PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA

MINISTRY OF HIGHER EDUCATION AND SCIENTIFIC RESEARCH

UNIVERSITY MOHAMED BOUDIAF OF M'SILA

FACULTY OF TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

Course Material for the Subject:

Solar and Wind Resources

Intended for 2^{nd} Year Bachelor's Students

Specialty: Renewable Energies and Environment

Prepared by:

Dr. Bilal BOUDJELLAL

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Foreword

This manuscript is intended for 2nd Year Bachelor's (LMD) students, specializing in Renewable Energies and Environment. It complies with the official program.

The aim of this course is to familiarize students with meteorological data (solar irradiation and its various components, wind speed, relative humidity, temperature…) and the assessment of renewable energy production for a site (solar resource, wind resource).

I hope this document will be appreciated by my colleagues and will help the students. I would be very pleased to receive their comments and suggestions with gratitude.

Chapitre I. Algerian Renewable Energy Resource Atlas

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I.1 Introduction

Engineering for sustainability is an emerging theme for the twenty-first century, and the need for more environmentally benign electric power systems is a critical part of this new thrust. Renewable energy systems that take advantage of energy sources that will not diminish over time and are independent of fluctuations in price and availability are playing an ever-increasing role in modern power systems.

I.2 Renewable energy and climate change

Demand for energy and associated services to meet social and economic development and improve human welfare and health is increasing. All societies require energy services to meet basic human needs (e.g., lighting, cooking, space comfort, mobility and communication) and to serve productive processes. Since approximately 1850, global use of fossil fuels (coal, oil and gas) has increased to dominate energy supply, leading to a rapid growth in carbon dioxide (CO_2) emissions and have contributed significantly to the historic increase in atmospheric Greenhouse gas (GHG) concentrations. Most of the observed increase in global average temperature since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.

There are multiple options for lowering GHG emissions from the energy system while still satisfying the global demand for energy services. Some of these possible options, such as energy conservation and efficiency, fossil fuel switching, RE, nuclear and carbon capture and storage.

As well as having, a large potential to mitigate climate change, RE can provide wider benefits and contribute to social and economic development, energy access, a secure energy supply, and reducing negative impacts on the environment and health.

I.3 Renewable energy technologies

RE comprises a heterogeneous class of technologies. Various types of RE can supply electricity, thermal energy and mechanical energy, as well as produce fuels that are able to satisfy multiple energy service needs. Some RE technologies that can be deployed at the point of use (decentralized) in rural and urban environments, whereas others are primarily deployed within large (centralized) energy networks. The most popular renewable energy sources currently are: Solar, Wind, Hydro, Geothermal, Biomass and Hydrogen.

I.4 Solar and wind energy potential in Algeria

Algeria has a vast surface area of 2,381,741 km², characterized by diverse topographical and climatic conditions. Located in North Africa, it spans a longitude range of 8.68°W to 12°E and a latitude range of 18.96°N to 37.05°N. Moreover, the country encompasses three distinct geographical regions: coastal, highlands, and desert.

The Algerian government seeks to reduce reliance on fossil fuels in the electricity sector and promote sustainable economic development by prioritizing renewable energy. Through its ambitious 2030 program, Algeria aims to diversify its energy mix, protect the environment, and combat climate change by prioritizing large-scale deployment of Renewable Energy Sources (RES).

Algeria has made many efforts in renewable energy development. A 25 MW hybrid solar-gas power station was installed in Hassi R'mel, while the Algerian company of electricity and renewable energies (SKTM) set up 344 MW of PV farms in southern regions. Additionally, a 10 MW wind park was established in Adrar. Algeria's large-scale renewable energy deployment leverages its vast solar, wind, geothermal, and bioenergy potential. The country has one of the world's highest solar potentials, with over 2500 hours of annual sunlight and solar radiation in the order of 3000 kWh/m²/year. Wind energy is also promising, with several sites having average wind speeds above 5 m/s.

I.5 Solar energy potential in Algeria

The solar energy potential is in annual average sum of 2.10 MWh/m^2/year. The Algerian coastal zone is characterized by the lowest solar potential particularly in the northeast region amounted to an annual sum of 1.62 MWh/m^2/year. In contrast, the southeast regions (Tamanrasset) have the highest solar potential in the country amounted to 2.38 MWh/m^2/year.

The solar potential is uniformly distributed compared to wind power. Both potentials are lowest near the major population center, particularly surrounding Algiers. However, there are a number of sites for grid-connected wind power and PV within the current power grid infrastructure of Algiers city.

I.5.1 Outer space solar irradiation map

Solar radiation that reaches the upper limit of the atmosphere depends mainly on the inclination of the sun radiation with respect to the equatorial plane and distributed according to geographical latitudes. Its value increases towards the equator. This parameter is also used to predict the global solar radiation on the surface of the earth. Indeed the same amount of solar energy intercepted by the earth sphere is spread over a larger area in the high latitudes than at the equator. Therefore, the available energy per unit area decreases from the equator to the poles.

The solar constant represents the amount of solar energy that would be received, per unit of time, one square meter of surface on the edge of the atmosphere at normal incidence. It varies from 1320 W/m2 to 1410 W/m2 according to the eccentricity of the Earth's orbit, its annual average is equal to 1368 W/m2.

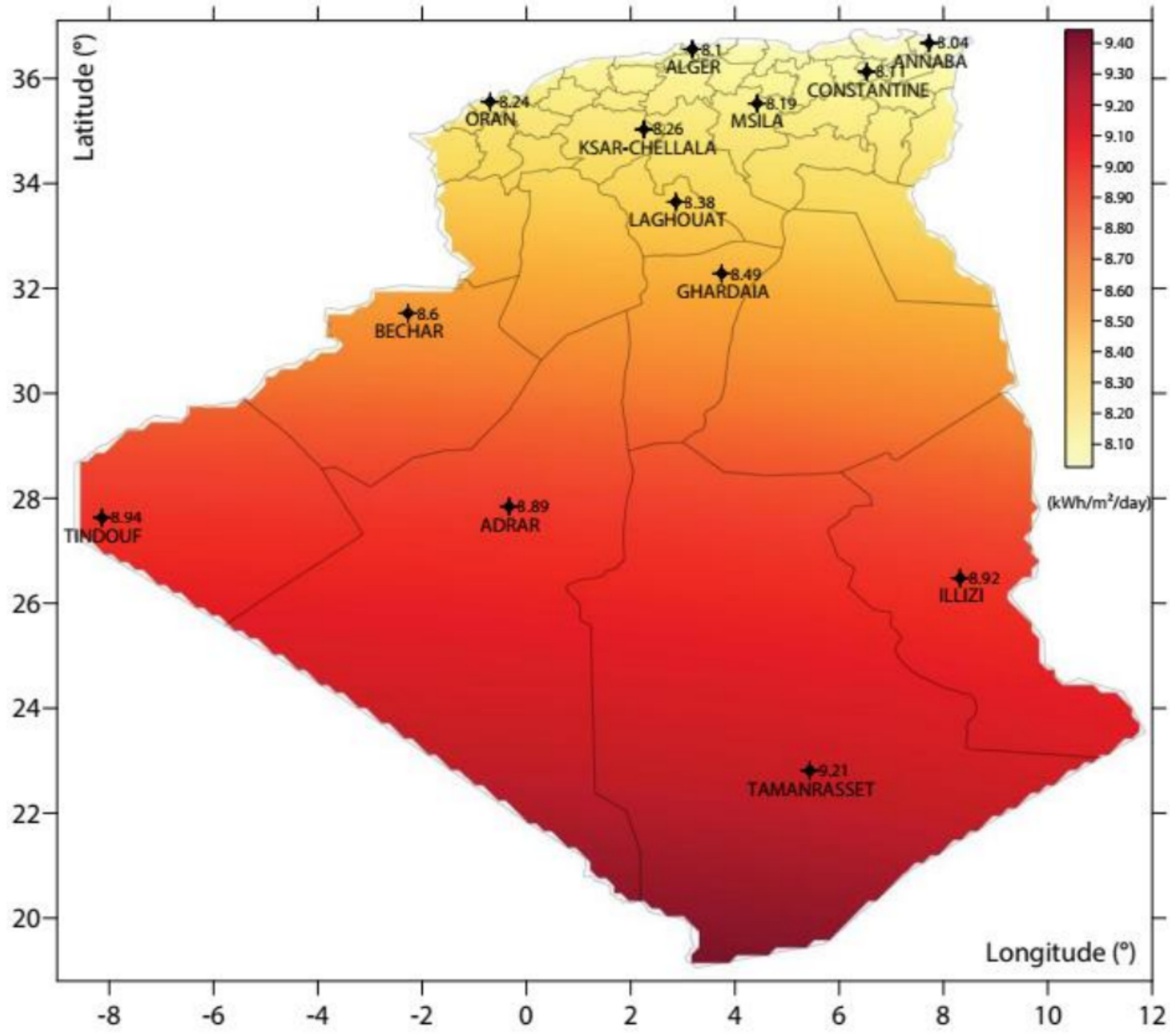

Figure I.1– Outer space solar irradiation map.

I.5.2 Clear sky global Irradiation map

Clear sky global radiation is the result of the sum of the normal component of the solar radiation and the radiation scattered by particles suspended in the atmosphere in the absence of clouds. It depends only on the natural molecules that make up the earth's atmosphere but is highly dependent on atmospheric turbidity.

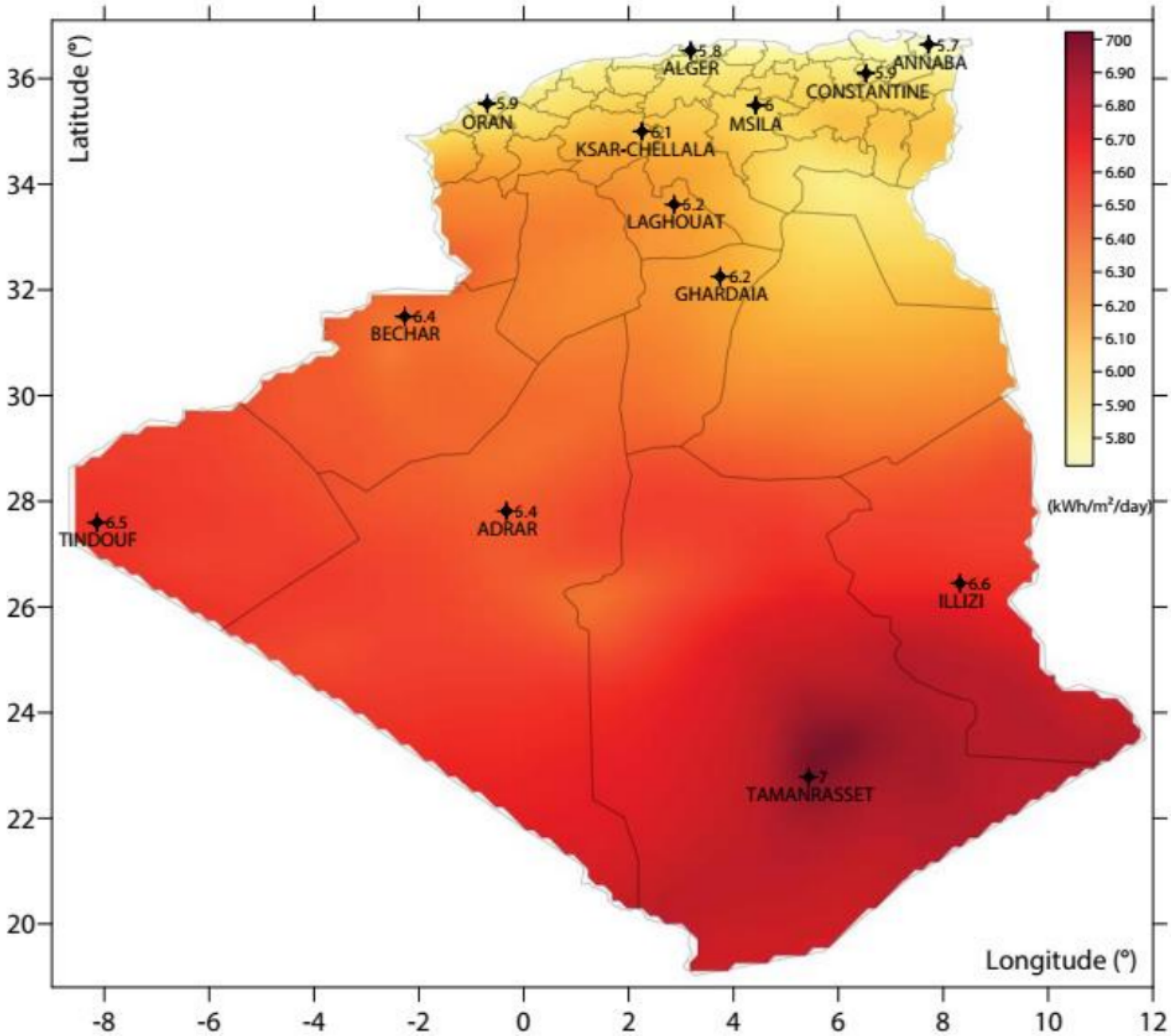

Figure I.2– Clear sky global Irradiation map.

I.5.3 Global horizontal Irradiation map

When passing the atmosphere, solar radiation is scattered, absorbed and reflected by atmospheric molecules (CO2, O3, H2O, etc ...), natural aerosols or due to human activity and the different types of clouds that form ac- cording to the season of the year.

Therefore, global solar radiation received on a horizontal plane can be divided into two components (direct and diffuse).

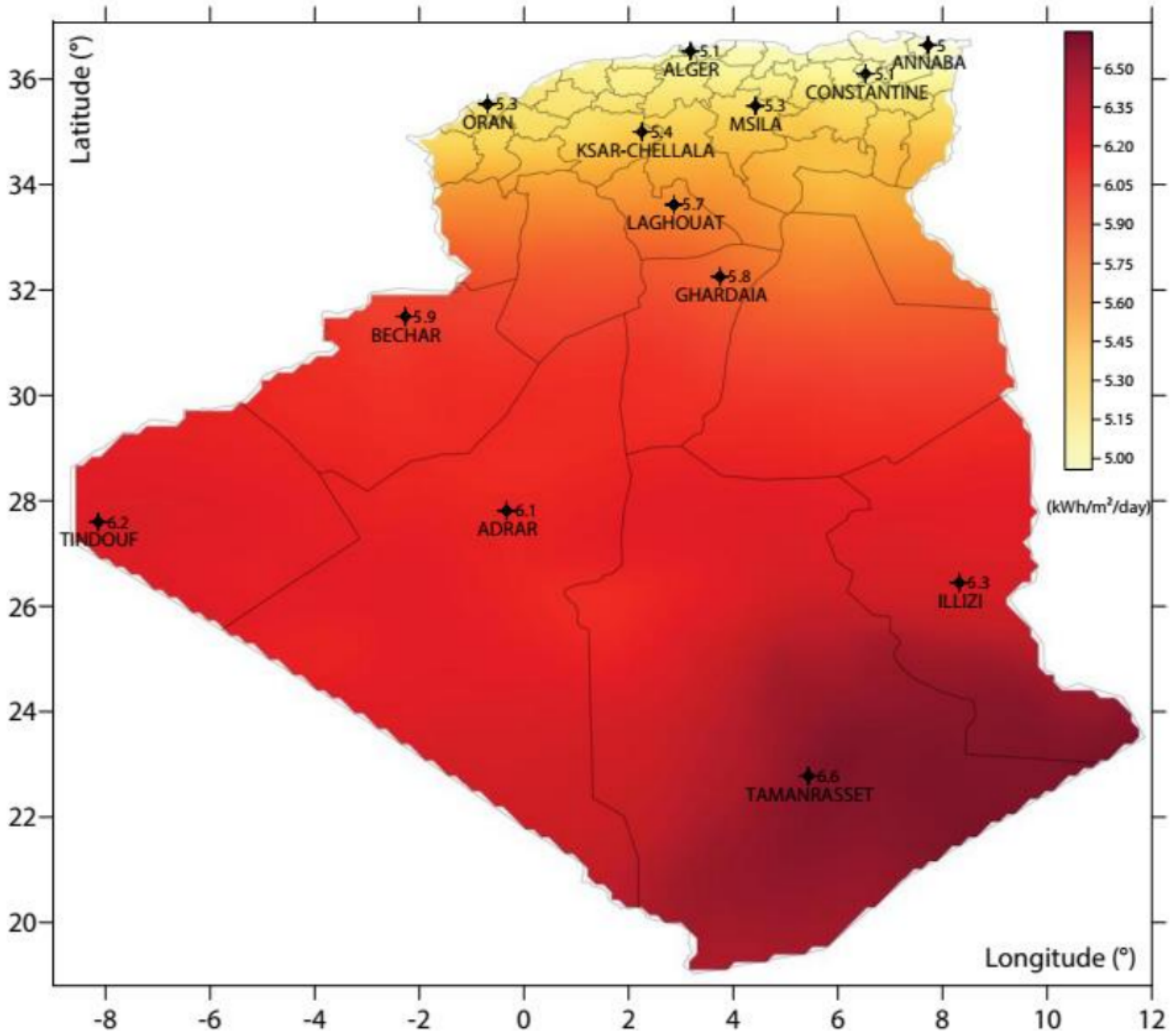

Figure I.3– Global horizontal Irradiation map.

I.5.4 Direct irradiation (beam) map

Direct radiation, is also sometimes called «beam radiation» or «direct be am radiation». It is used to describe solar radiation traveling on a straight line from the sun down to the surface of the earth. This parameter is important for the deployment of concentrated solar technologies.

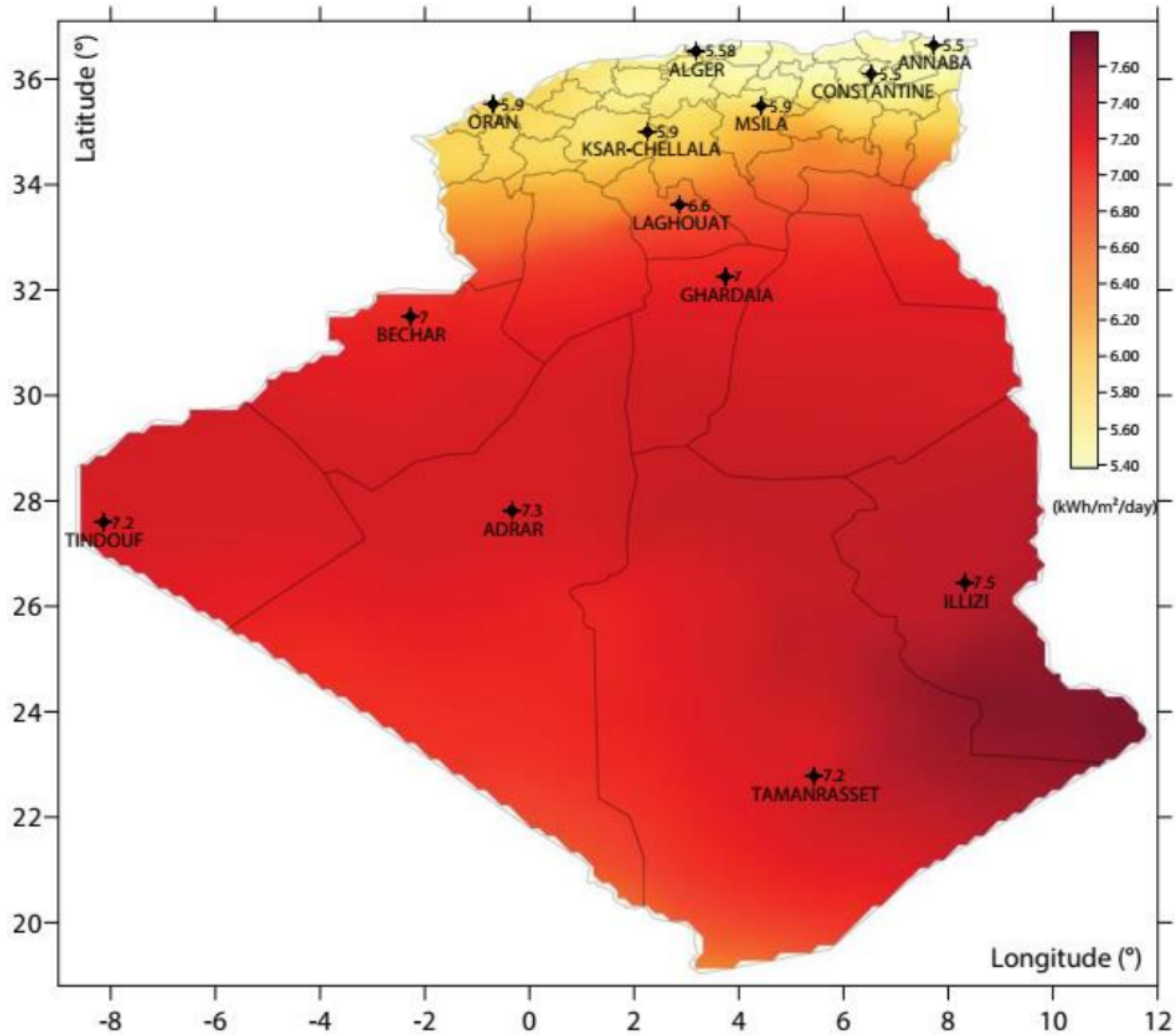

Figure I.4– Direct irradiation (beam) map.

I.5.5 Cloud coverage map

Cloud cover is one of the key parameters for estimating sunshine duration. Its value ranges from ***0*** for a totally clear sky, to ***1*** for a totally overcast sky.

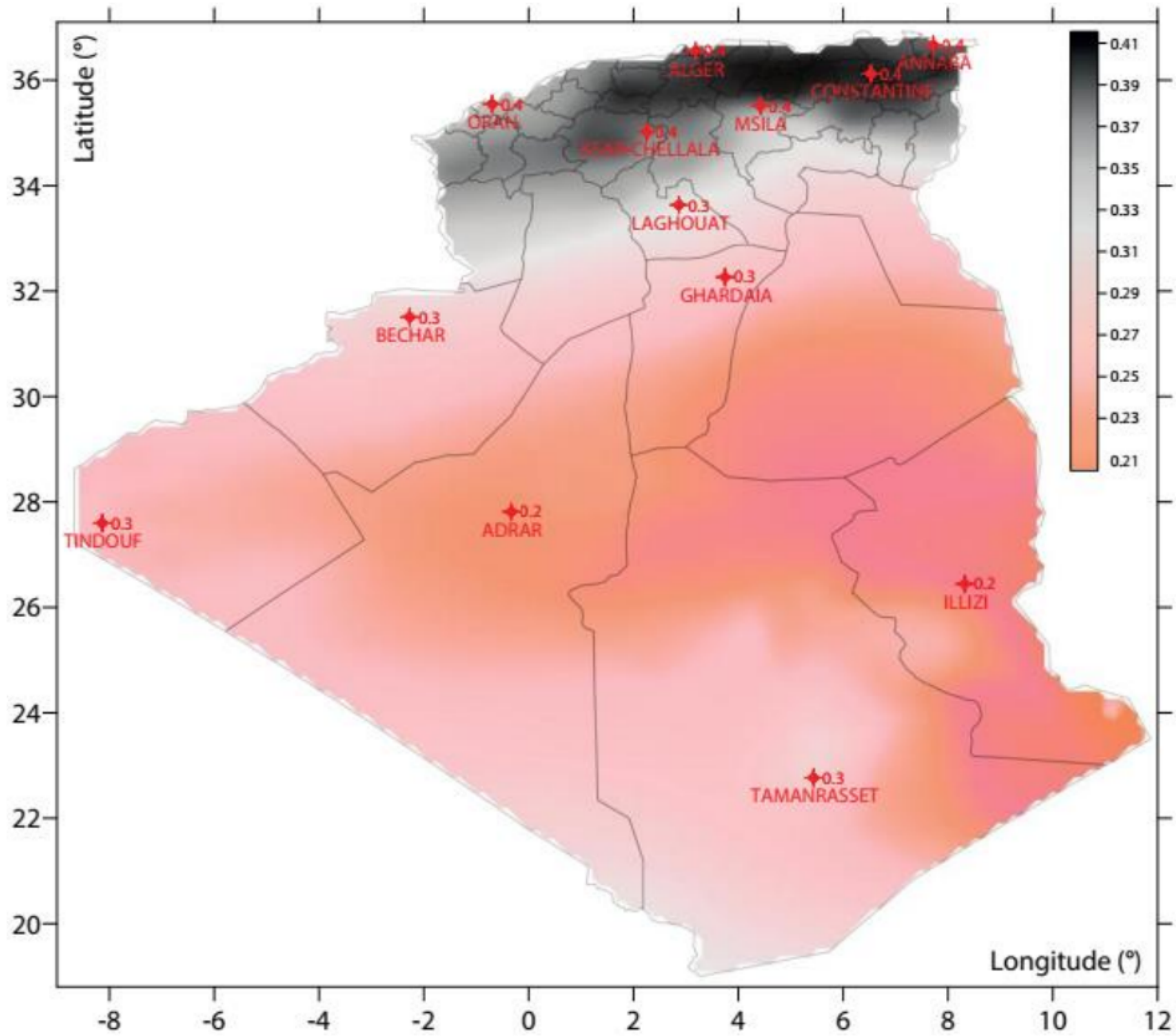

Figure I.5– Cloud coverage map.

I.6 Wind energy potential in Algeria

The average wind potential in Algeria is estimated at 1.90 MWh/m^2/year. The highest annual sum of wind potential located in the region of Ain Salah amounted to 3.33 MWh/m^2/year. Moreover, another important wind potential is observed in the highlands of Algeria as well as in the northwest regions (Oran province). In contrast, the lowest potential is located in the regions from the capital Algiers to the province of Bejaia and the sum of annual energy is around 380.84 kWh/m2/year.

I.6.1 Mean wind speed map

The CDER has developed several wind maps, which are continually updated, using more recent meteorological data and collected over a larger number of measurement points. The wind map given in these two figures, represents the distribution of the mean wind speed (m/s) over the Algerian territory at *10* and *80m* above ground level (***a.g.l.***).

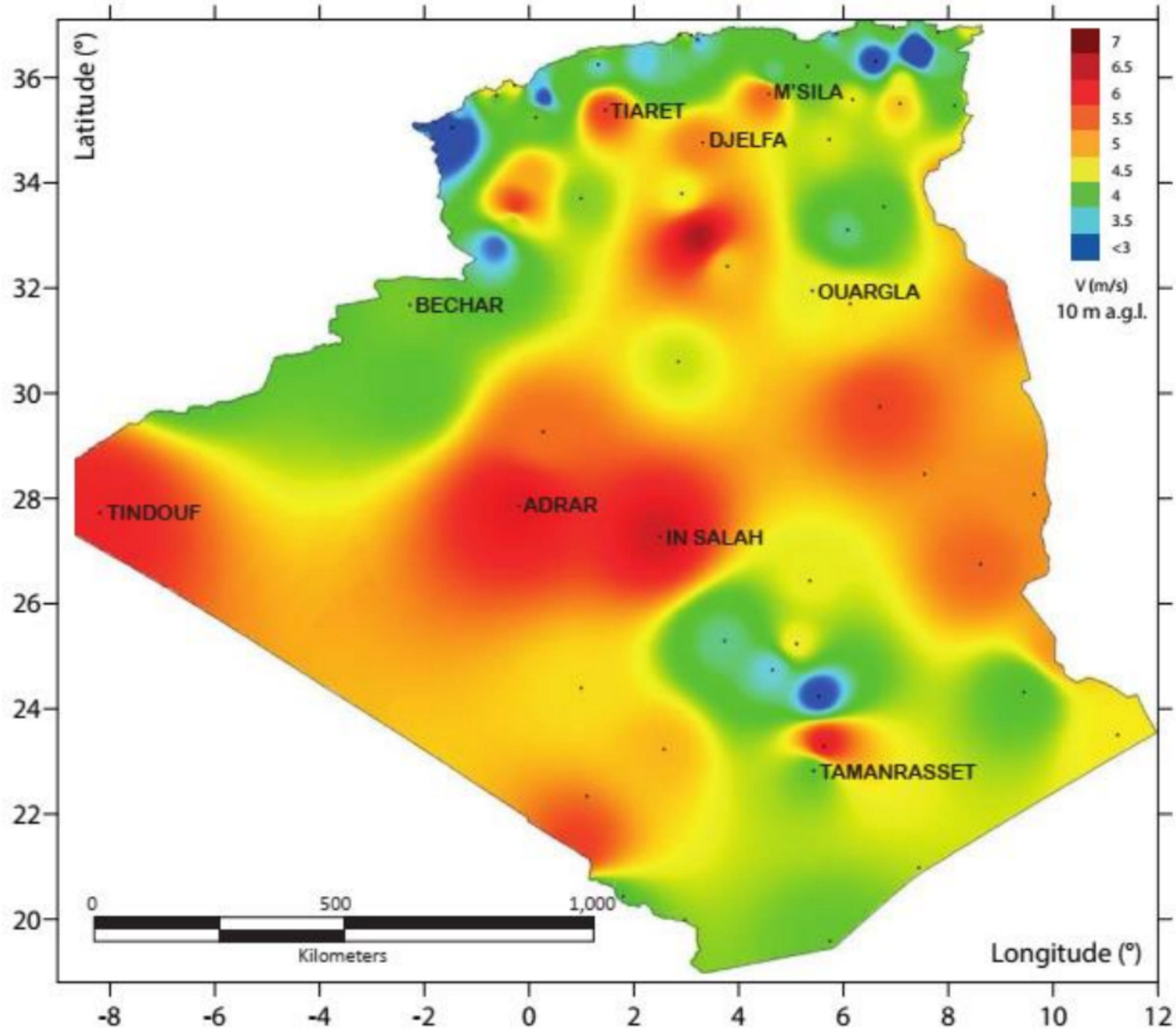

Figure I.6– Mean wind speed map 10m a.g.l.

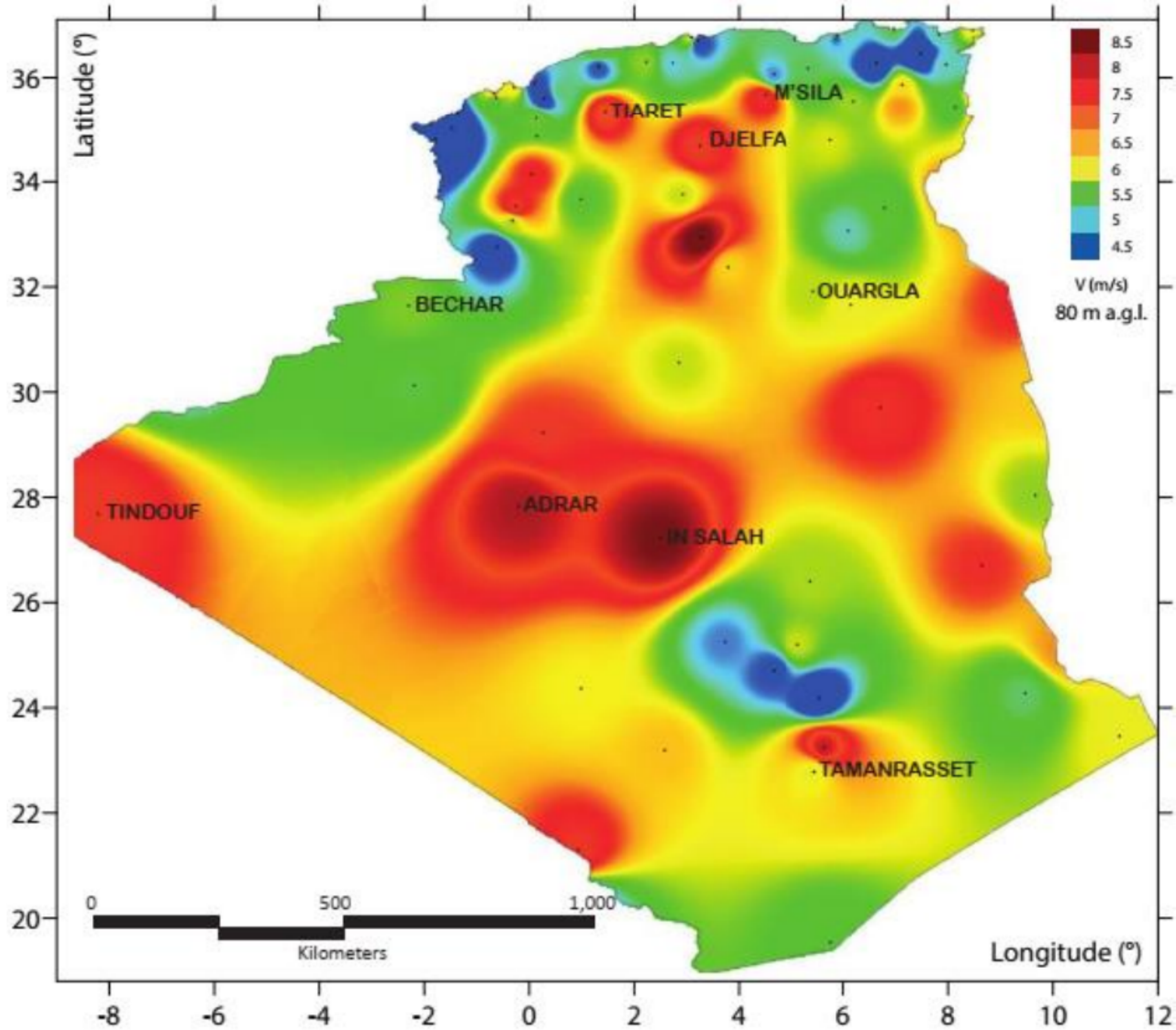

Figure I.7– Mean wind speed map 80m a.g.l.

I.6.2 Mean wind power density map

For an optimal assessment of the wind resource available at a given site, it is necessary to calculate the average power density (W/m²) of the wind. It indicates the energy available on the site recoverable for conversion into electricity using wind turbine. At *50m* height, a site is considered eligible for wind farm installation if it has a power density between *300* and *400 W/m²*.

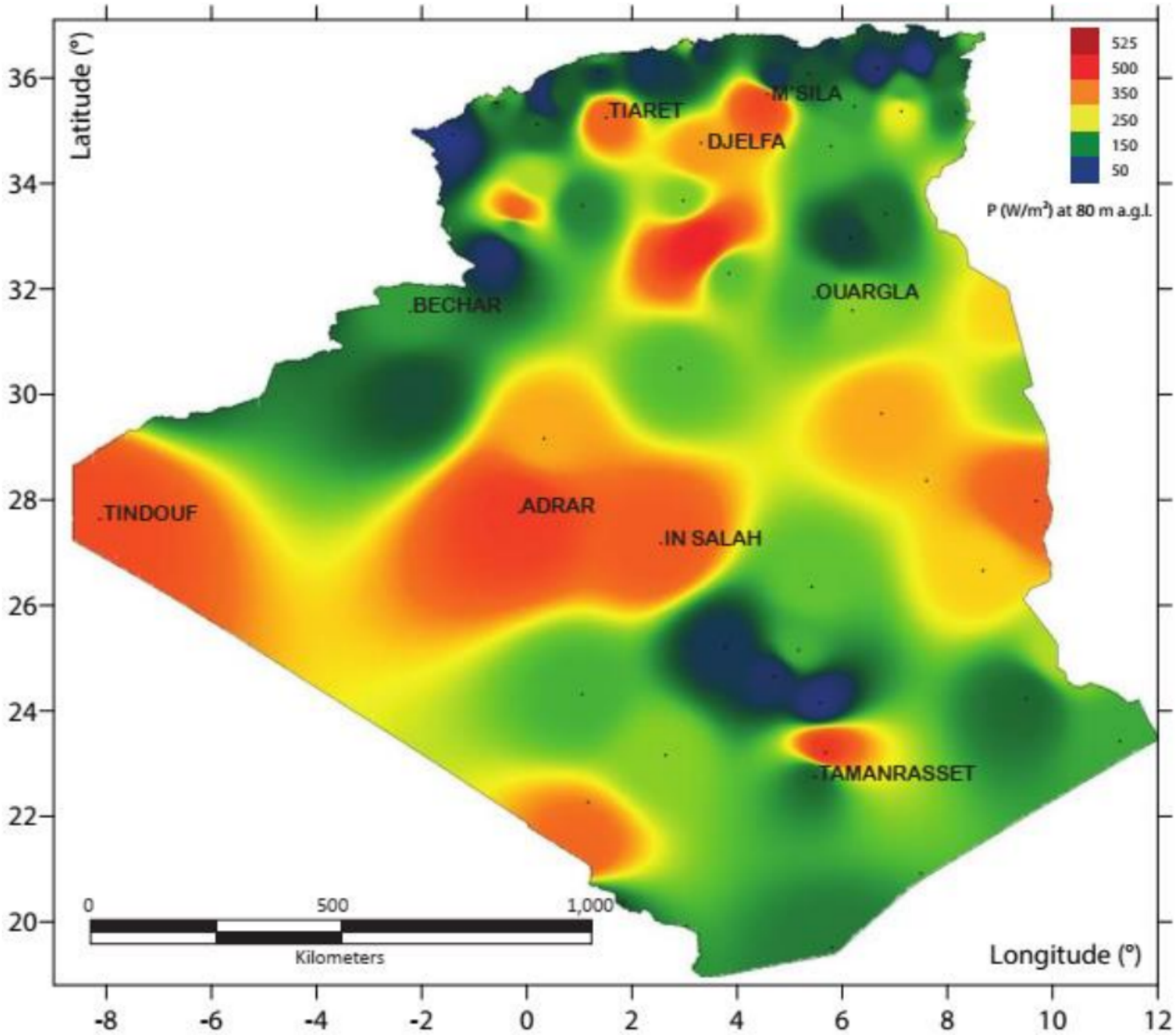

Figure I.8– Mean wind power density map.

I.6.3 Weibull parameters

Due to the randomly behavior of the wind speed and its variation over the time, the two-parameter Weibull function is used to characterize the frequency distribution of wind speeds over a given period.

The scale parameter: The scale parameter (m/s) provides information on the average wind characteristic at the studied site, taking into account the variability of the wind.

The shape parameter: The shape parameter indicates the more or less pointed character of the Weibull distribution. A lower value would imply a highly variable of wind whereas a constant wind would imply a higher value.

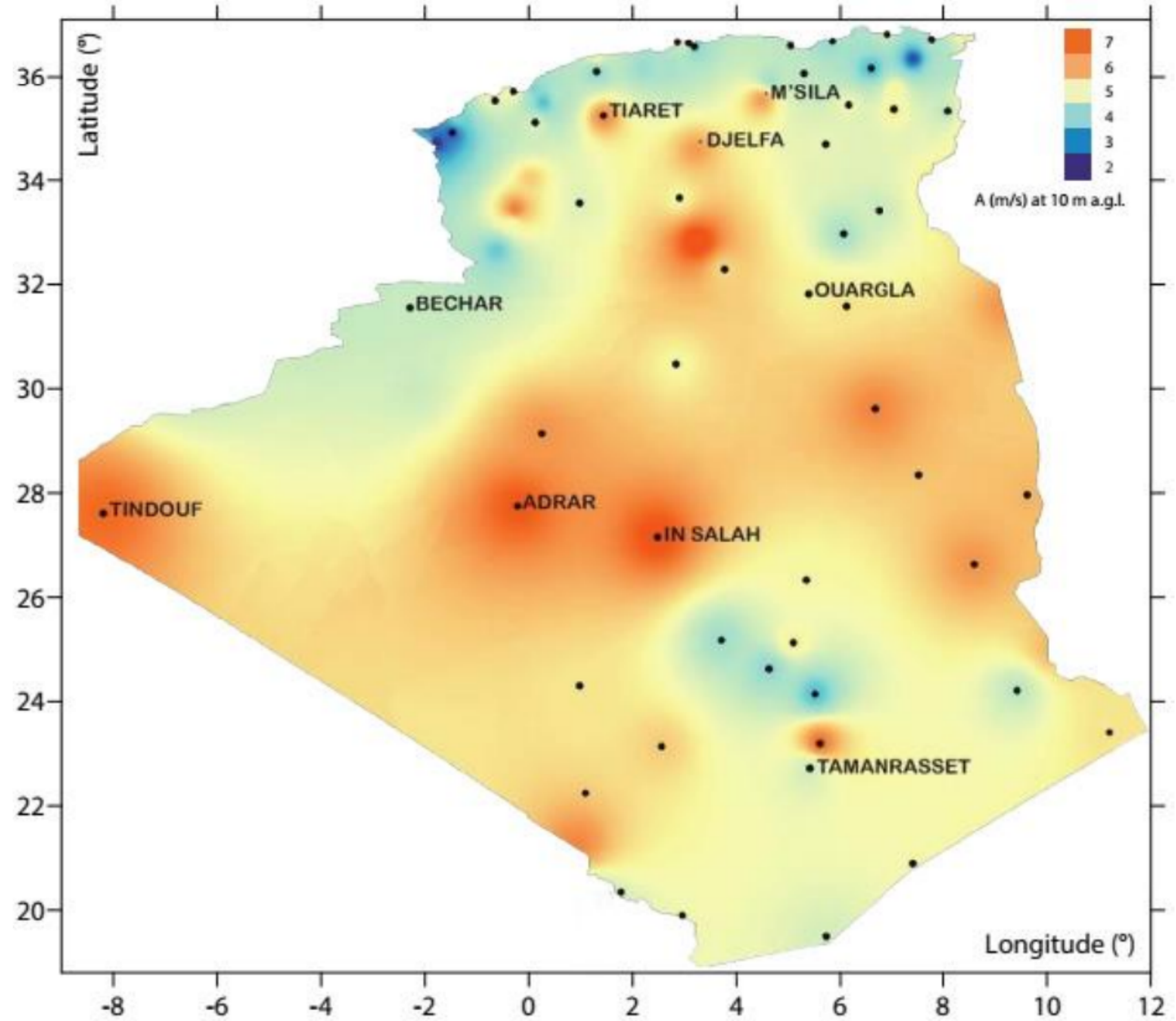

Figure I.9– The scale weibull parameter.

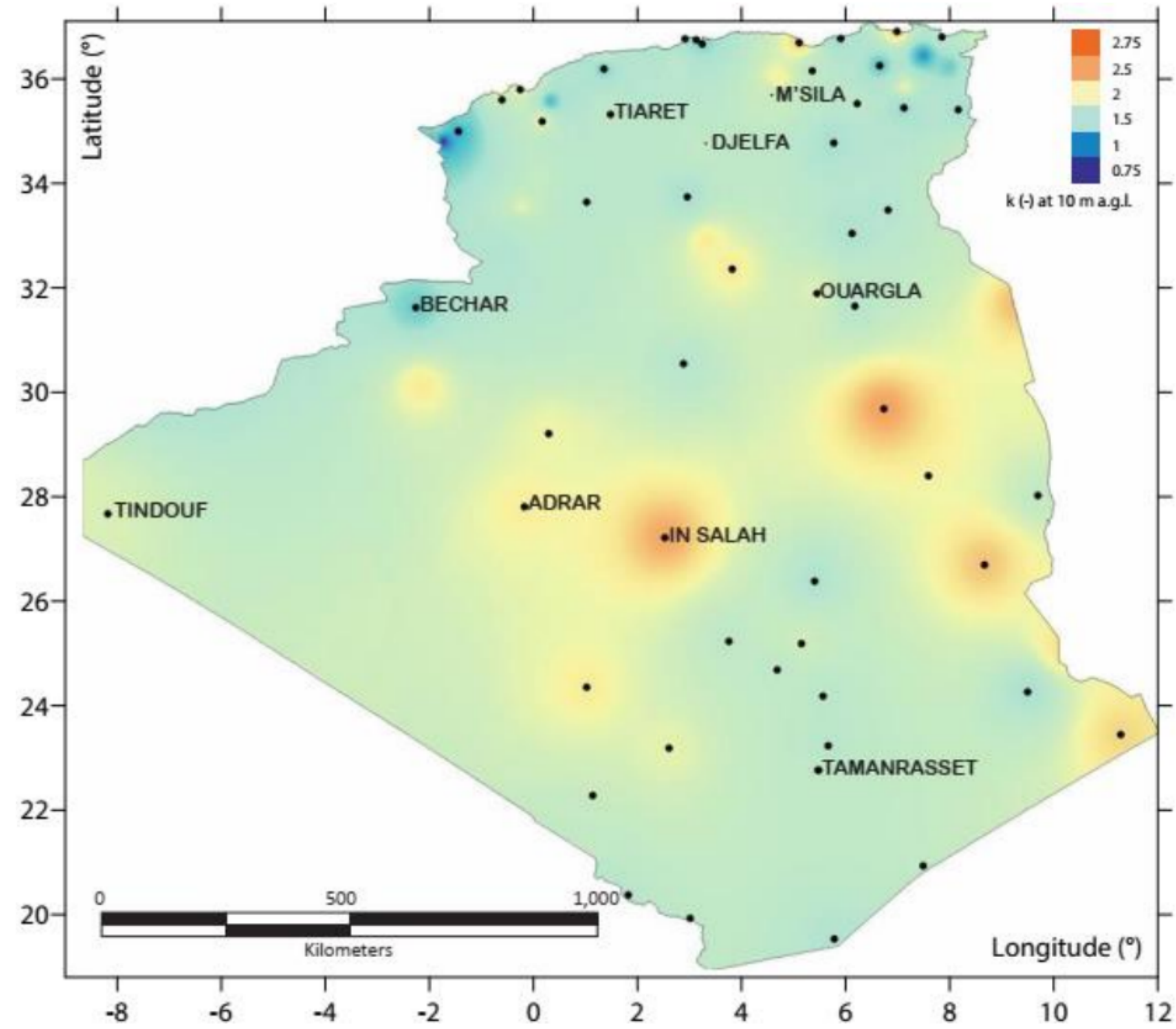

Figure I.10– The shape weibull parameter.