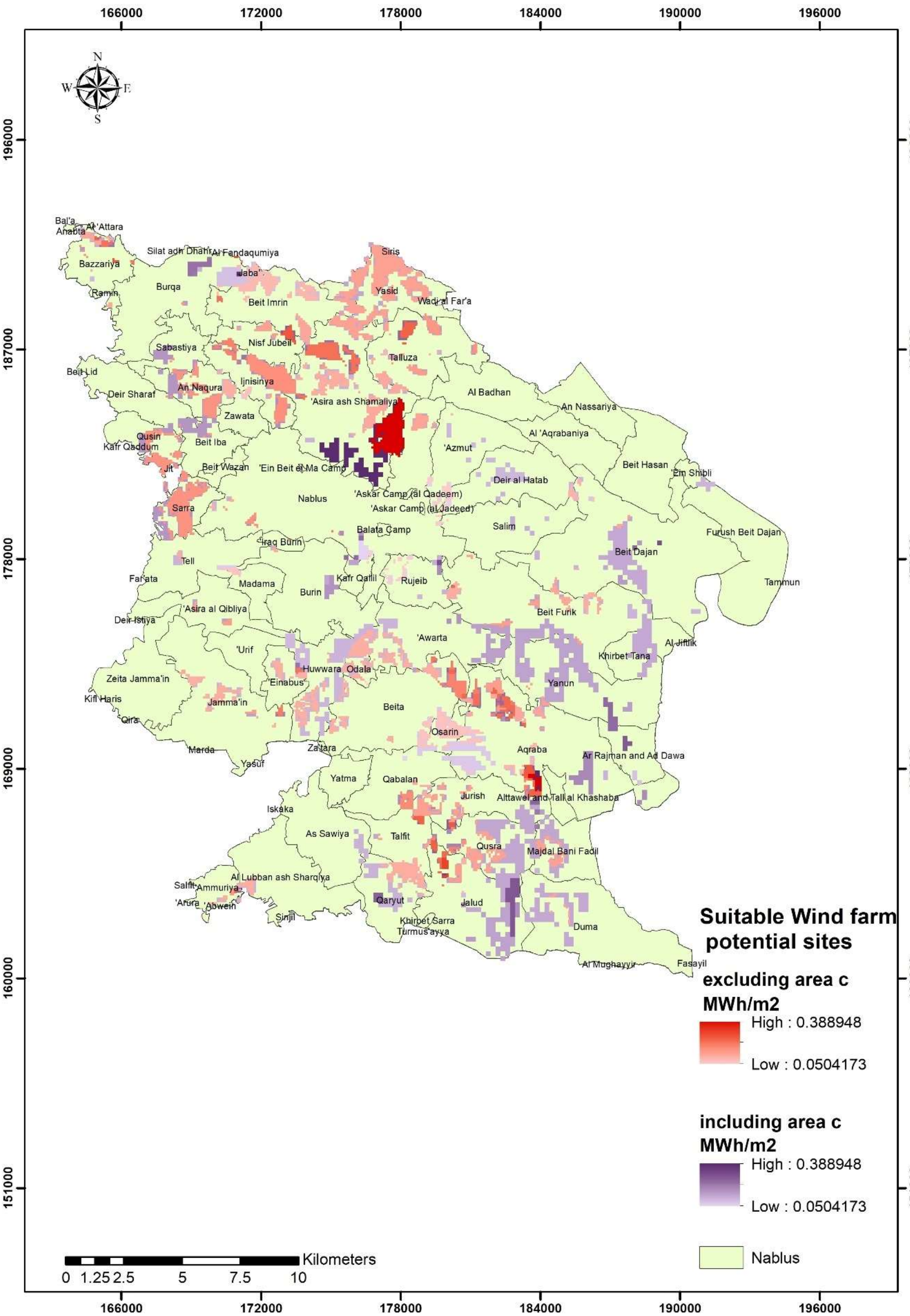


Figure 48: Suitable sites for Wind systems in Nablus

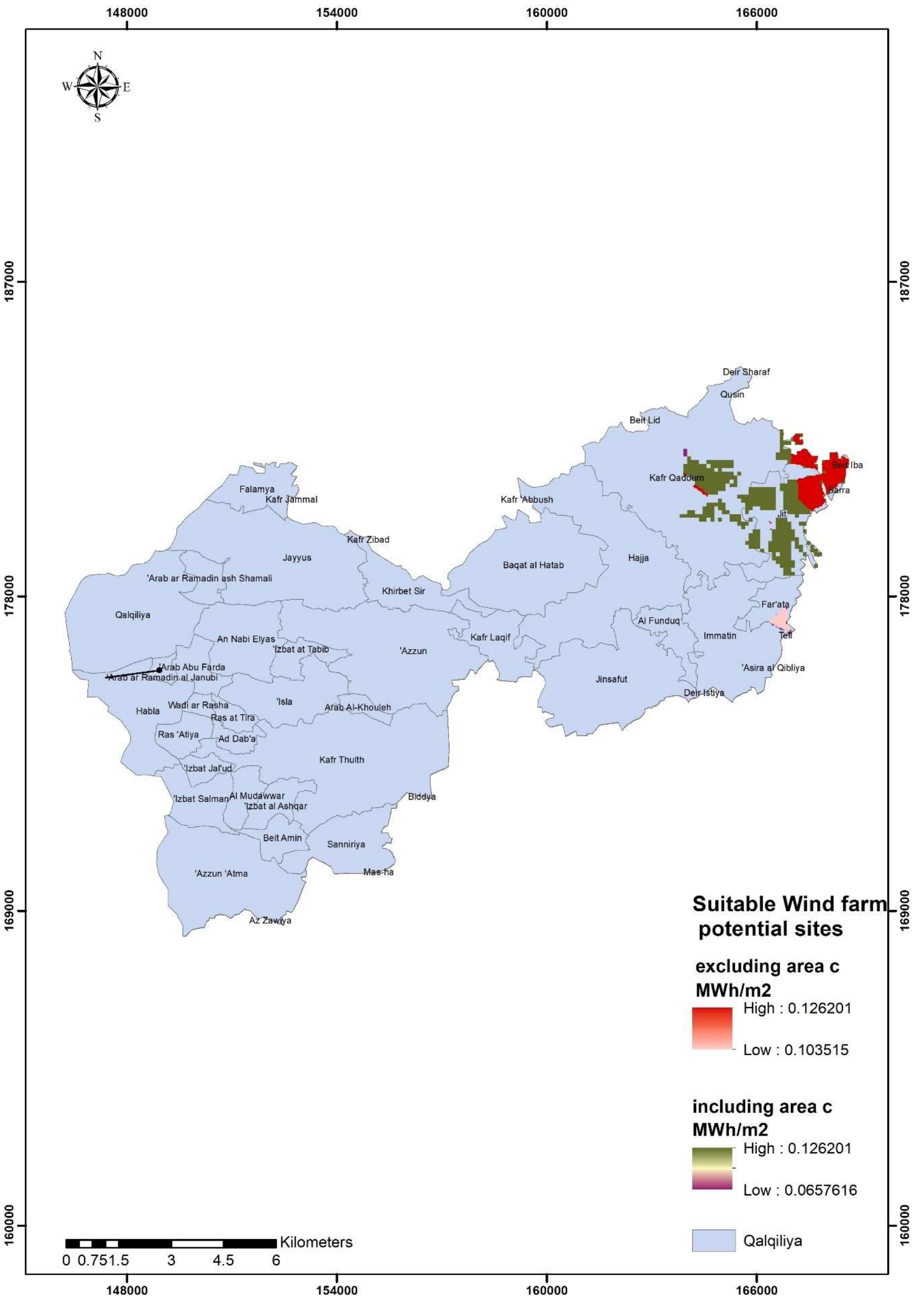


Figure 49: Suitable sites for Wind systems in Qalqiliya

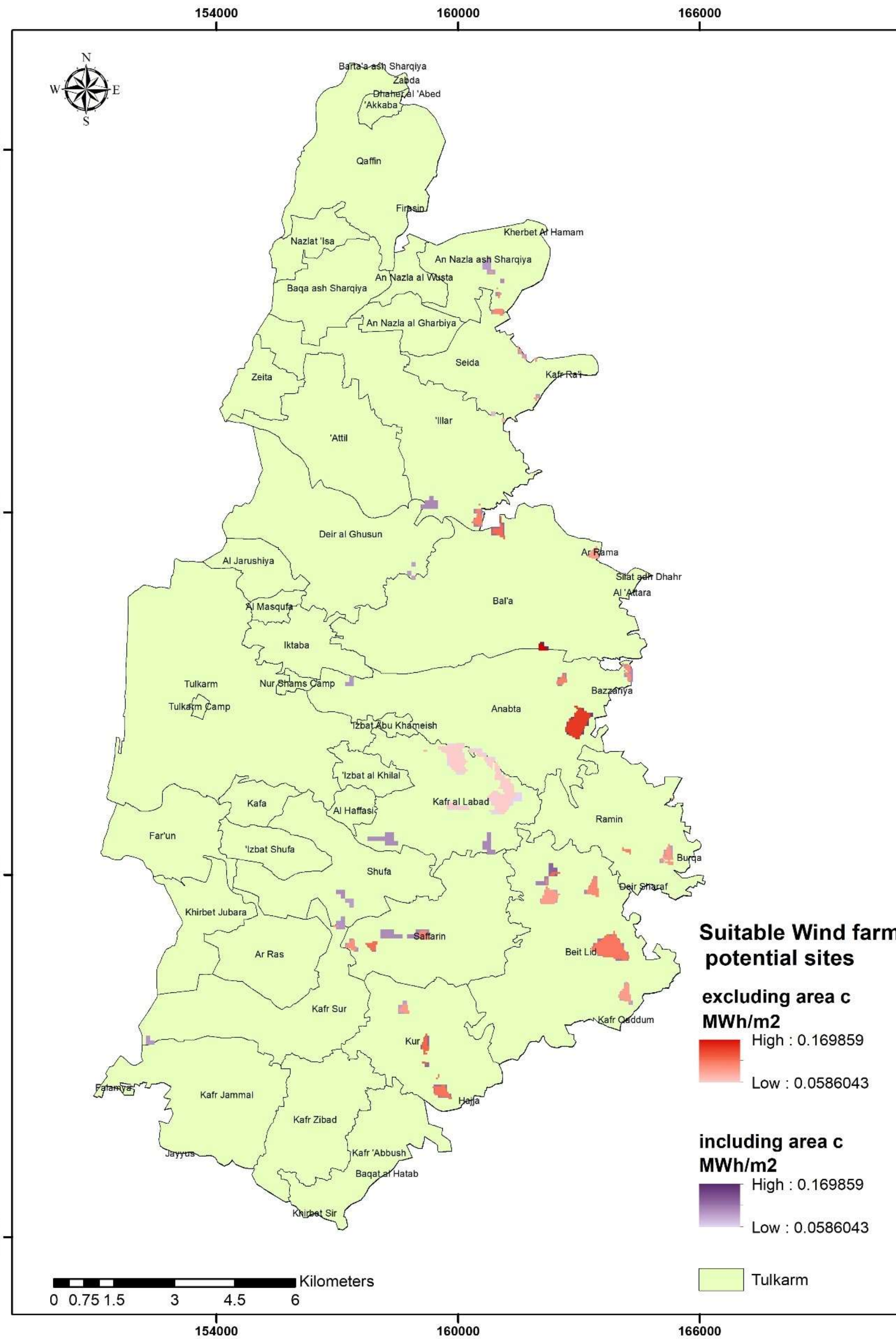


Figure 50: Suitable sites for Wind systems in Tulkarm

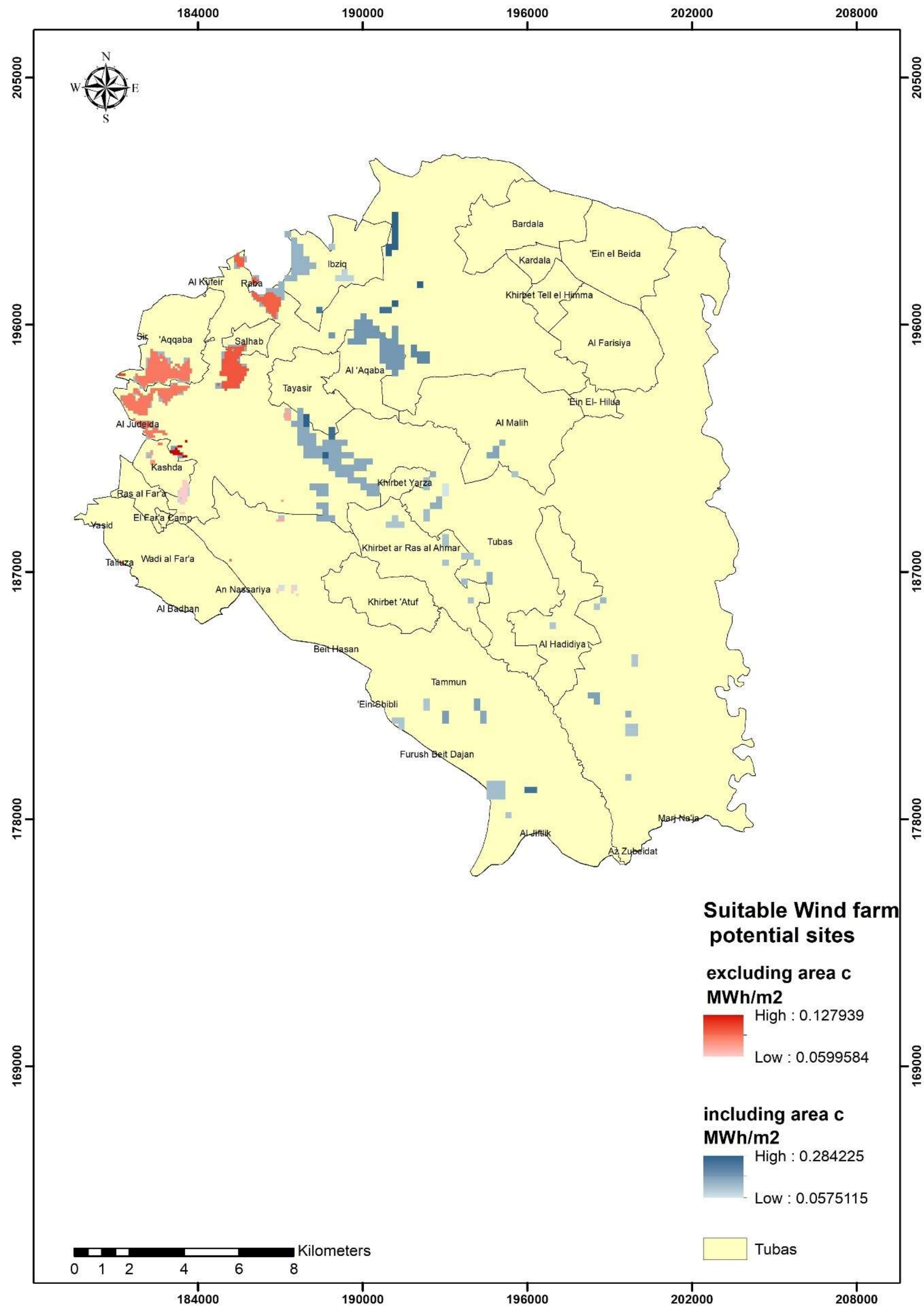


Figure 51: Suitable sites for Wind systems in Tubas

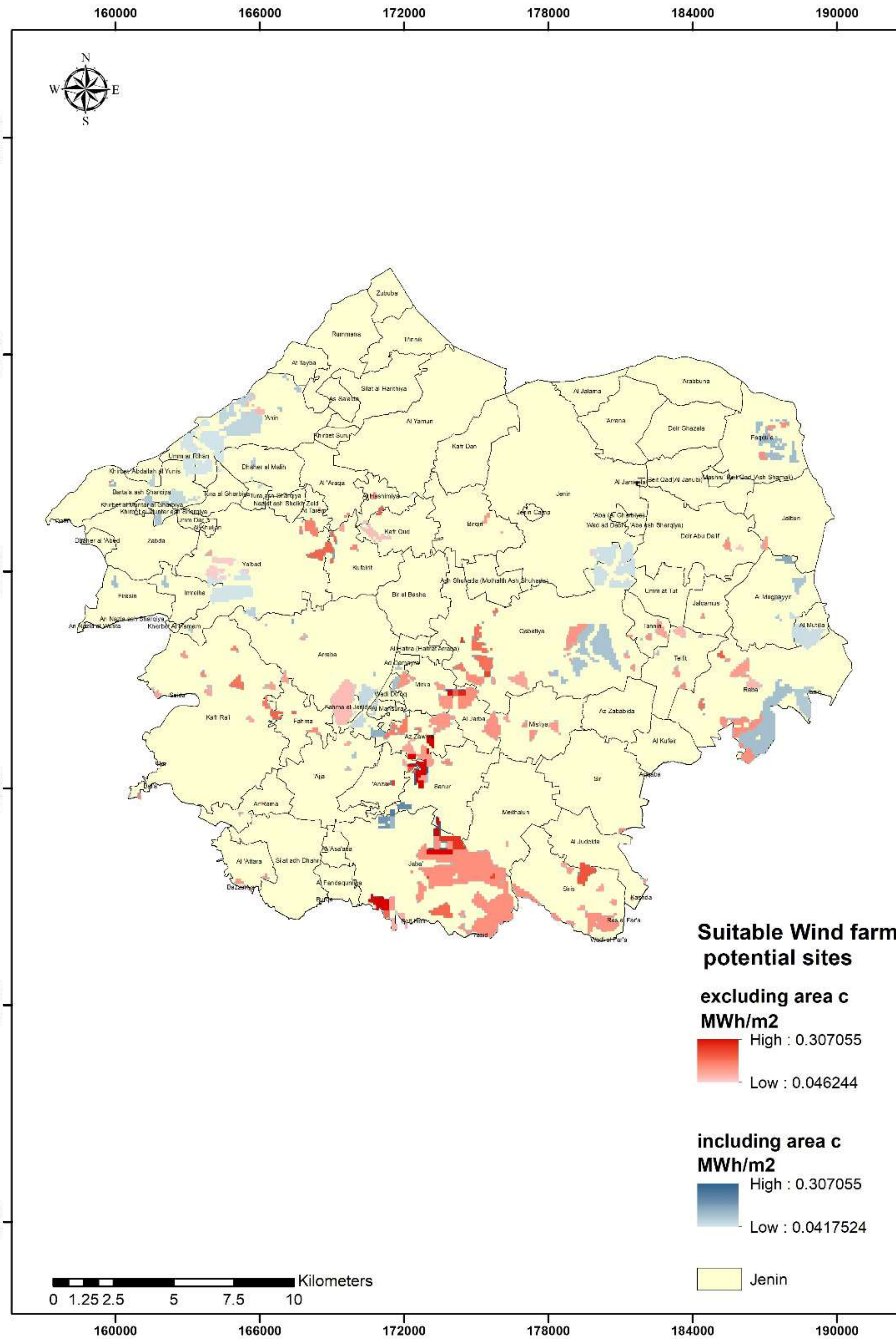


Figure 52: Suitable sites for Wind systems in Jenin

9- Data analysis results

The best way to analyze data is to compare it in graphs, especially when a fair amount exists, so it can be easily understood and user-friendly.

Data have been calculated by km^2 and GWh units, each application has been analyzed alone.

- **PV Systems**

Figure 53 below shows the percentage of available area in km^2 for PV systems including area C in each governorate. As said before Hebron has the largest percentage of suitable areas for this system, and Qalqiliya has the lowest number of available areas for PV systems.

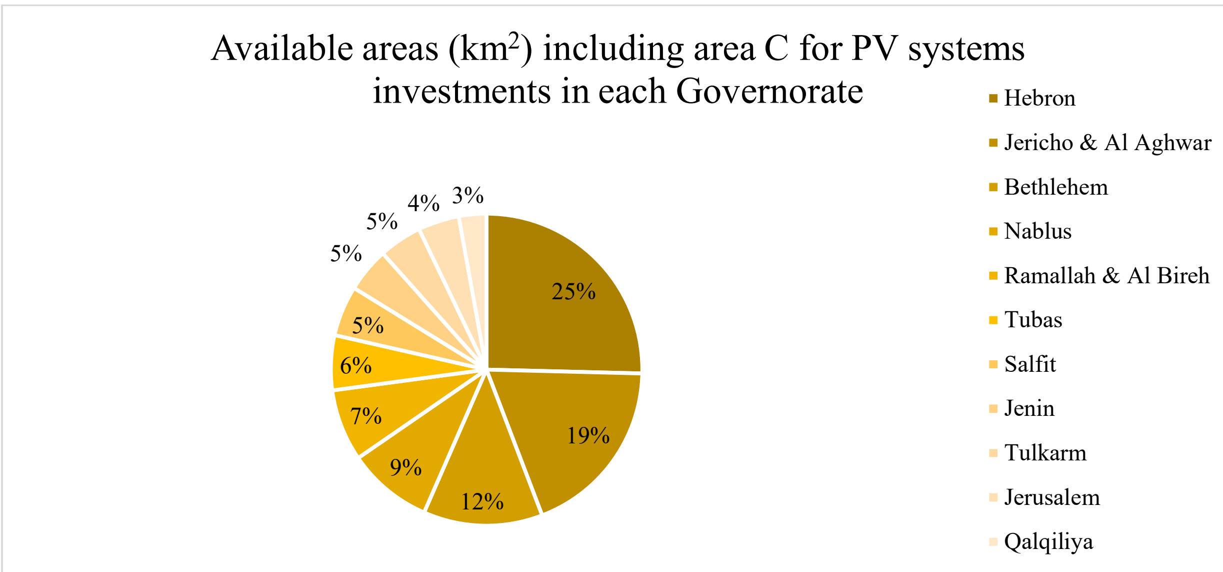


Figure 53: The percentage of Available areas in km^2 including area C for PV systems in each Governorate

Figure 54 below shows the annual potential in GWh for the available areas for the system in each governorate from highest to lowest. It is noticeable that Hebron has great potential comparing to other governorates.

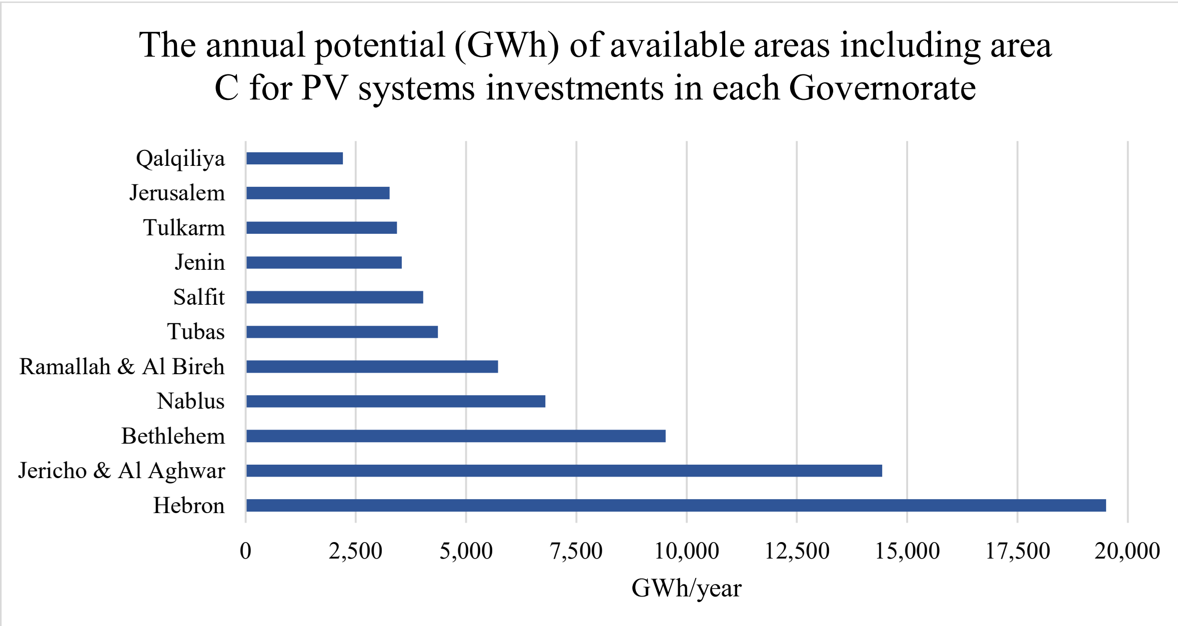


Figure 54: The annual potential in GWh for available areas for PV systems including area C in each Governorate

Figure 55 below shows the percentage of available areas in km^2 for PV systems in each electricity company's concession area including area C, considering Bethlehem, Jericho & Al-Aghwar, Ramallah & Al-Bireh, and Jerusalem under JEDCO's, Nablus and Jenin under NEDCO's, The whole governorate of Hebron under both HEBCO and SELCO and each of Salfiet, Tulkarem, and Qalqilya independent. In a total of 444 km^2 of suitable area, JEDCO, as seen in the graph, has the highest percentage of available area for PV systems investments, with a total estimated production of 32,948 GWh per year.

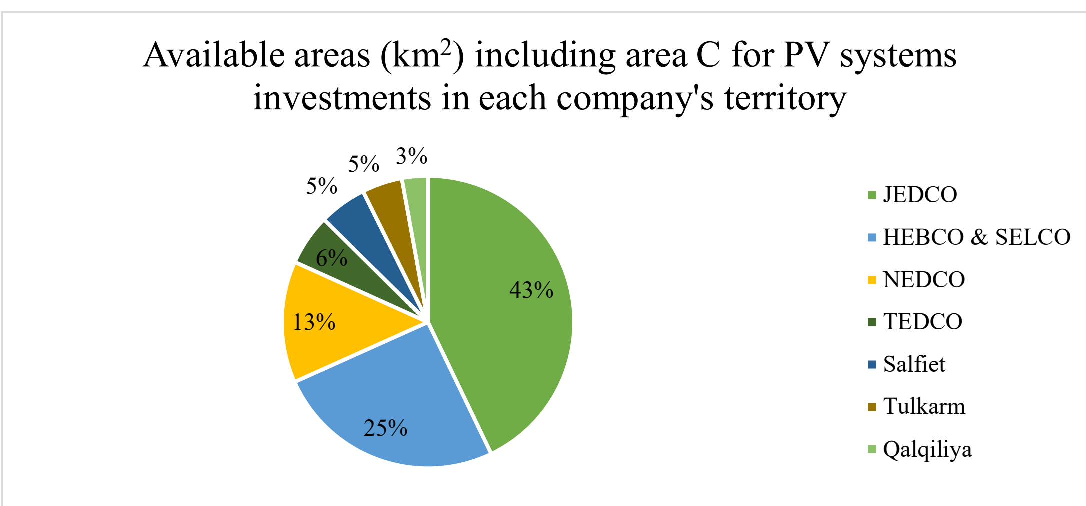


Figure 55: The percentage of available area in each electricity company's territory for PV systems including area C

Figure 56 below is the completion for Figure 55 to show the annual potential in GWh for the available areas in each electricity company's concession area including area C.

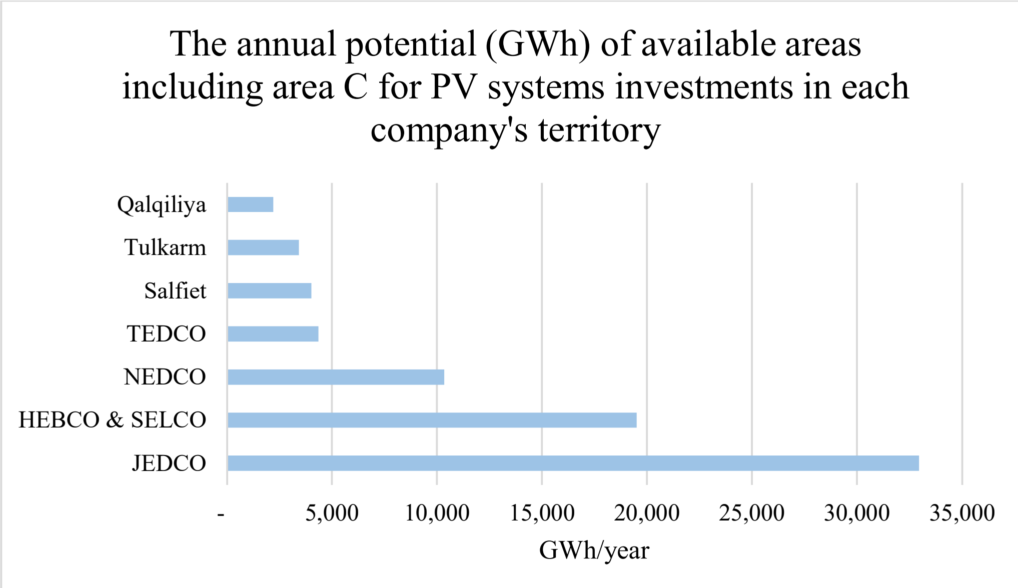
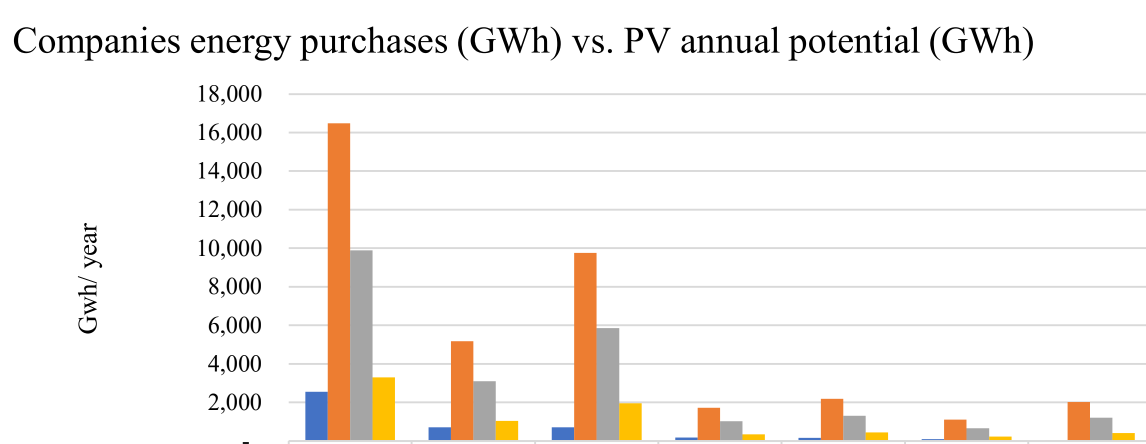


Figure 56: The annual potential in GWh for available areas for PV systems including area C in each company's territory

Figure 57 below compares the annual energy purchases in GWh[54] and three scenarios for the estimated energy potential in GWh in each governorate's territory, considering 50%, 30%, and 10% of the estimated annual potential in GWh for PV systems including area C. as can be noticed the 10% scenario can cover the energy purchase for all of the governorates and more, which opens a lot of options to reduce the energy bill in each governorate.



	JEDCO	NEDCO	HEBCO & SELCO	Tulkarm	TEDCO	Qalqiliya	Salfiet
Energy purchases (GWh) per year	2,545	703	700	180	158	86	20
50% of the annual potential (GWh)	16,474	5,171	9,754	1,715	2,180	1,105	2,013
30% of the annual potential (GWh)	9,885	3,103	5,852	1,029	1,308	663	1,208
10% of the annual potential (GWh)	3,295	1,034	1,951	343	436	221	403

Figure 57: Companies energy purchases (GWh) vs. PV annual potential (GWh) for PV systems including area C

Figure 58 below represents the percentage of available area in km^2 for PV systems excluding area C in each governorate. As said before Hebron has the largest percentage of suitable areas for this system, and Tubas has 0.1 km^2 of the suitable area which is considered 0%, that means the 26 km^2 of suitable areas in Tubas are all classified area C, and this is also the same for Jerusalem and Salfit since they have 0.61 and 0.86 km^2 suitable areas only, respectively. But brings Jenin to the top 3.

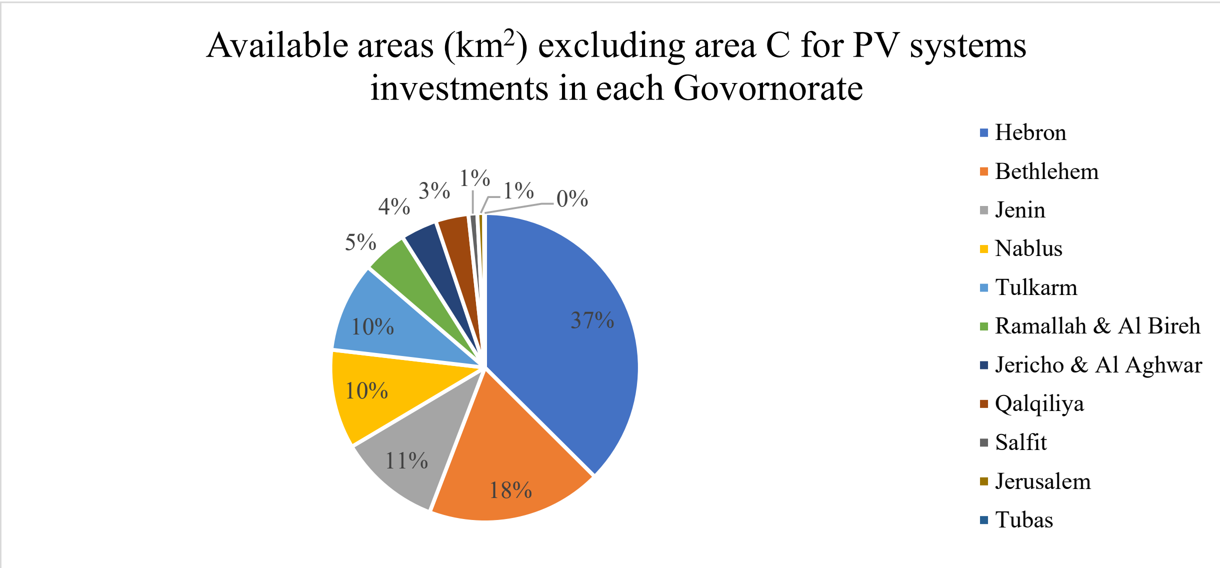


Figure 58: The percentage of Available areas in km^2 excluding area C for PV systems in each Governorate

Figure 59 below shows the annual potential in GWh for the available areas for the system in each governorate from highest to lowest. It is noticeable that Hebron has great potential comparing to other governorates also while excluding area C.

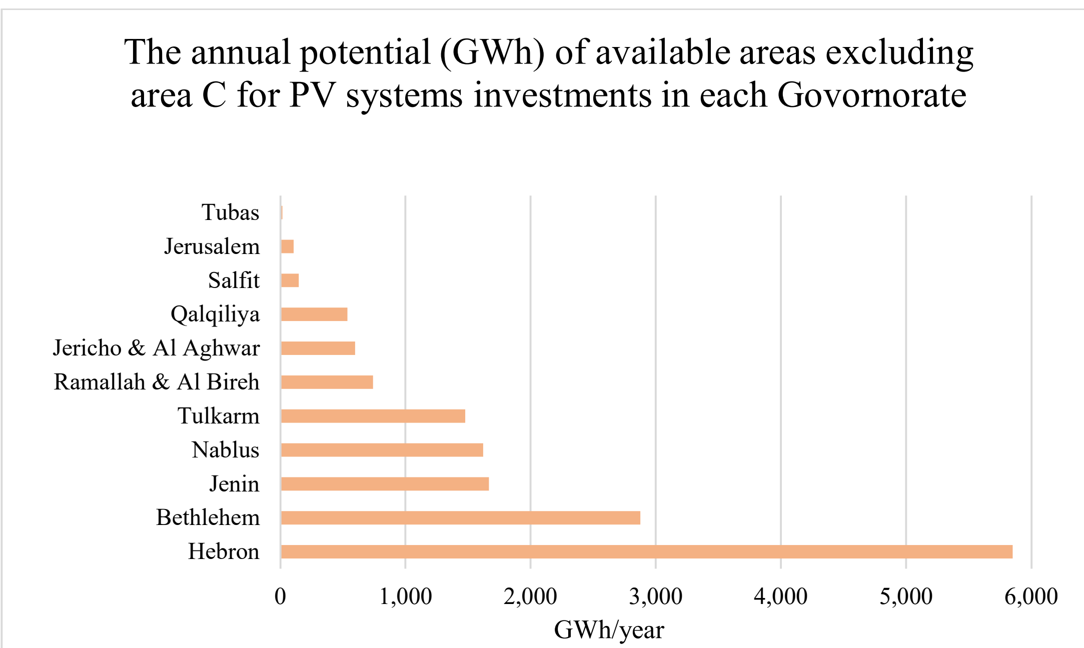


Figure 59: The annual potential in GWh for available areas for PV systems excluding area C in each Governorate

Figure 60 below shows the percentage of available areas in km^2 for PV systems in each electricity company's concession area excluding area C. In a total of 90 km^2 of suitable area, HEBCO & SELCO, as seen in the graph, have the highest percentage of available area for PV systems investments, with a total estimated area of 33 km^2 and an annual potential of 5,851 GWh.

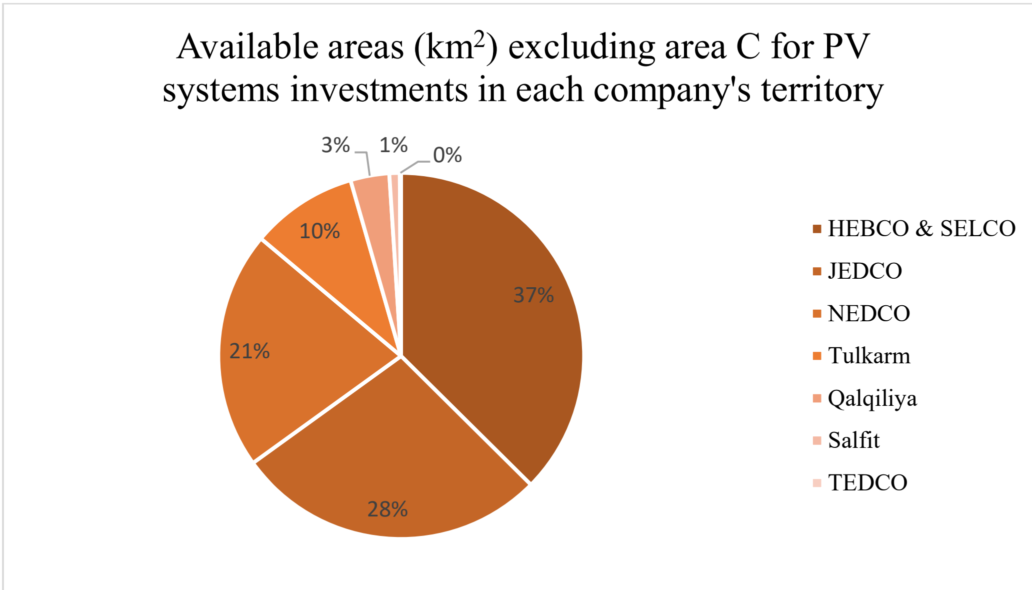


Figure 60: The percentage of available area in each electricity company's territory for PV systems excluding area C

Figure 61 below is the completion for Figure 60 to show the annual potential in GWh for the available areas in each electricity company's concession area excluding area C.

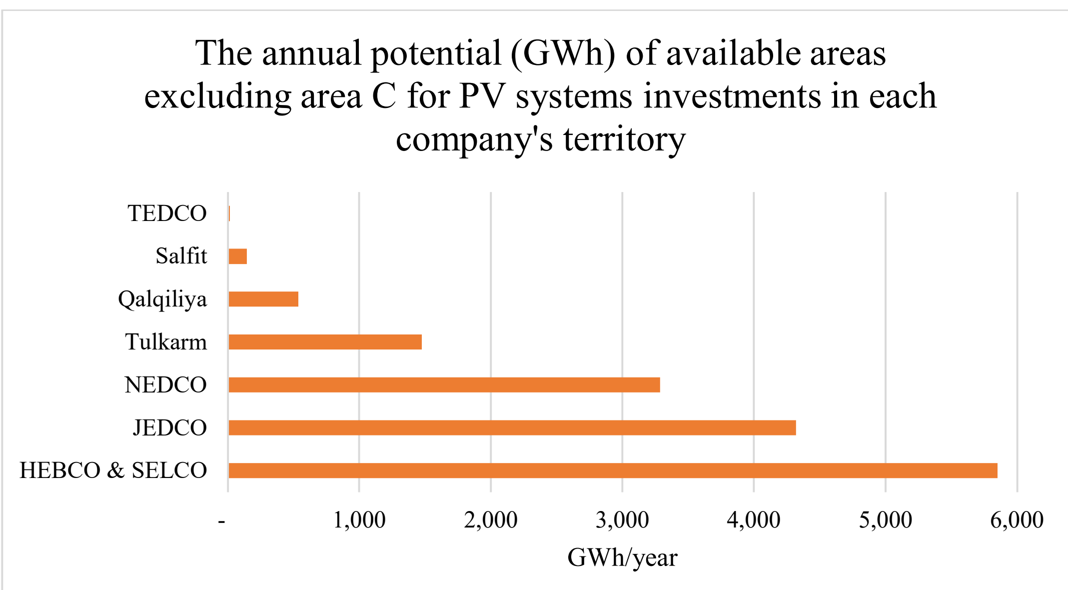
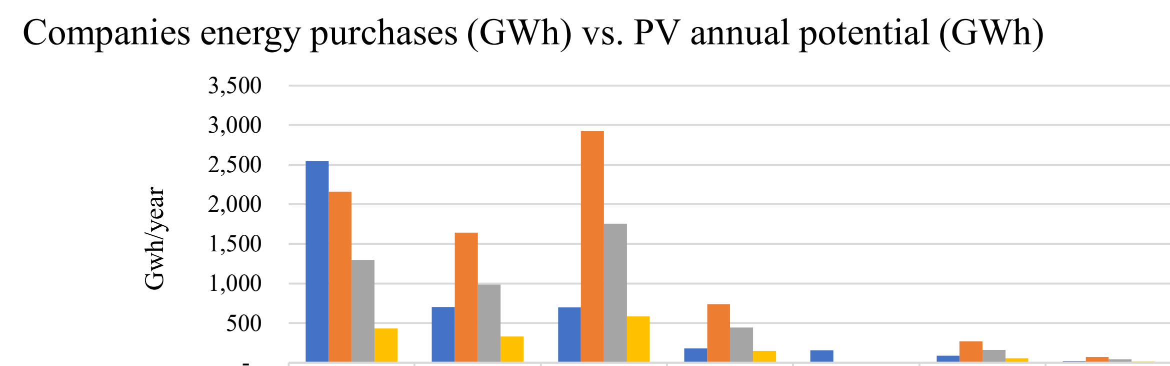


Figure 61: The annual potential in GWh for available areas for PV systems excluding area C in each company's territory

Figure 62 below compares the annual energy purchases in GWh and three scenarios of the estimated annual potential in GWh that mentioned before for PV systems excluding area C. as can be noticed the 30% scenario can cover the energy purchase for all of the governorates and more, which opens some options to reduce the energy bill in each governorate.



	JEDCO	NEDCO	HEBCO & SELCO	Tulkarm	TEDCO	Qalqiliya	Salfiet
Energy purchases (GWh) per year	2,545	703	700	180	158	86	20
50% of the annual potential (GWh)	2,160	1,643	2,926	738	8	268	73
30% of the annual potential (GWh)	1,296	986	1,755	443	5	161	44
10% of the annual potential (GWh)	432	329	585	148	2	54	15

Figure 62: Companies energy purchases (GWh) vs. PV annual potential (GWh) for PV systems excluding area C

Figure 63 clearly shows the difference between the annual potential in GWh for areas including area C and excluding it.

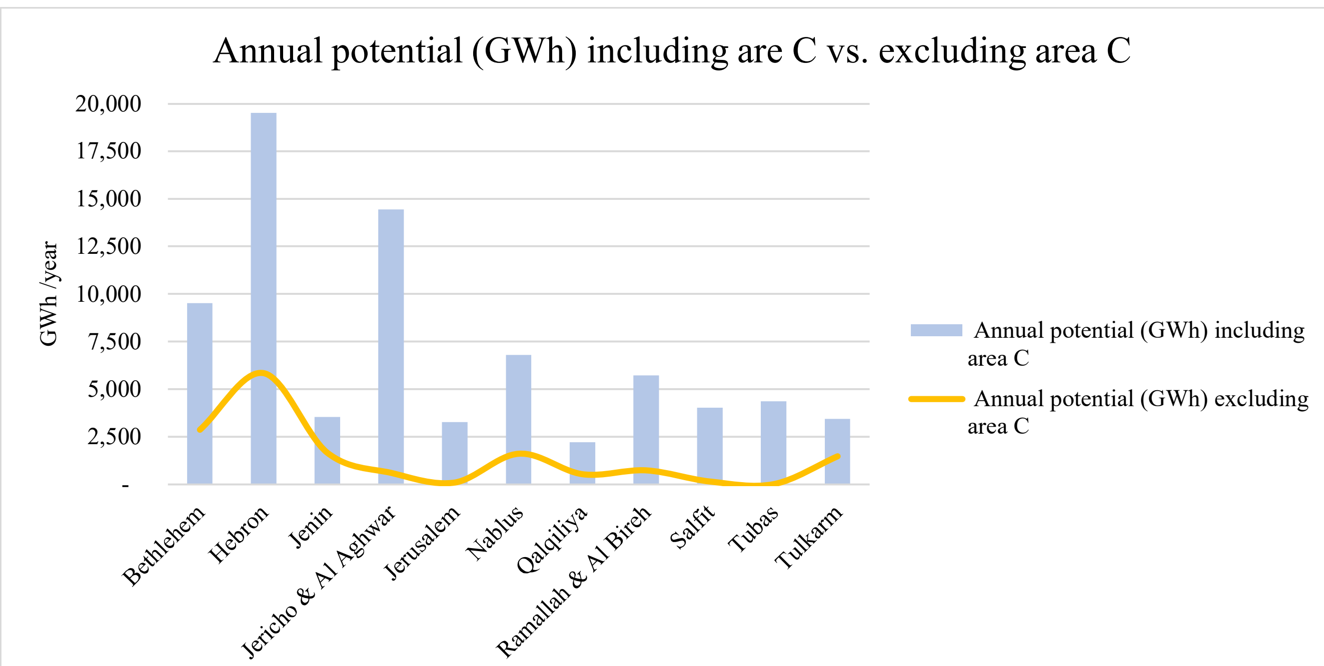


Figure 63: Annual potential (GWh) including are C vs. excluding area C for PV systems

- **CSP Systems**

Figure 64 below shows the percentage of available area in km^2 for CSP systems including area C in each governorate. As said before Hebron has the largest percentage of suitable areas for this system, and Bethlehem has the lowest number of available areas.

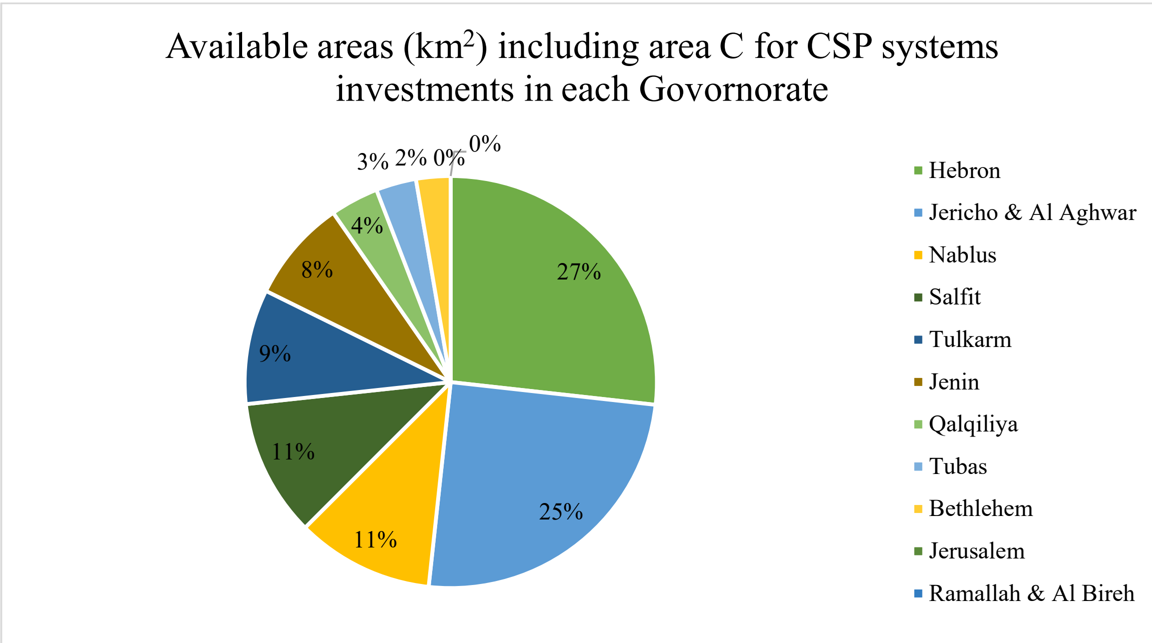


Figure 64: The percentage of Available areas in km^2 including area C for CSP systems in each Governorate

Figure 65 below shows the annual potential in GWh for the available areas for the system in each governorate from highest to lowest. It is noticeable that Hebron has great potential comparing to other governorates.

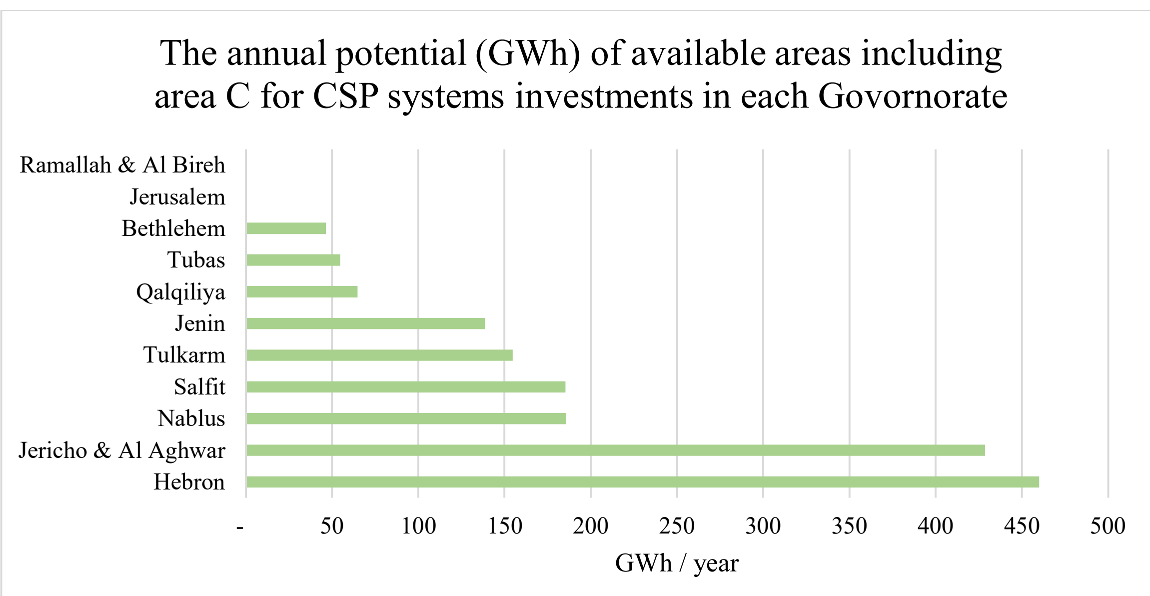


Figure 65: The annual potential in GWh for available areas for CSP systems including area C in each Governorate

Figure 66 below shows the percentage of available areas in km^2 for CSP systems in each electricity company's concession area including area C. In a total of 14 km^2 of suitable area, JEDCO, as seen in the graph, has the highest percentage of available area for CSP systems investments, with a total estimated area of 3.77 km^2 and an annual potential of 475 GWh.

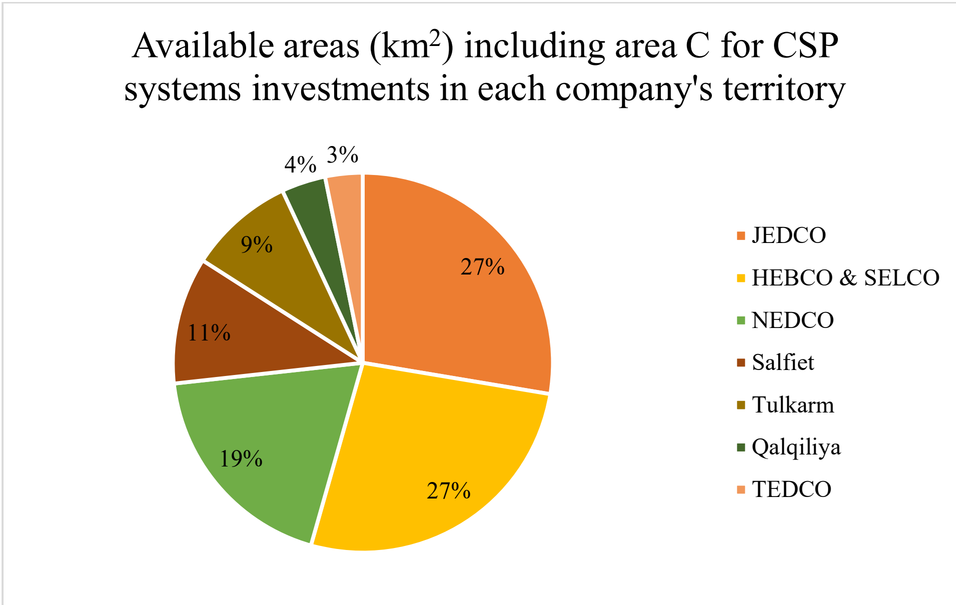


Figure 66: The percentage of available area in each electricity company's territory for CSP systems including area C

Figure 67 below is the completion for Figure 66 to show the annual potential in GWh for the available areas in each electricity company's concession area including area C.

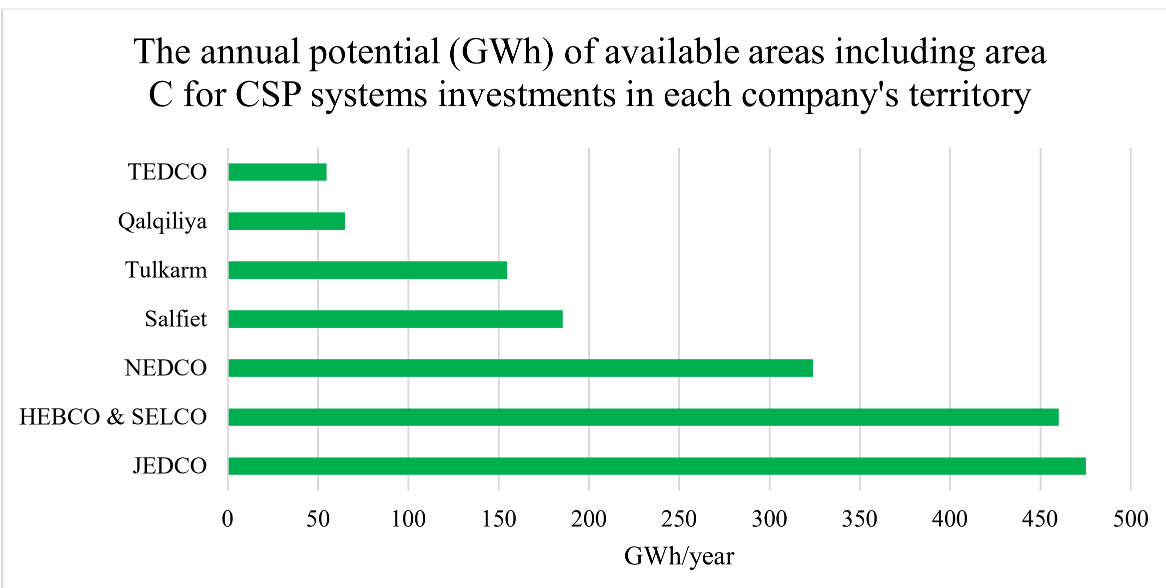
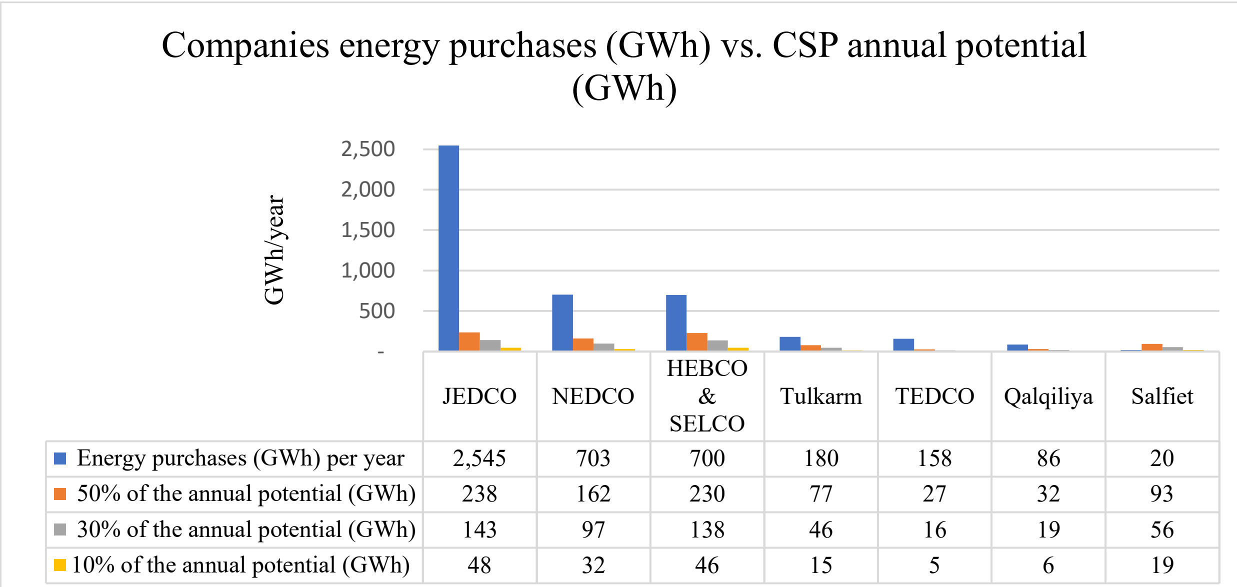


Figure 67: The annual potential in GWh for available areas for CSP systems including area C in each company's territory

Figure 68 below compares the annual energy purchases in GWh and three scenarios for the estimated energy potential in GWh in each governorate's territory, considering 50%, 30%, and 10% of the estimated annual potential in GWh for CSP systems including area C. as can be noticed none of the scenarios can cover the energy purchase for all of the governorates totally, which restrict our options to whats available only.



	JEDCO	NEDCO	HEBCO & SELCO	Tulkarm	TEDCO	Qalqiliya	Salfiet
Energy purchases (GWh) per year	2,545	703	700	180	158	86	20
50% of the annual potential (GWh)	238	162	230	77	27	32	93
30% of the annual potential (GWh)	143	97	138	46	16	19	56
10% of the annual potential (GWh)	48	32	46	15	5	6	19

Figure 68: Companies energy purchases (GWh) vs. CSP annual potential (GWh) for CSP systems including area C

Figure 69 below represents the percentage of available area in km^2 for CSP systems excluding area C in each governorate. As said before Hebron has the largest percentage of suitable areas for this system, while Tubas, Jerusalem, Bethlehem, Ramallah & Al-Bireh, and Salfit have no available areas for this system.

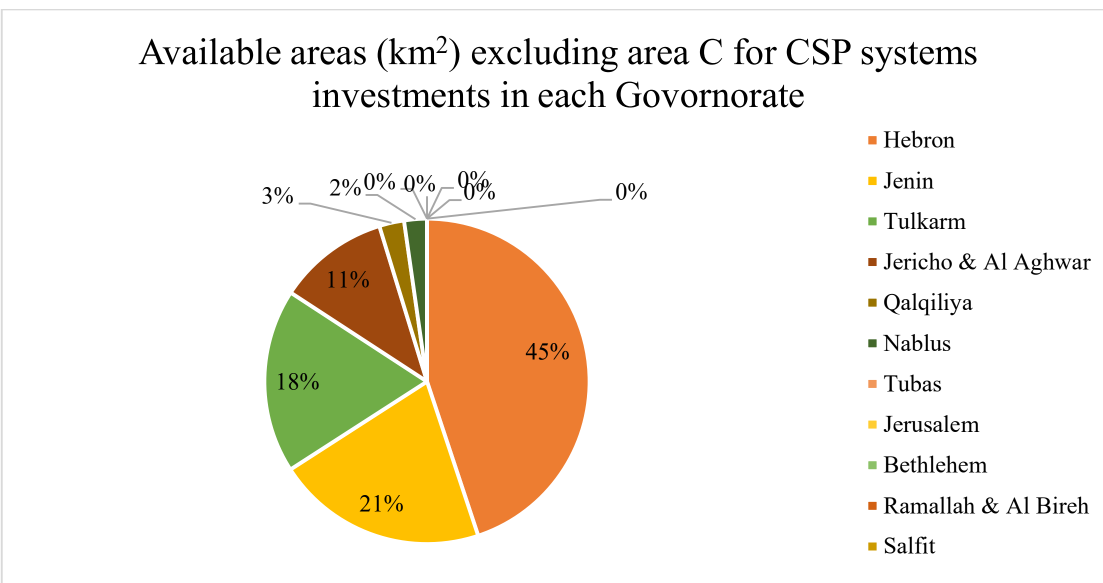


Figure 69: The percentage of Available areas in km^2 excluding area C for CSP systems in each Governorate

Figure 70 below shows the annual potential in GWh for the available areas for the system in each governorate from highest to lowest. It is noticeable that Hebron has great potential comparing to other governorates also while excluding area C.

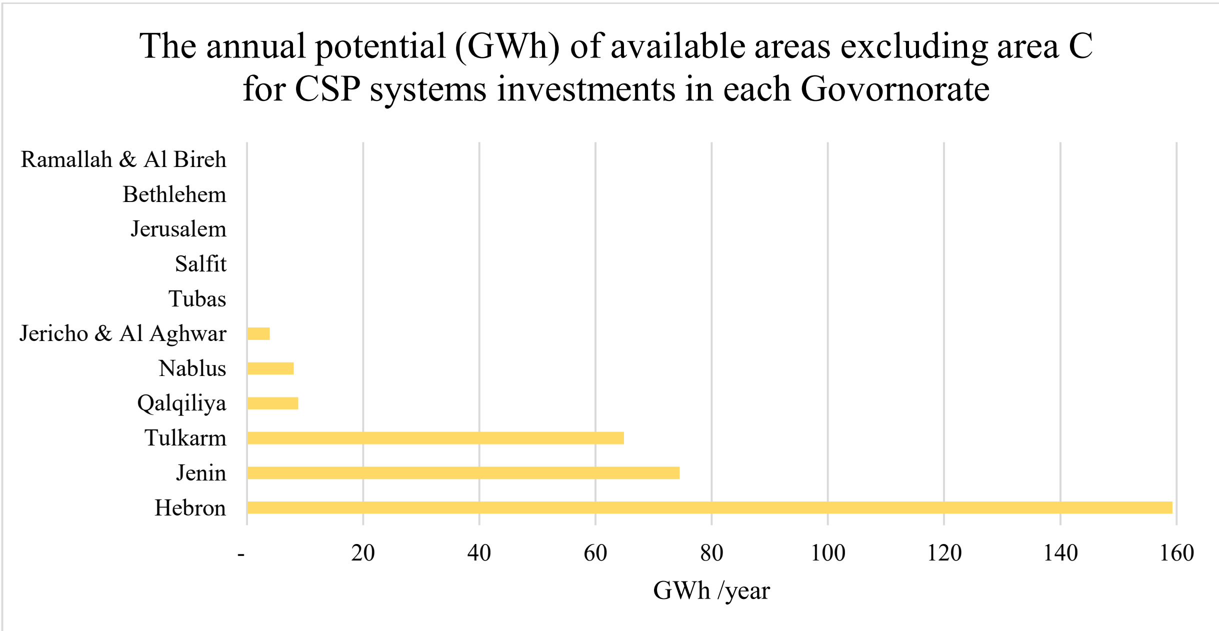


Figure 70: The annual potential in GWh for available areas for CSP systems excluding area C in each Governorate

Figure 71 below shows the percentage of available areas in km^2 for CSP systems in each electricity company's concession area including area C. In a total of 2.81 km^2 of suitable area, HEBCO & SELCO, as seen in the graph, have the highest percentage of available area for CSP systems investments, with a total estimated area of 1.26 km^2 and an annual potential of 159 GWh.

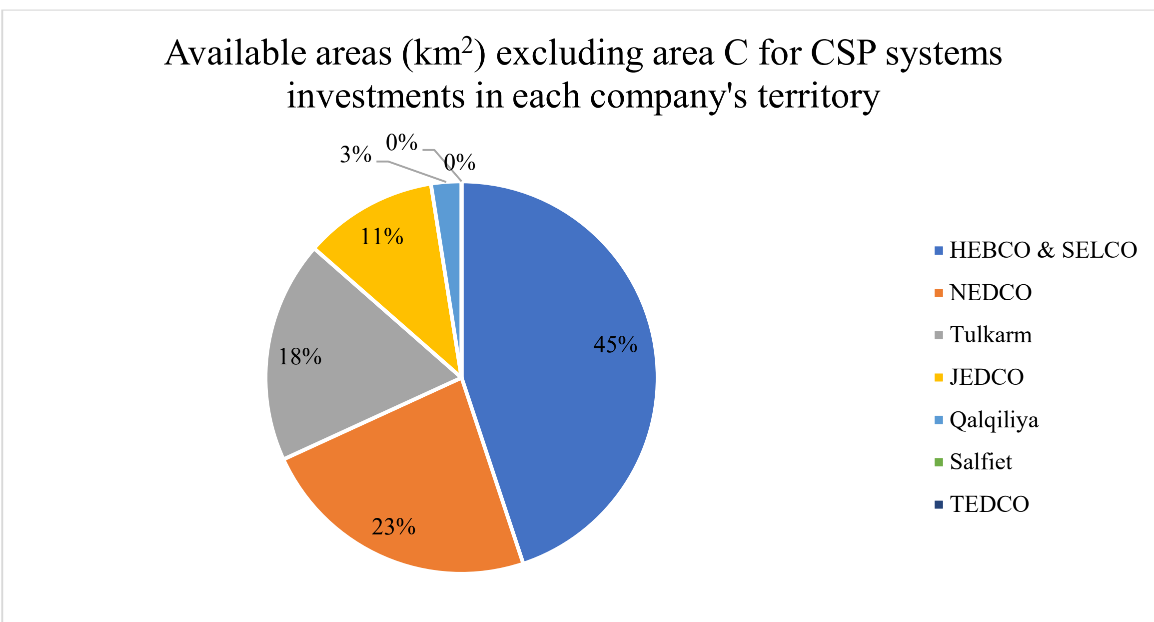


Figure 71: The percentage of available area in each electricity company's territory for CSP systems excluding area C

Figure 72 below is the completion for Figure 71 to show the annual potential in GWh for the available areas in each electricity company's concession area excluding area C.

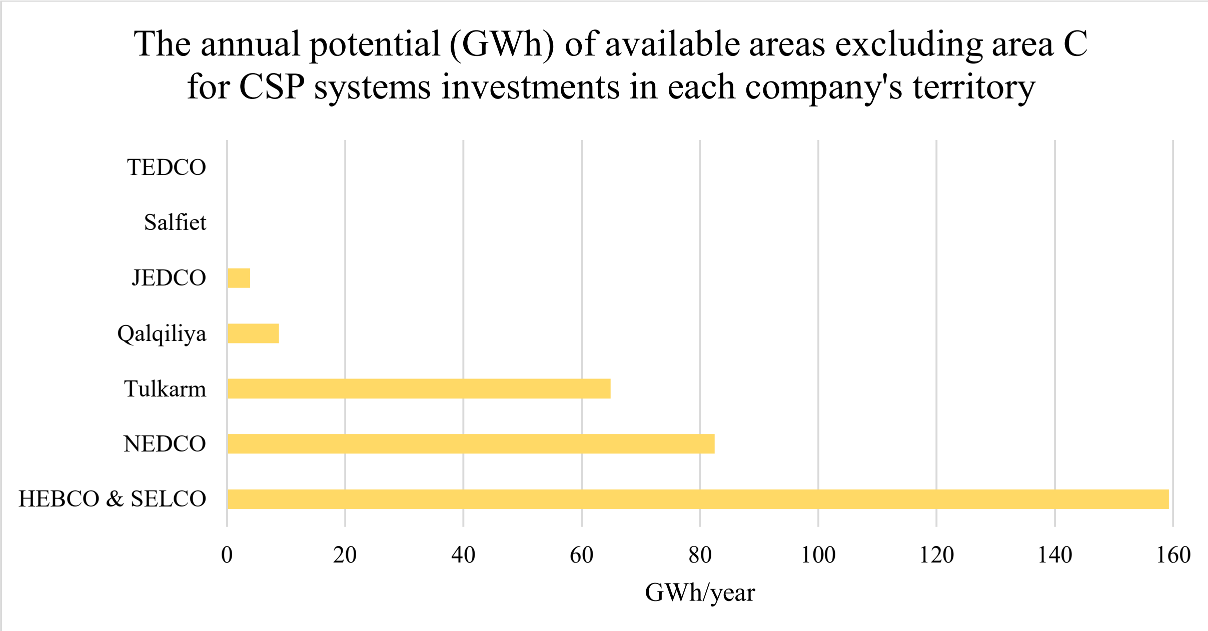
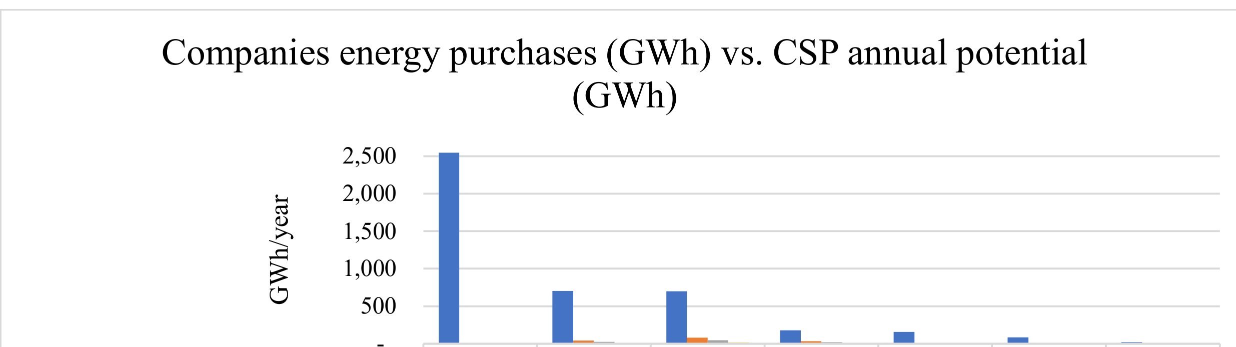


Figure 72: The annual potential in GWh for available areas for CSP systems excluding area C in each company's territory

Figure 73 below compares the annual energy purchases in GWh and three scenarios for the estimated energy potential in GWh in each governorate's territory, considering 50%, 30%, and 0% of the estimated annual potential in GWh for CSP systems excluding area C. As can be noticed the also here none of the scenarios can cover the total annual energy purchases.



	JEDCO	NEDCO	HEBCO & SELCO	Tulkarm	TEDCO	Qalqiliya	Salfiet
Energy purchases (GWh) per year	2,545	703	700	180	158	86	20
50% of the annual potential (GWh)	2	41	80	32	-	4	-
30% of the annual potential (GWh)	1	25	48	19	-	3	-
10% of the annual potential (GWh)	0	8	16	6	-	1	-

Figure 73: Companies energy purchases (GWh) vs. CSP annual potential (GWh) for CSP systems excluding area C

Figure 74 clearly shows the difference between the annual potential for CSP systems in GWh for areas including area C and excluding it.

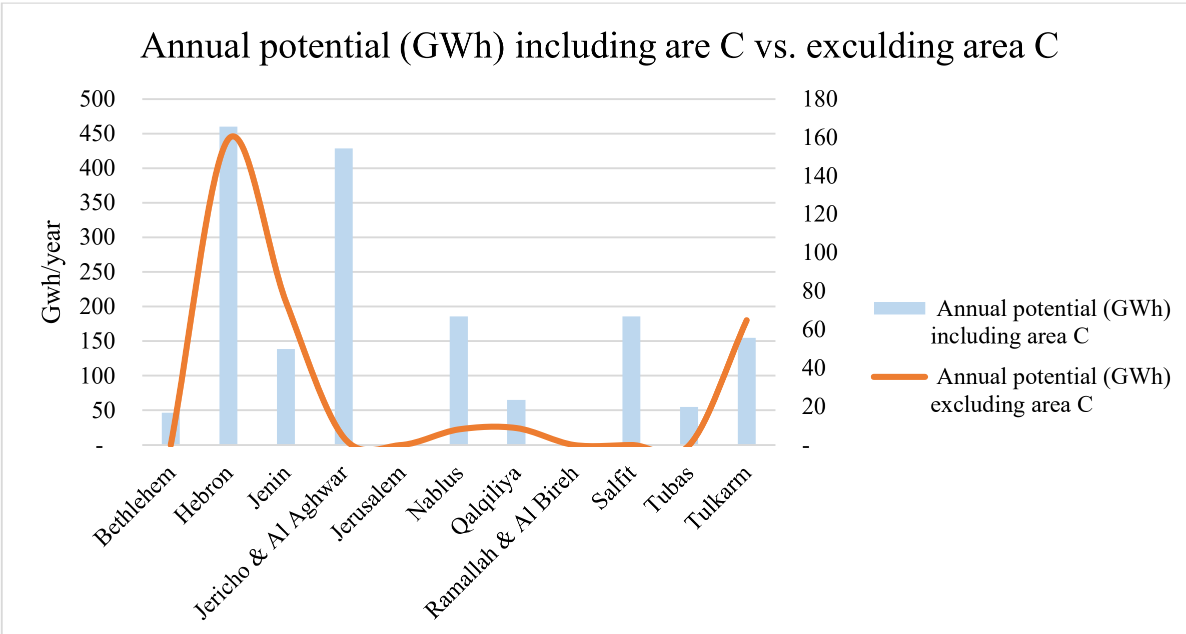


Figure 74: Annual potential (GWh) including area C vs. excluding area C for CSP systems

- **Wind Systems**

Figure 75 below shows the percentage of available area in km^2 for Wind systems including area C in each governorate. As said before Nablus has the largest percentage of suitable areas for this system, and Jericho & Al-Aghwar has the lowest number of available areas.

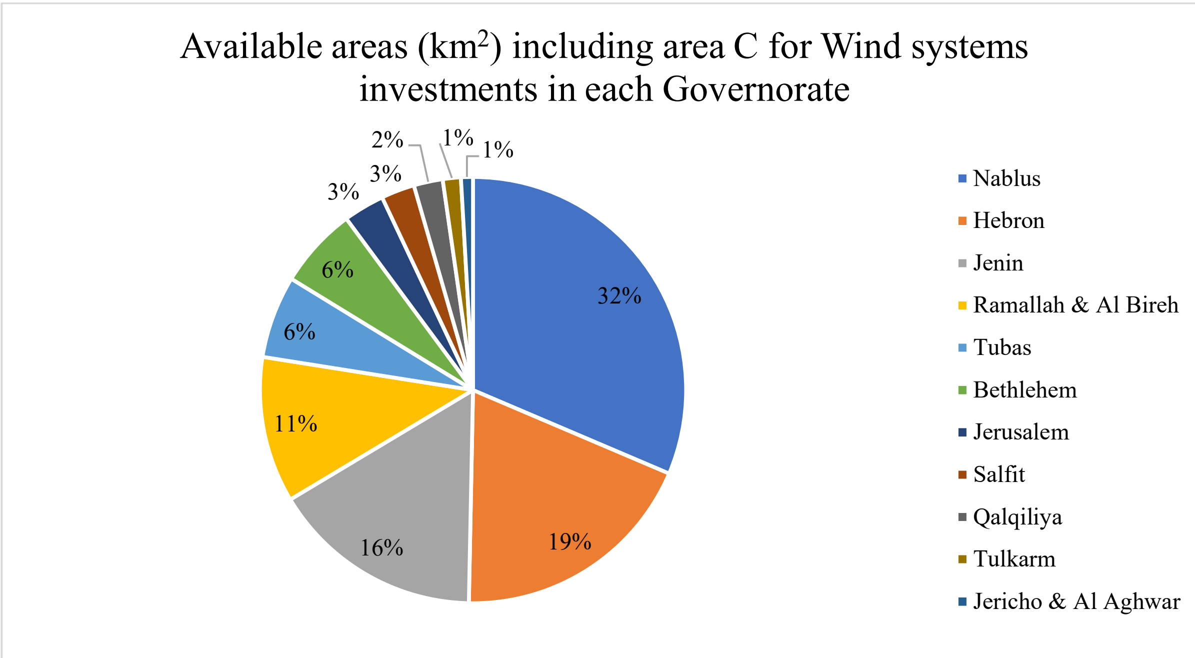


Figure 75: The percentage of Available areas in km^2 including area C for Wind systems in each Governorate

Figure 76 below shows the annual potential in GWh for the available areas for the system in each governorate from highest to lowest. It is noticeable that Nablus has great potential comparing to other governorates.

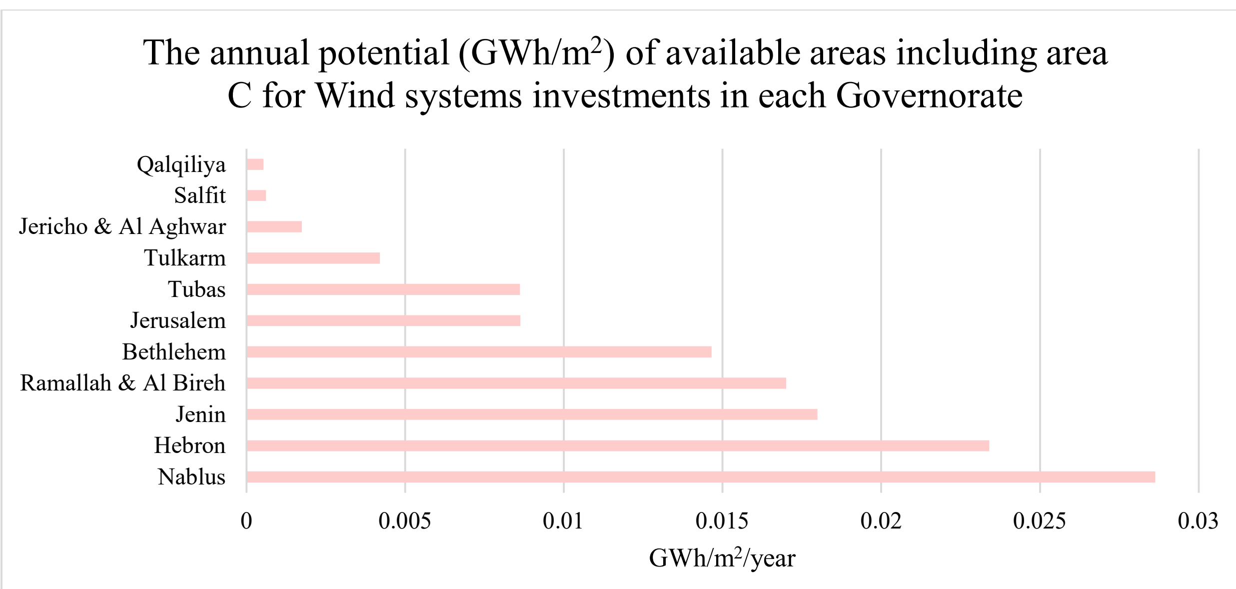


Figure 76: The annual potential in GWh/m^2 for available areas for Wind systems including area C in each Governorate

Figure 77 below shows the percentage of available areas in km^2 for wind systems in each electricity company's concession area including area C. In a total of 267 km^2 of suitable area, NEDCO, as seen in the graph, has the highest percentage of available area for wind systems investments, with a total estimated area of 127 km^2 and an annual potential of 0.042 GWh/m^2.

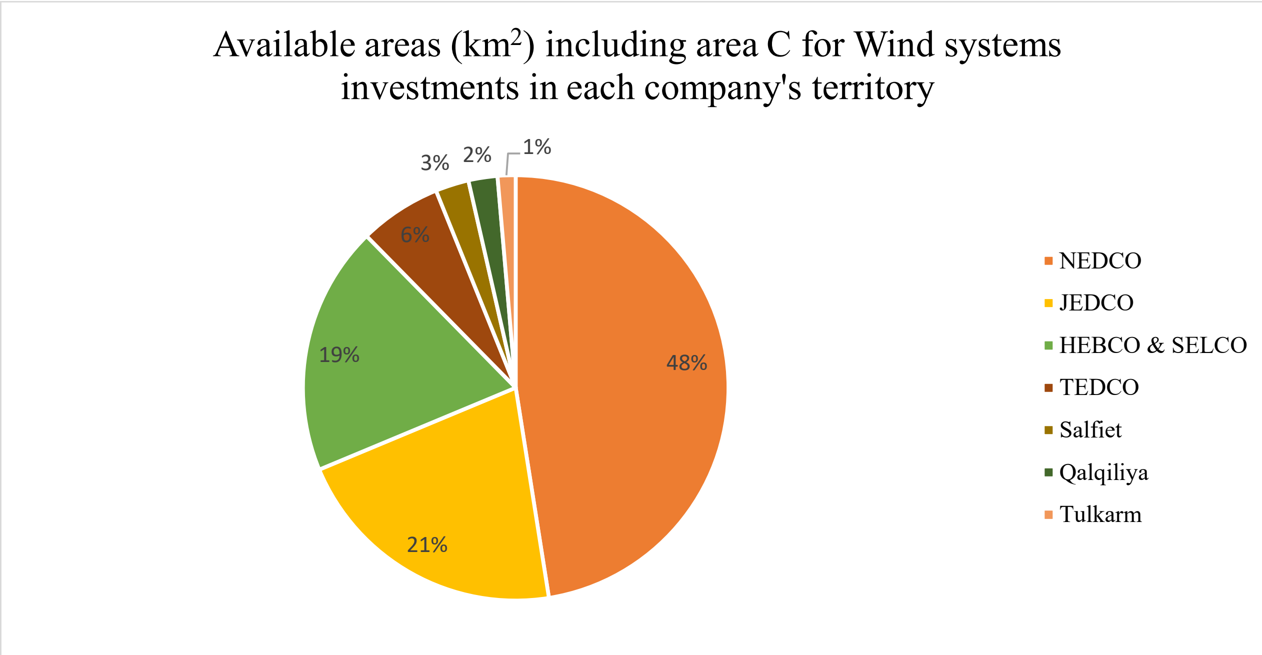


Figure 77: The percentage of available area in each electricity company's territory for Wind systems including area C

Figure 78 below is the completion for Figure 77 to show the annual potential in GWh/m^2 for the available areas in each electricity company's concession area including area C

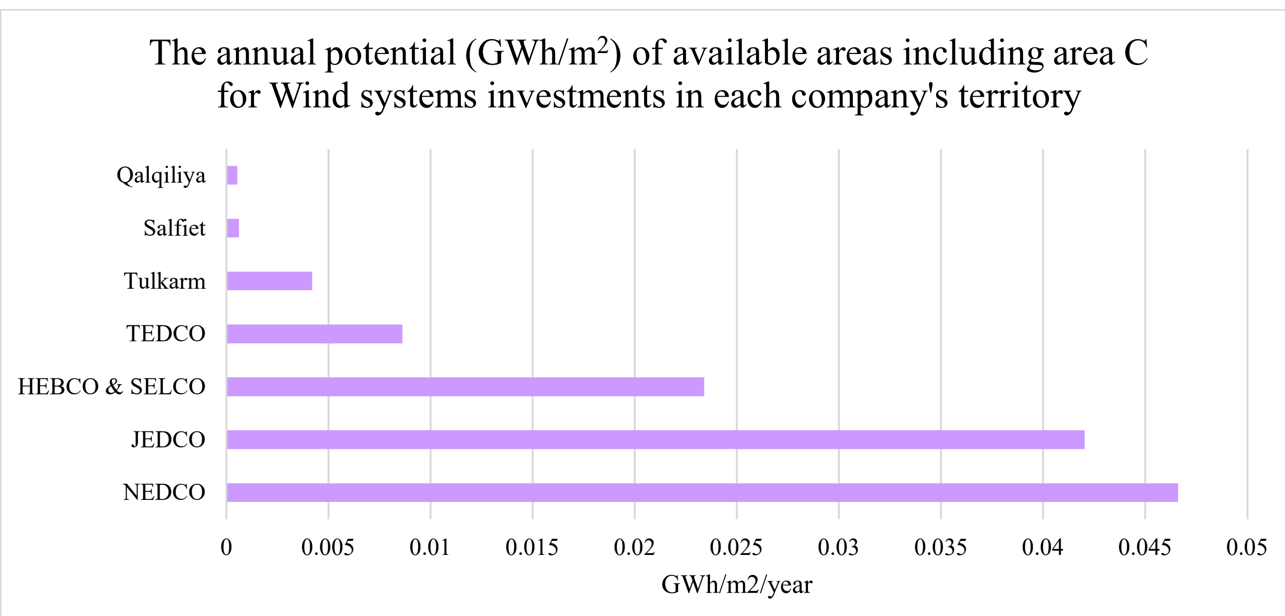


Figure 78: The annual potential in GWh/m^2 for available areas for Wind systems including area C in each company's territory

Figure 79 below represents the percentage of available area in km^2 for Wind systems excluding area C in each governorate. As said before Nablus has the largest percentage of suitable areas for this system, Jericho & Al-Aghwar has a solid 0 km^2 of the suitable, and Salfit has 0.097 km^2 that means the 6.8 km^2 of suitable areas in Salfit are all classified area C, and this is also the same for Jerusalem with only 0.669 km^2 suitable areas only.

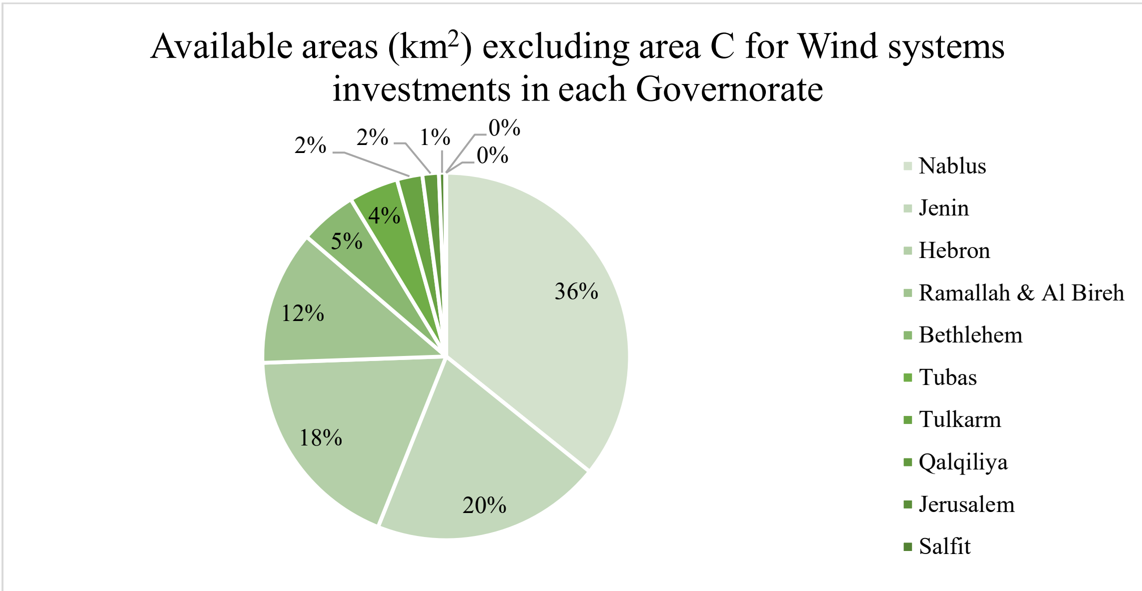


Figure 79: The percentage of Available areas in km^2 excluding area C for Wind systems in each Governorate

Figure 80 below shows the annual potential in GWh/m^2 for the available areas for the system in each governorate from highest to lowest. It is noticeable that Nabls has great potential comparing to other governorates also while excluding area C

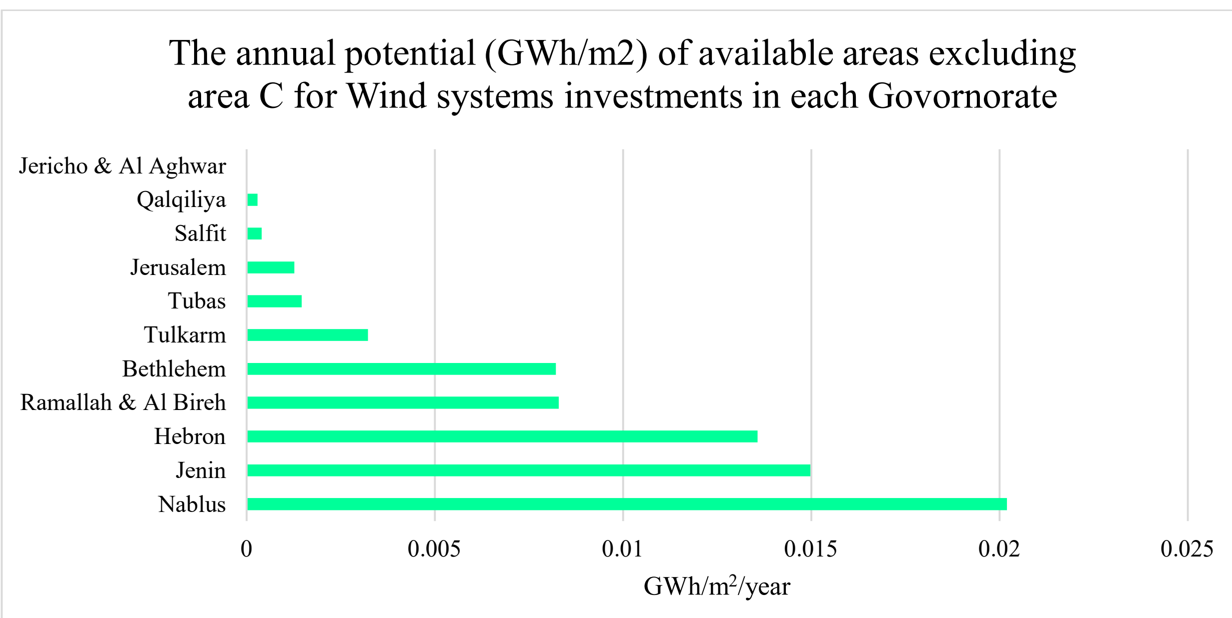


Figure 80: The annual potential in GWh/m^2 for available areas for Wind systems excluding area C in each Governorate

Figure 81 below shows the percentage of available areas in km^2 for wind systems in each electricity company's concession area excluding area C. In a total of 121 km^2 of suitable area, NEDCO, as seen in the graph, has the highest percentage of available area for wind systems investments, with a total estimated area of 68 km^2 and an annual potential of 0.0352 GWh/m^2.

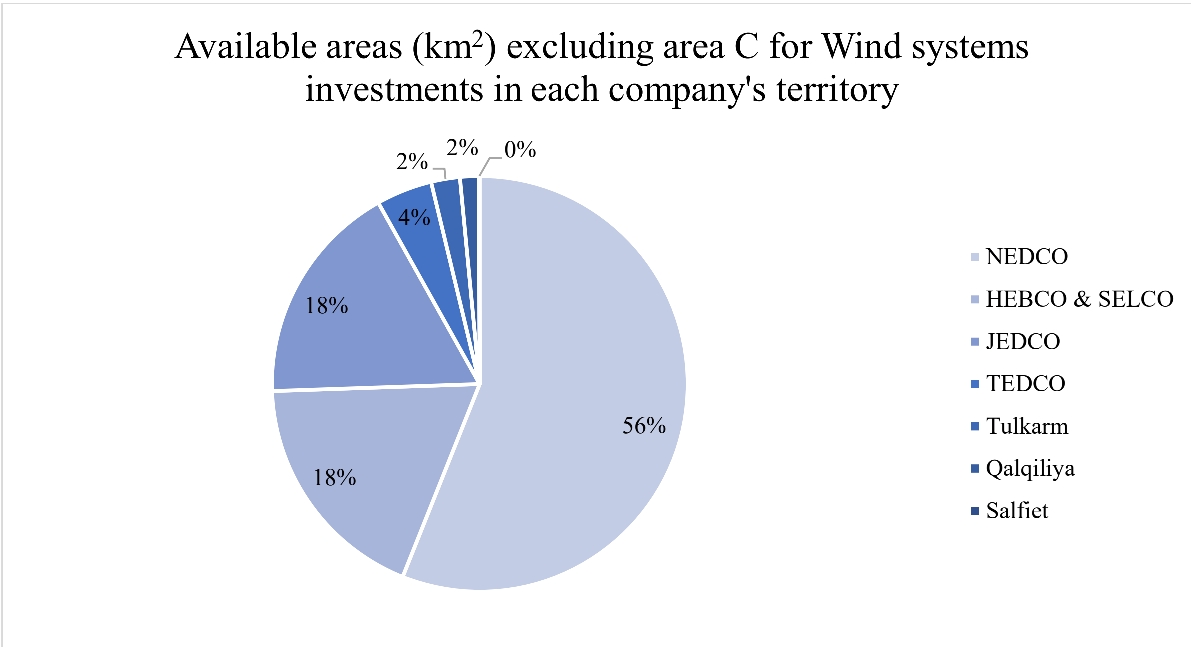


Figure 81: The percentage of available area in each electricity company's territory for Wind systems excluding area C

Figure 82 below is the completion for Figure 81 to show the annual potential in GWh/m^2 for the available areas in each electricity company's concession area excluding area C.

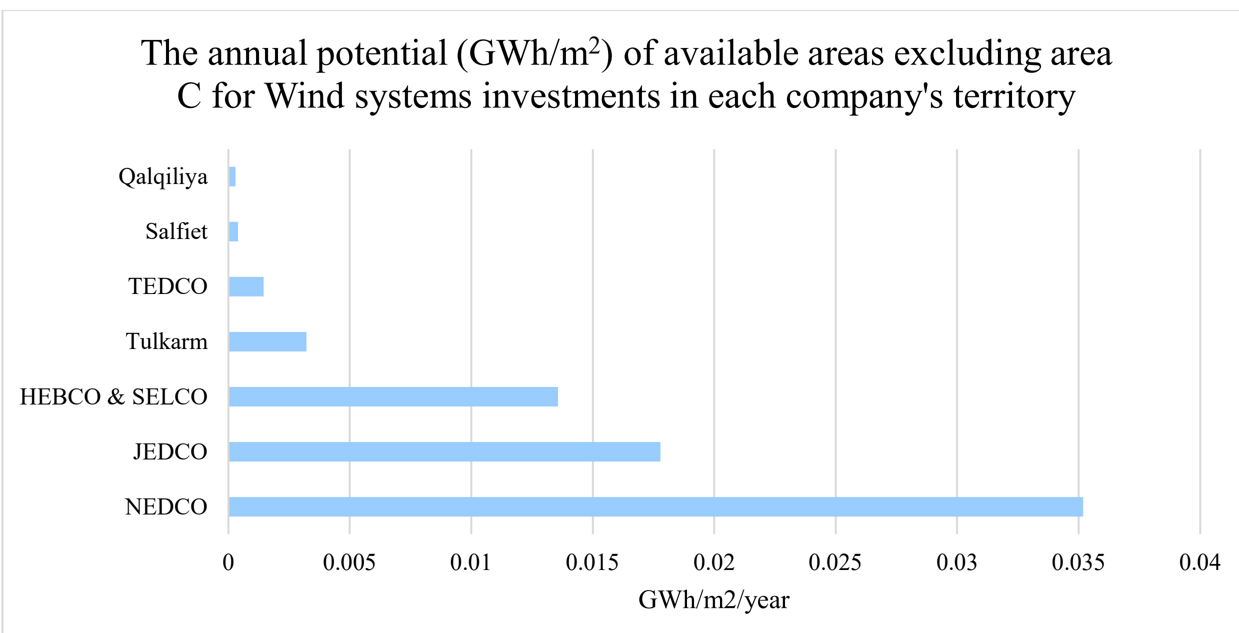


Figure 82: The annual potential in GWh/m^2 for available areas for Wind systems excluding area C in each company's territory

For further analysis, we located the highest-ranked lands according to our scale with high potential and excluding area C from this analysis.

For the PV system, the most suitable area in the West Bank is located in Tulkarem, in Ramin as shown below with an area of 0.28652 km^2 and a total annual production of 47.87 GWh.

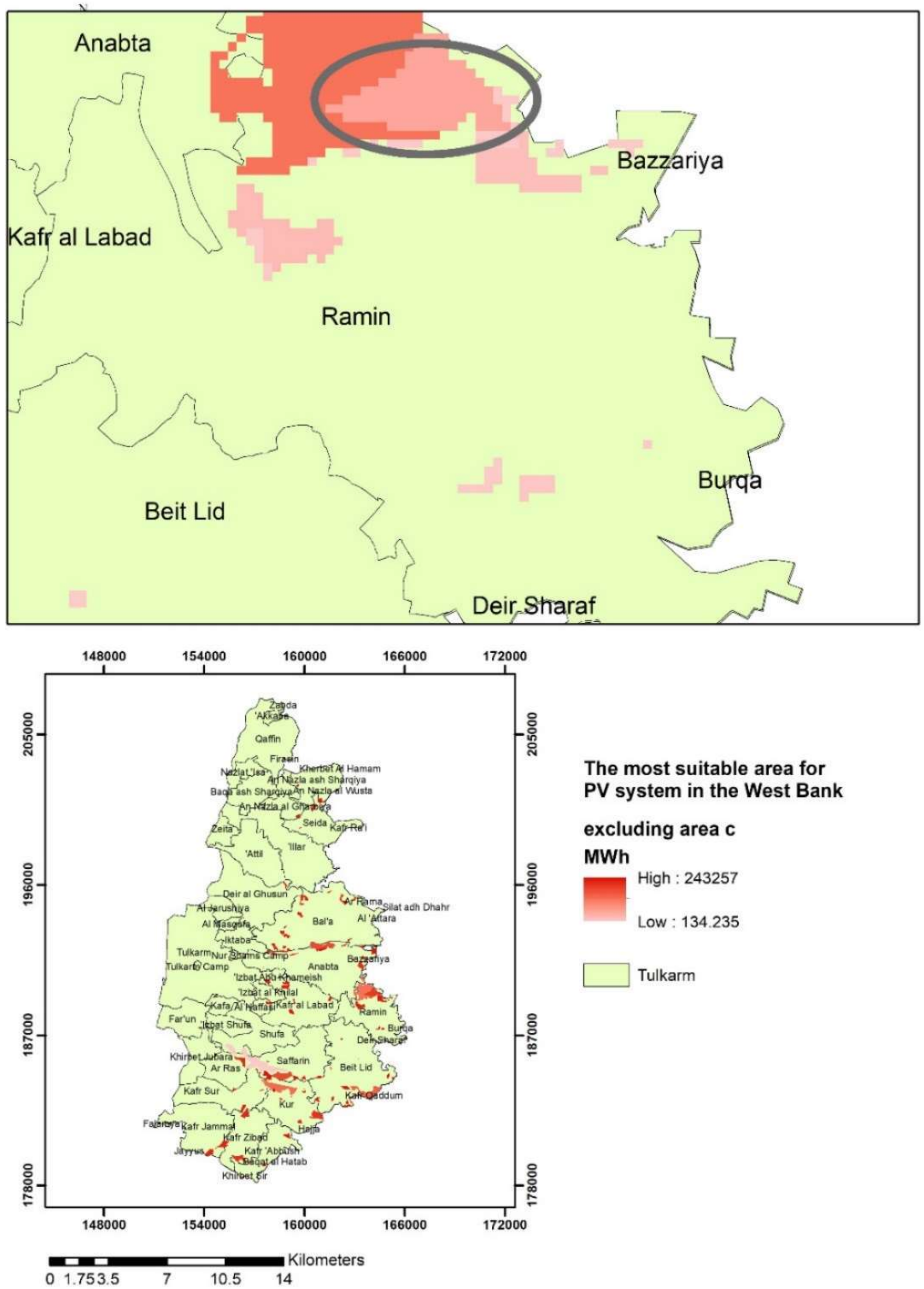


Figure 83: The most suitable location for the PV system in the West Bank

For CSP systems, the most suitable location is in Hebron, at As-Samu' village at the south as shown in the fire below. With an area of 0.21344 km^2 and a total production of 26.92 GWh per year.

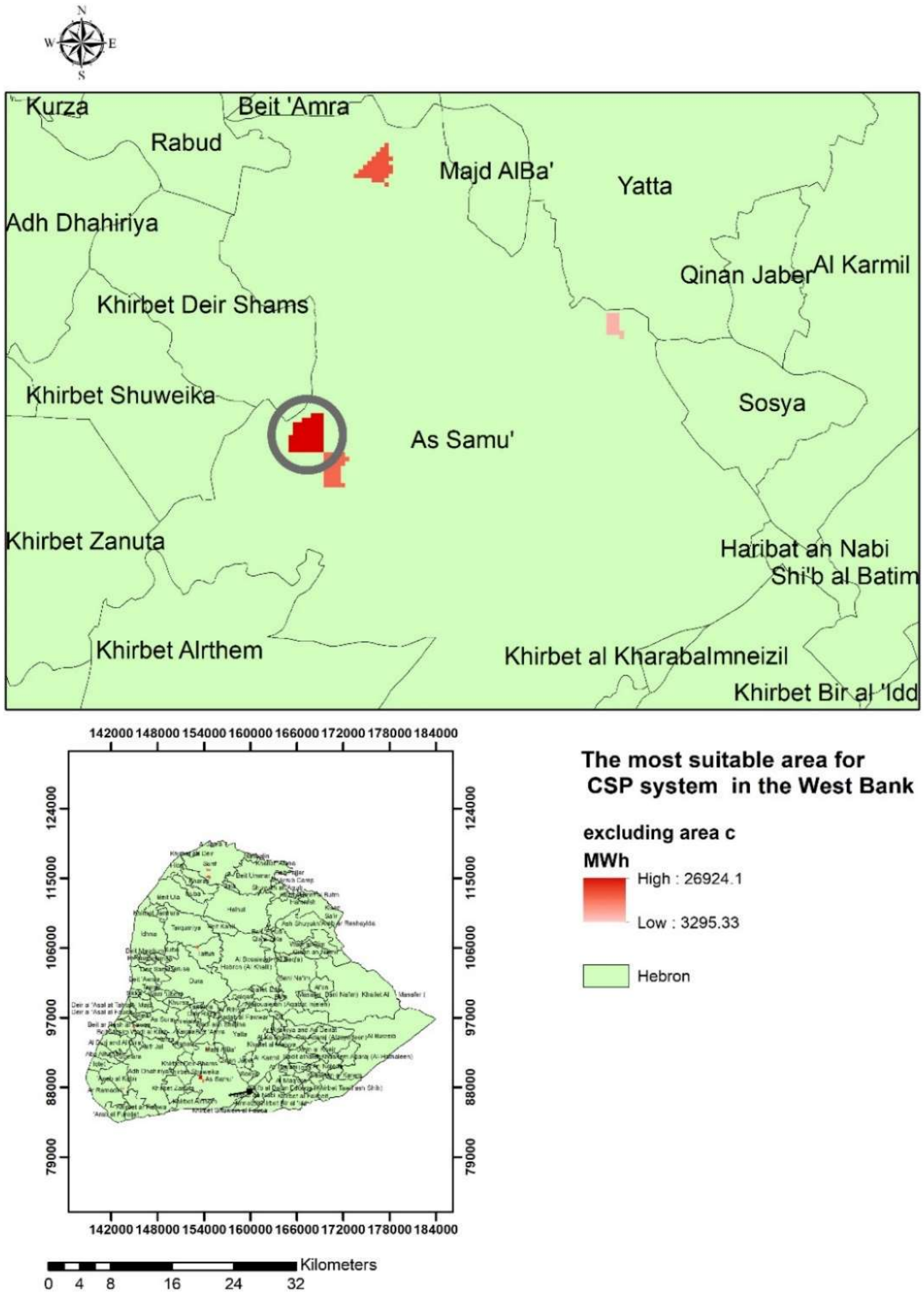


Figure 84: The most suitable location for the CSP system in the West Bank

For Wind systems, the most suitable location is in Nablus, at Aqraba village has shown in the fire below. With an area of 0.20658 km^2 and a total production of 0.00039 GWh/m^2 per year.

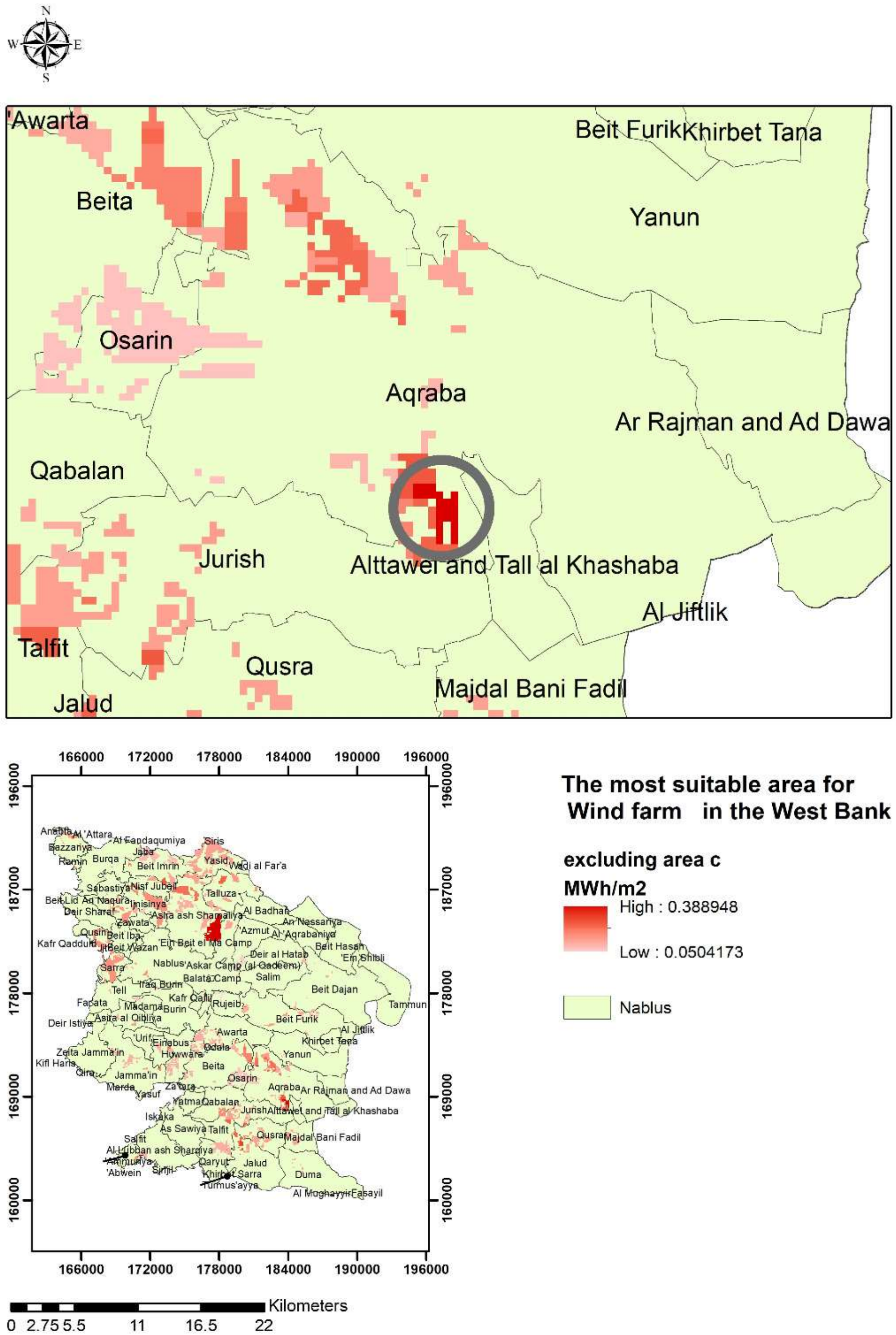


Figure 85: The most suitable location for Wind system in the West Bank

Discussion and Conclusion

The emphasis on affordable and sustainable energy sources has been accentuated by international policies [16]. Renewable energies are the key to energy independence away from all of the huge debts that Palestine is suffering and referring to the gathered data Palestine has a good potential for RE investments.

The findings of this study are promising and display several potential sites for different RE applications.

PV highest potential sites are scattered in all the governorates, Hebron, Jericho & al-Aghwar, Bethlehem, Nablus and Ramallah & Al-Bireh mainly if we included area C in the study On the other hand if we excluded area C from the study, the suitable sites are located in Hebron, Bethlehem, Jenin Nablus and Tulkarem mainly, which is about 20% only from the area including area C.

CSP systems potential sites have the highest available area according to the criteria applied, the sites with the highest potential are located in all of the governorates if we included area C except Jerusalem and Ramallah & Al-Bireh, and excluding area C will exclude Tubas, Salfit and Tulkarem also with almost 21% only of the high suitability area with area C.

Regarding Wind farms, at 10 m wind speeds, the highest potential sites including area C are located in Nablus, Hebron and Jenin. But excluding area C will result in a high potential in Nablus, Jenin and Hebron but Jericho & Al-Aghwar is excluded, the available area is about 45% of the total area for the highest potential sites including area C.

The availability of the missing data will improve the accuracy of the study. Many criteria were not considered in the current analysis. No site visits were conducted during this study due to covid-19, the potential sites could be located using Google Earth.

The usage of GIS-based MCDM for site selection was found to be very effective for classifying the suitability of the lands for each RE application. This study used the AHP method as it is easy to understand and modify for any future adjustments, and the results depend on the factors mentioned earlier in the study.

Following conclusions can be drawn from results:

- The study area after removing all the restricted areas mentioned in Data preparation equals 32% of the West Bank area including area C, and if we excluded area C only 7% of the West Bank area left for PV and CSP systems investing, while 58% of the West Bank area for Wind systems including area C and only 19% excluding area C.
- Suitable areas for PV systems investments with an area > 5,000 m^2 cover 8% of the West Bank with area C, and 2% of the West Bank area if we excluded area C.
- Suitable areas for CSP systems investments with an area > 25,000 m^2 cover 0.24% of the West Bank area with area C, and 0.05% without area C included.

- Suitable areas for Wind systems investments cover 5% of the West Bank area including area C in the calculations. Excluding area C from the study area will lead to only 2% of the West Bank area available for Wind investments.
- The suitable areas for the three applications are scattered in the governorates. Hebron is lucky to have the highest suitable locations for the two applications (PV, CSP) including and excluding area C, and Nablus is the highest for Wind systems including and excluding area C.
- Available areas for PV systems are scattered between the governorates, for CSP systems, Ramallah & Al-Bireh, and Jerusalem have zero available areas including area C, adding to that Tubas, Tulkarem, Salfit, and Jenin with zero available areas when we exclude area C.
- Investing in these locations will achieve PENRA's goal for RE investments as mentioned before.
- Investing in a small percentage of the available areas will cover a good percentage of the annual electricity bills, and reduce the shortage of electricity.
- Facilitating the construction and investment process in area C will rapidly increase the chance of achieving PENRA's goals.

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