جامعة الحسن الثاني بالدار البيضاء
UNIVERSITÉ HASSAN II DE CASABLANCA

2nd International Conference and Exhibition on
Satellite & Space Missions
July 21-23, 2016 Berlin, Germany

The evaluation of solar farm locations applying Geographic Information System and Multi-Criteria Decision-Making methods: Case study in southern Morocco

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Outline

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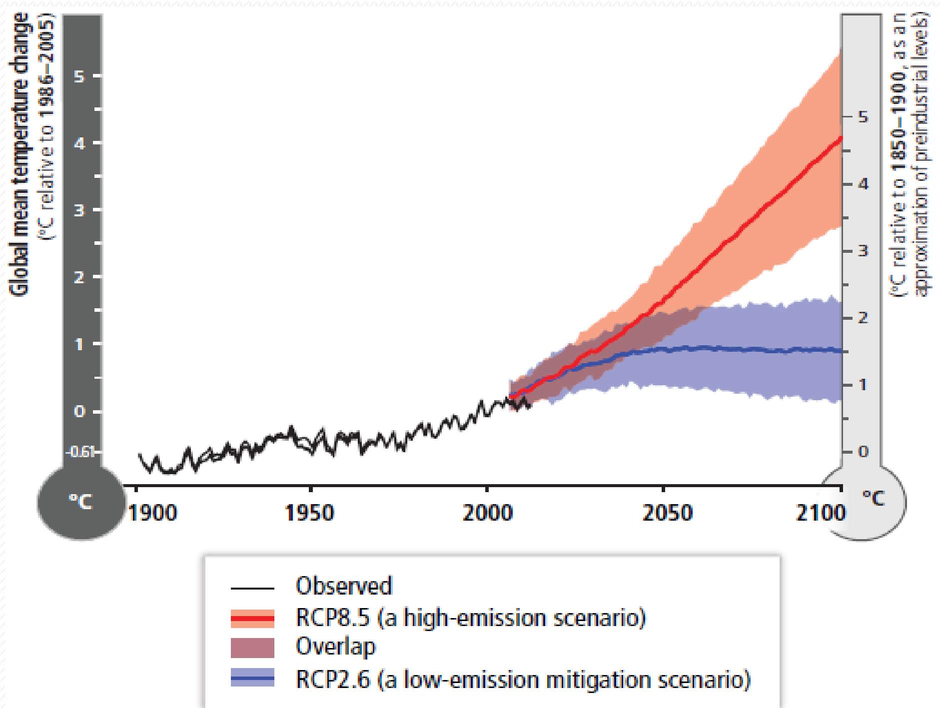
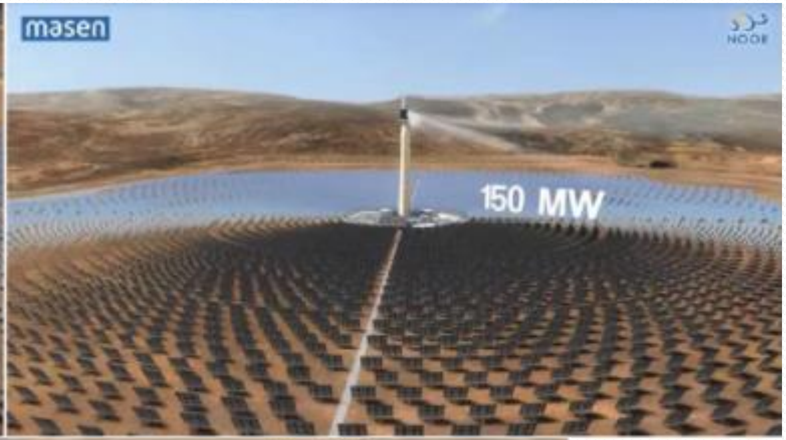
Introduction

The extraction and burning of fossil fuels cause the release of CO_2 and other global warming pollutants into the atmosphere *(IPCC - Working Group II Contribution to AR5, Impacts, Adaptation and Vulnerability 2014);*



Introduction

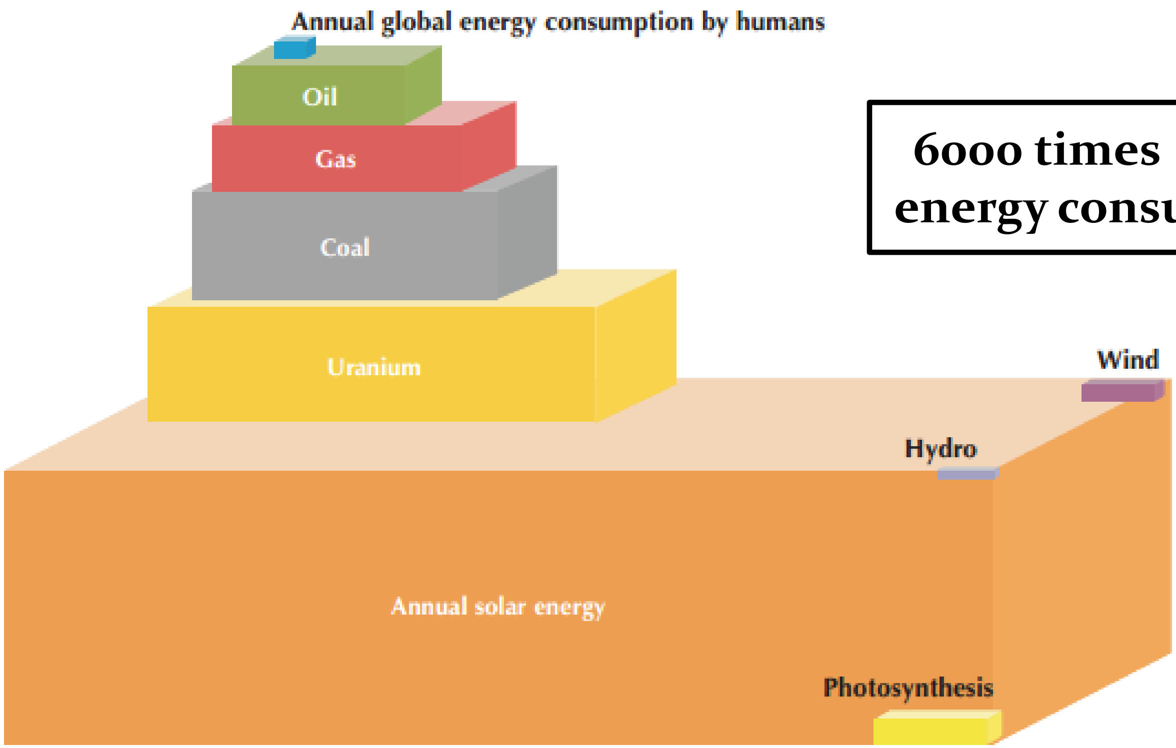
- A major decarbonization strategy is to substitute fossil power generation with renewable energy sources (IPCC : Special Report on Renewable Energy Sources and Climate Change Mitigation., 2011, United Nations, 1997);



Ouarzazate solar farm

Images : Moondar Casablanca (Masen – Noor II et Noor III, youtube.com)
Source data : http://www.nrel.gov/csp/solarpaces/by_project.cfm

Introduction

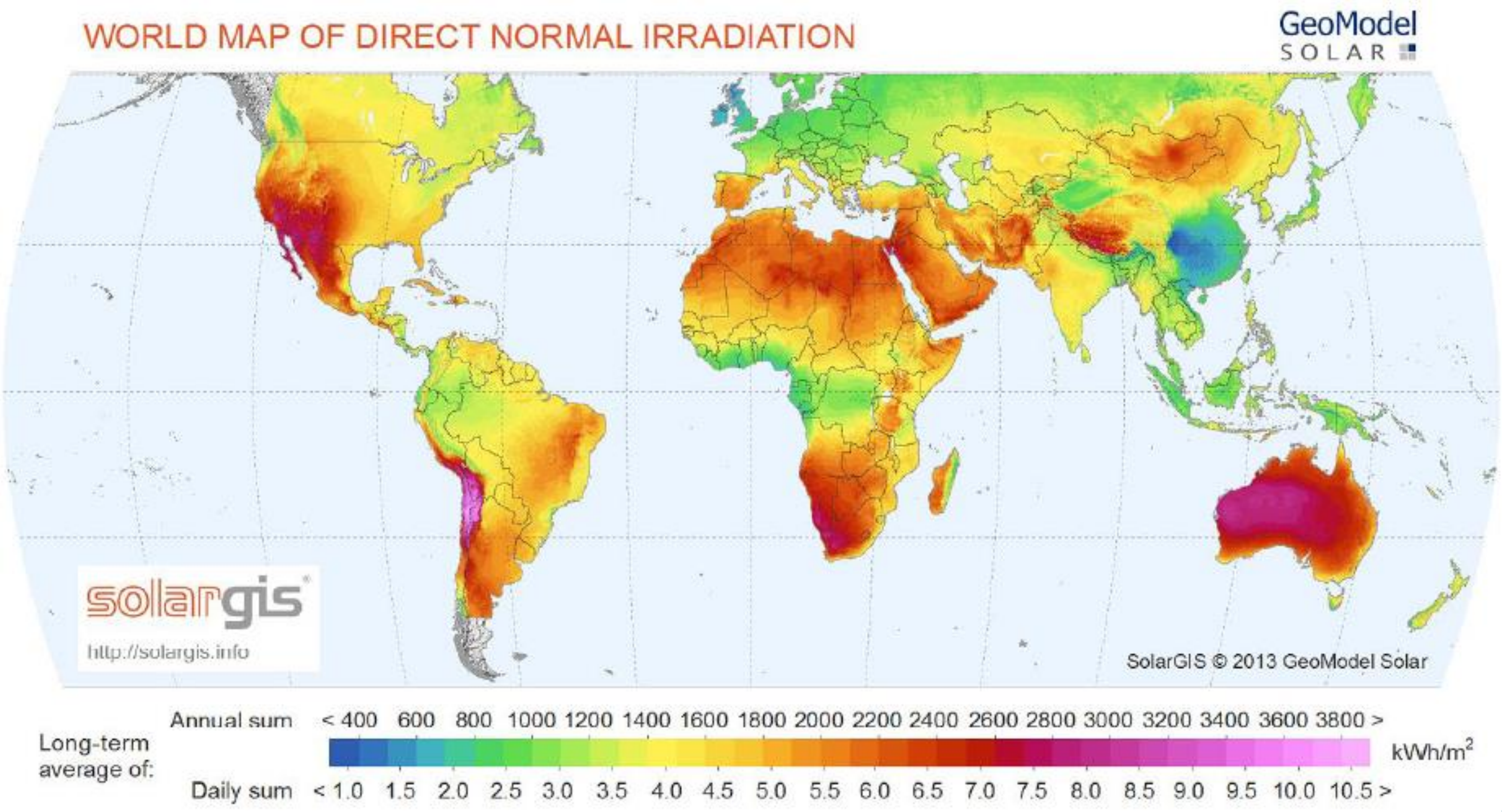


Source: National Petroleum Council, 2007, after Craig, Cunningham and Saigo (republished from IEA, 2008b).

6000 times the annual global energy consumption by human

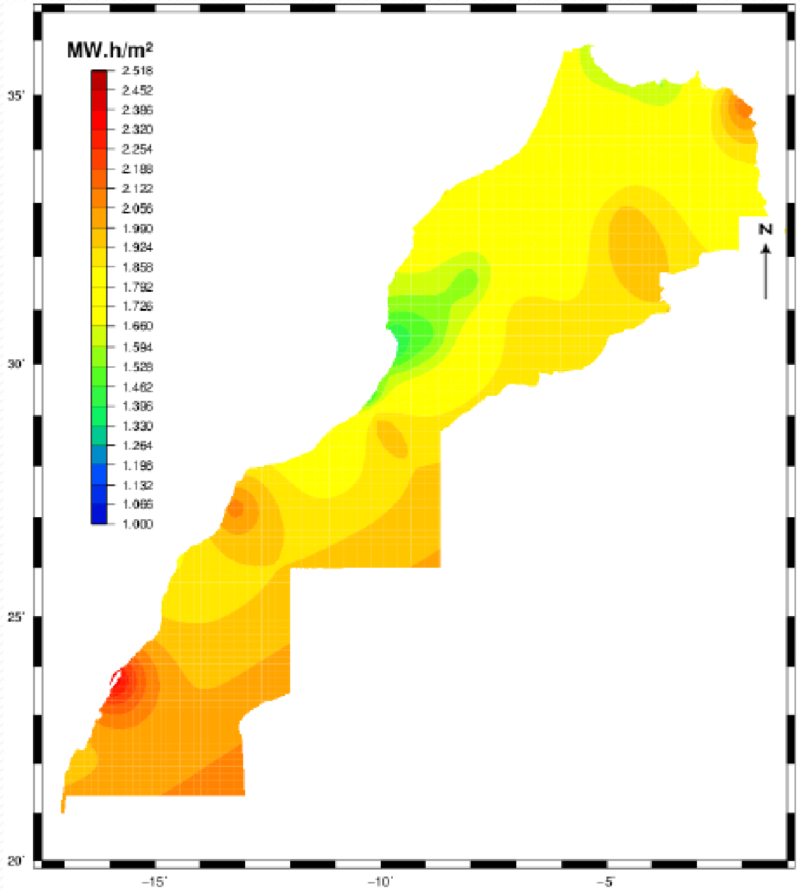
Introduction

The solar radiation is free, renewable and clean



Introduction

Morocco Map of Direct Normal Irradiation



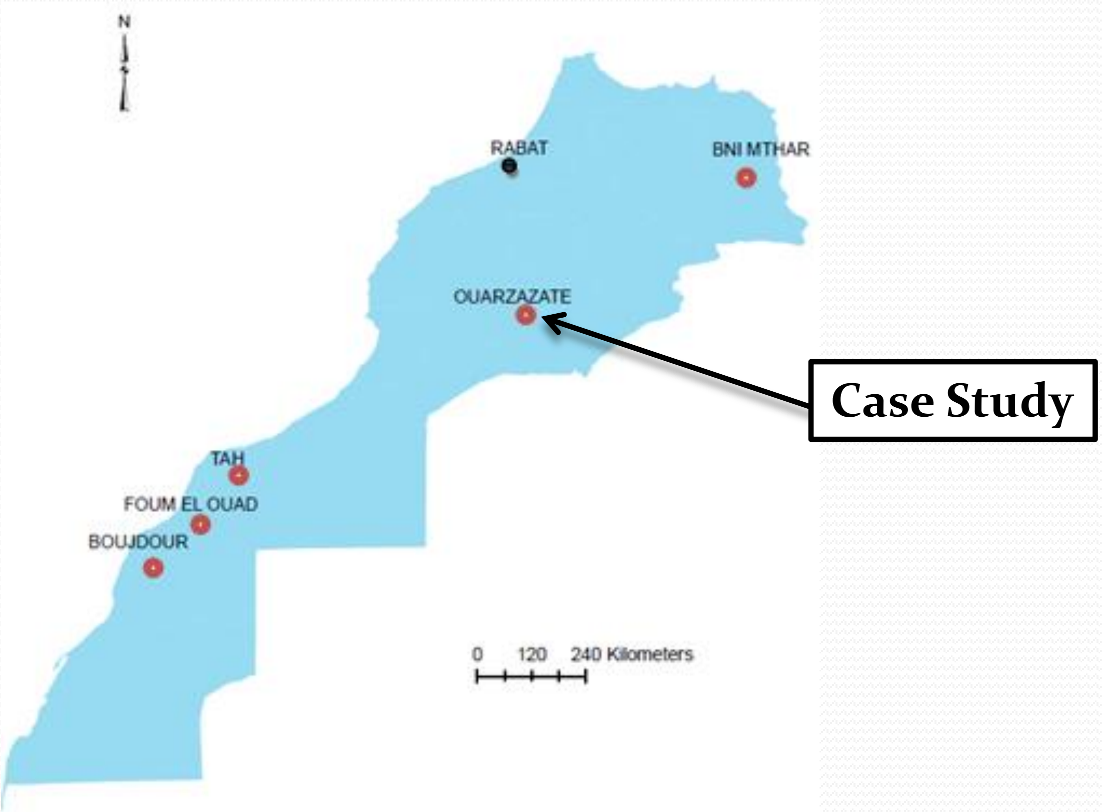
- The Middle East and North Africa has vast resources of solar energy due to their Density of Normal Irradiation (DNI) (*DLR - Institut für Technische Thermodynamik - MED-CSP*, 2005);

Objectif

- The aim objective of our case study is to assess the most appropriate optimal site selection for the implementation of renewable energy in the region of Ouarzazate.

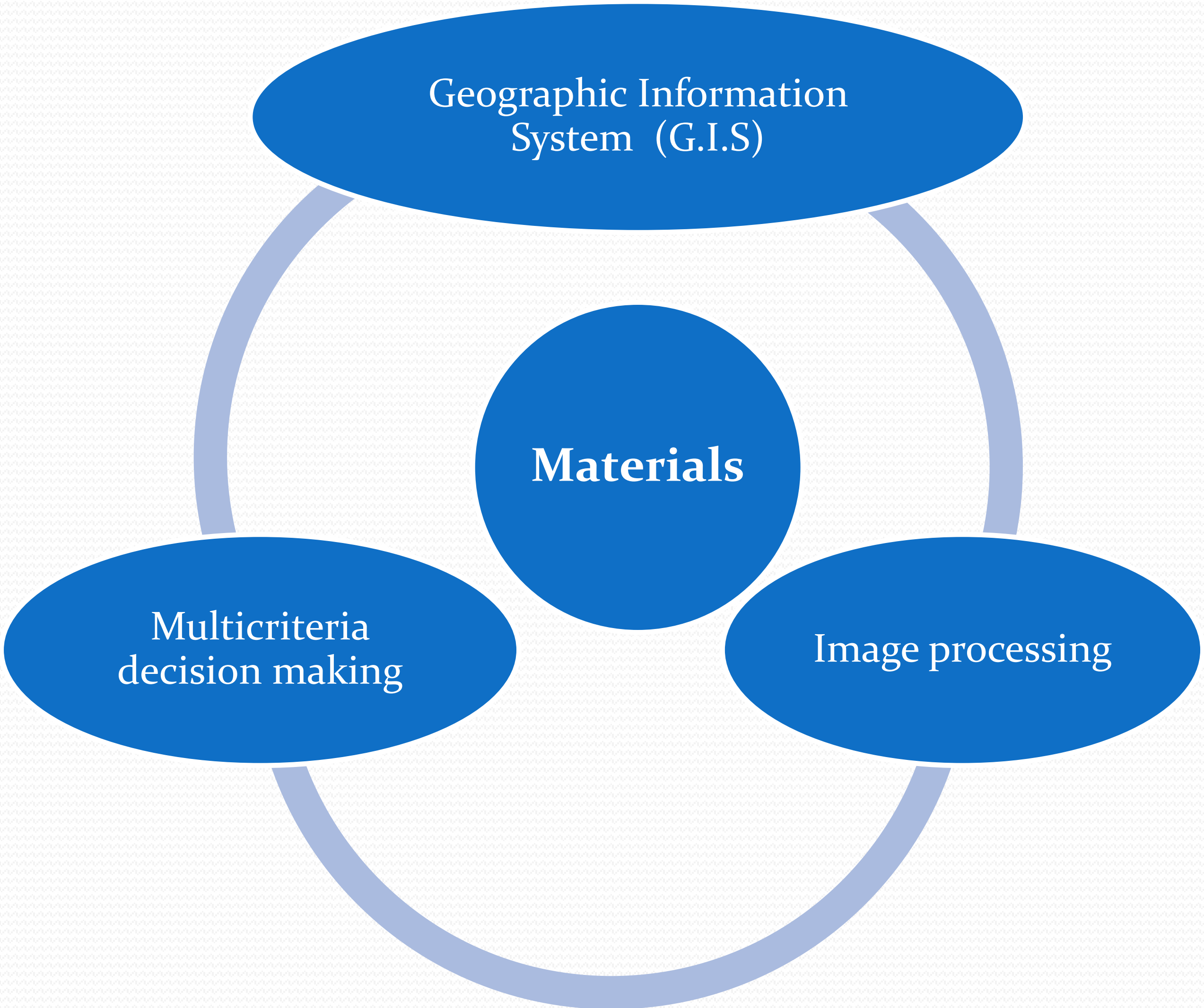
Study area

The study area is located in the southeast of Atlas mountains and includes the region of Ouarzazate



Materials and Methods

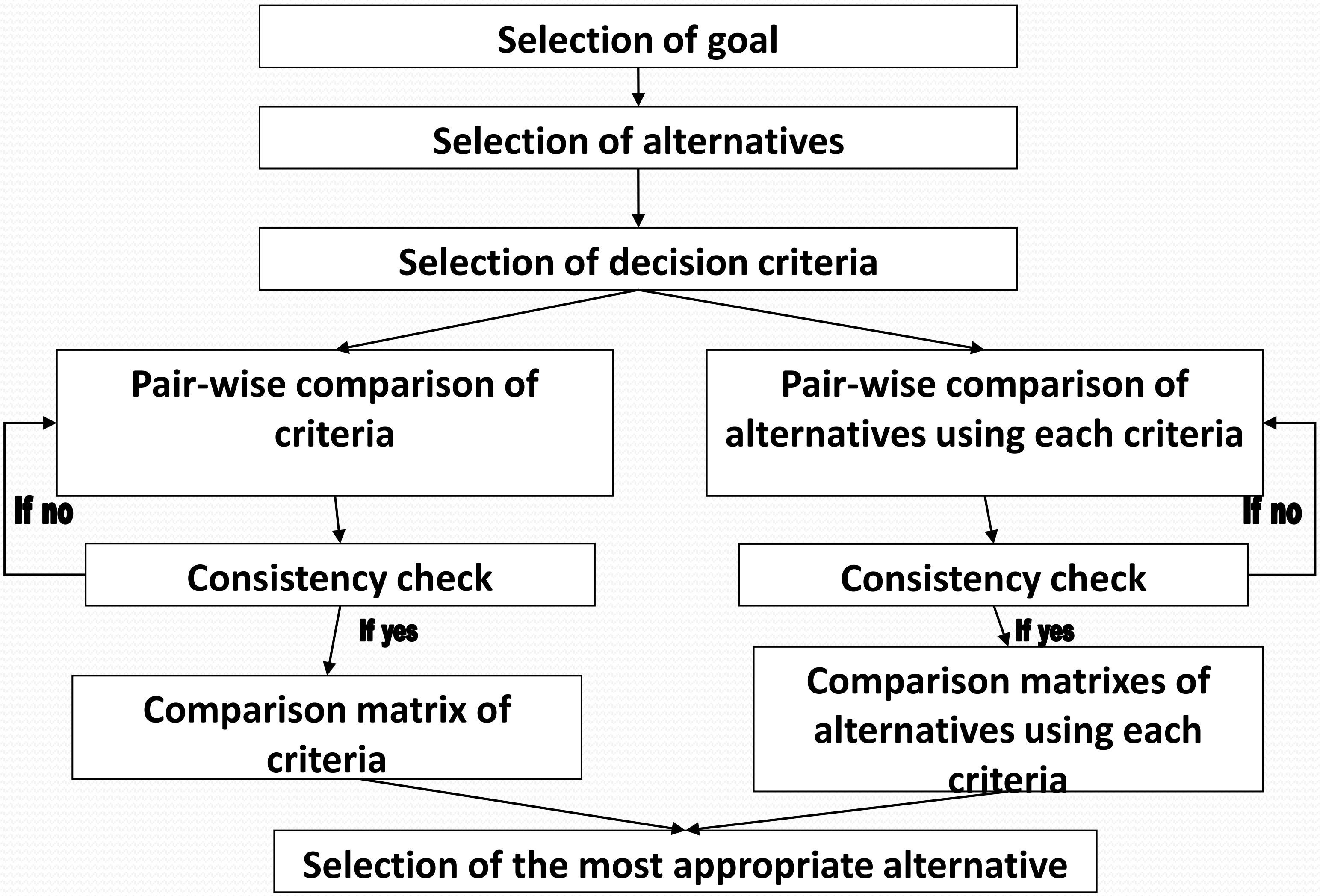
Materials and methods



Methods

- GIS have often been used to identify suitable areas for land developments and the use of GIS in sitting analysis started in the late 1970s ;
- AHP techniques were designed to analyze decision problems, generate useful alternative solutions, and to evaluate the alternatives based on a decision maker's values and preferences.

Building suitability models



Goal of study

- Find optimal sites for grid-connected photovoltaic power plants;
- Obtain coverage data that corresponds to the region of Ouarzazate criteria;
- Produce a map showing the suitable areas for solar farms.

Selection of criteria

Criteria	Criteria
Land use	Land use
Orography	Slope (%)
	Slope orientation

Criteria	Factors
Location	Distance to urban area (km)
	Distance to road (km)
Climate	Potential solar radiation ($kWh/m^2/year$)

Pair-wise comparison of criteria

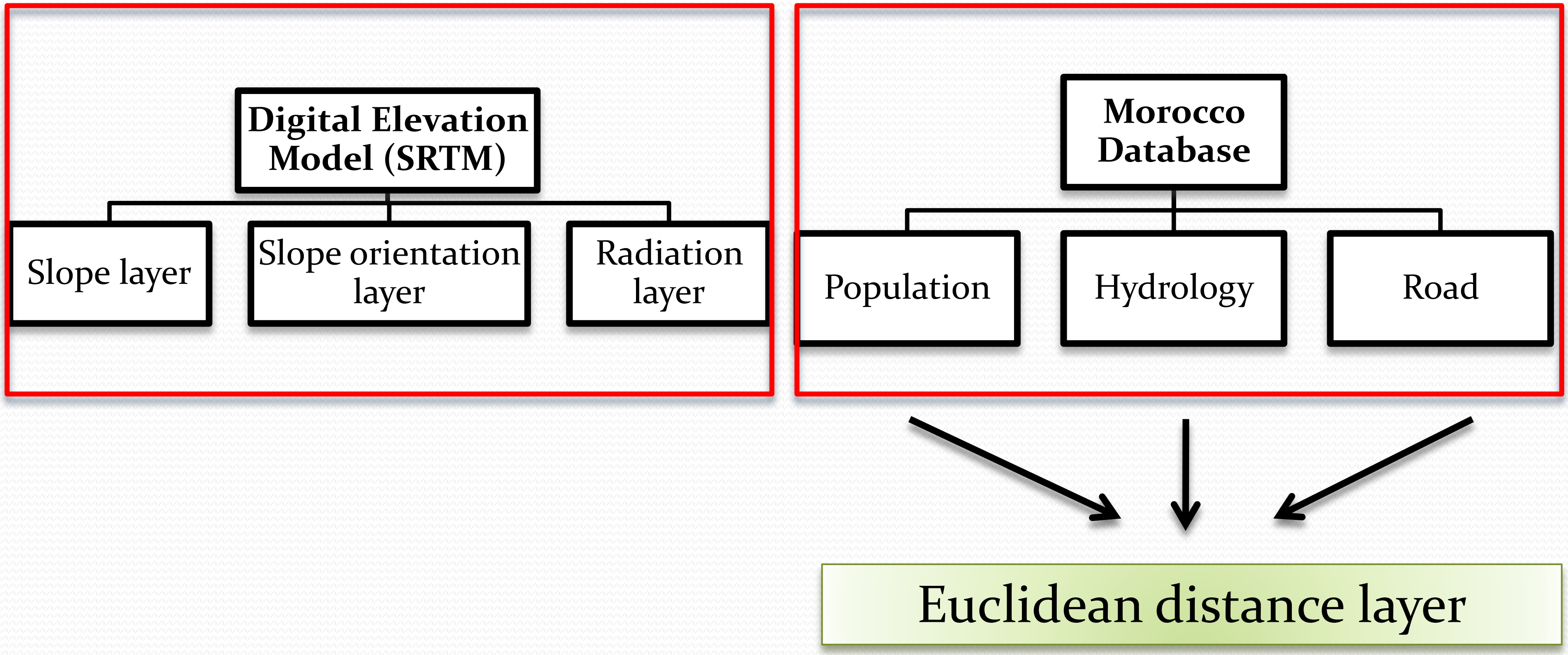
Criteria	Climate	Orography	Land use	Location
Climate	1	3,5	5	9
Orography	0,29	1	3	5
Land use	0,2	0,33	1	2,5
Location	0,1	0,2	0,4	1
Total	**1,64**	**5,03**	**9,4**	**17,5**

Weights

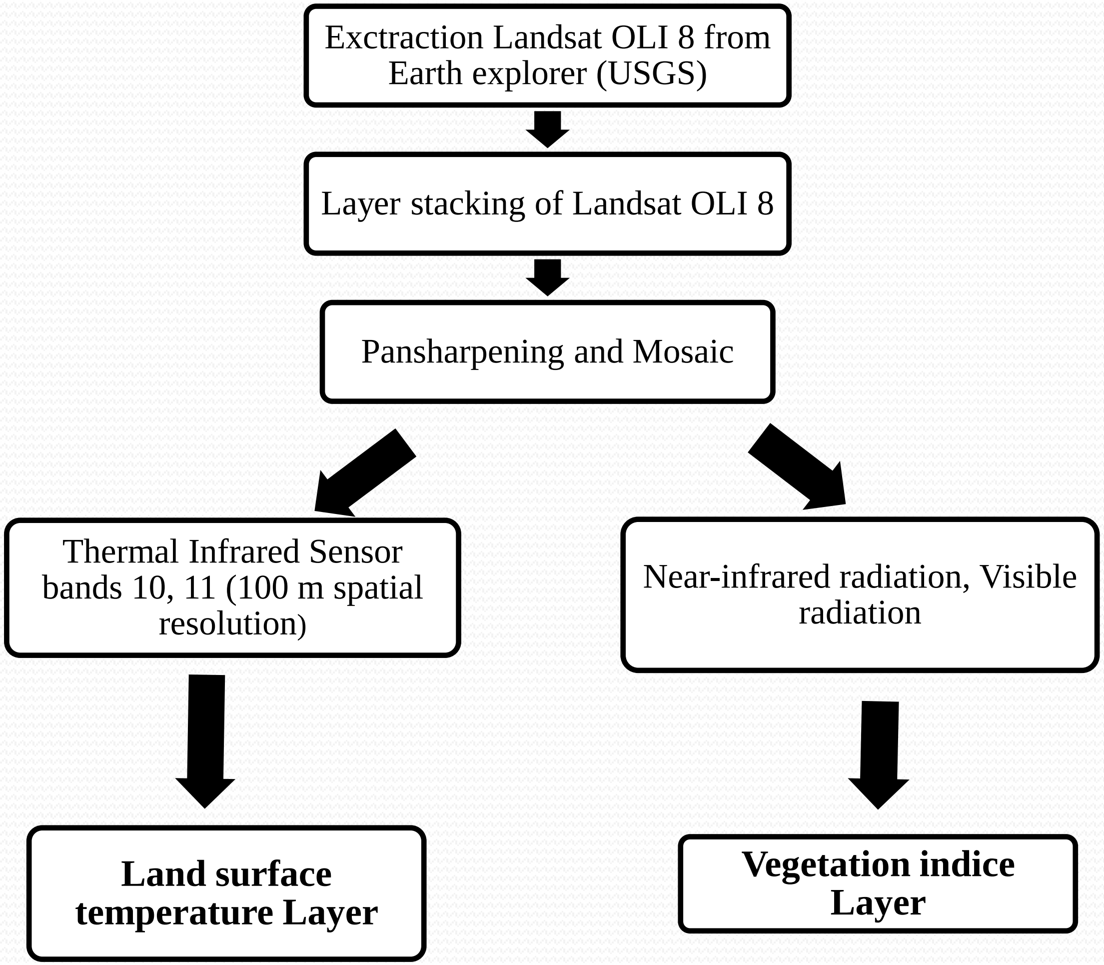
59 % **25 %** **11 %** **5%**

The Consistency Ratio = 0,09

Materials (GIS)



Landsat : image processing



Land surface temperature layer

- Convert the digital number (*DN*) into spectral radiance :

$$L = LMIN + (LMAX - LMIN) * DN/255$$

where:

L	=	spectral radiance
$LMIN$	=	spectral radiance of DN value 1
$LMAX$	=	spectral radiance of DN value 255
DN	=	digital number

Land surface temperature layer

- Convert the spectral radiance to brightness temperature Kelvin (*Tb*) :

$$Tb = \frac{K2}{Ln(\frac{K1}{L} + 1)}$$

where:

Tb	=	brightness temperature
$K1$	=	calibration constant 1
$K2$	=	calibration constant 2

- Convert Kelvin to Celsius (*TB*):

$$TB = Tb - 273$$

Land surface temperature layer

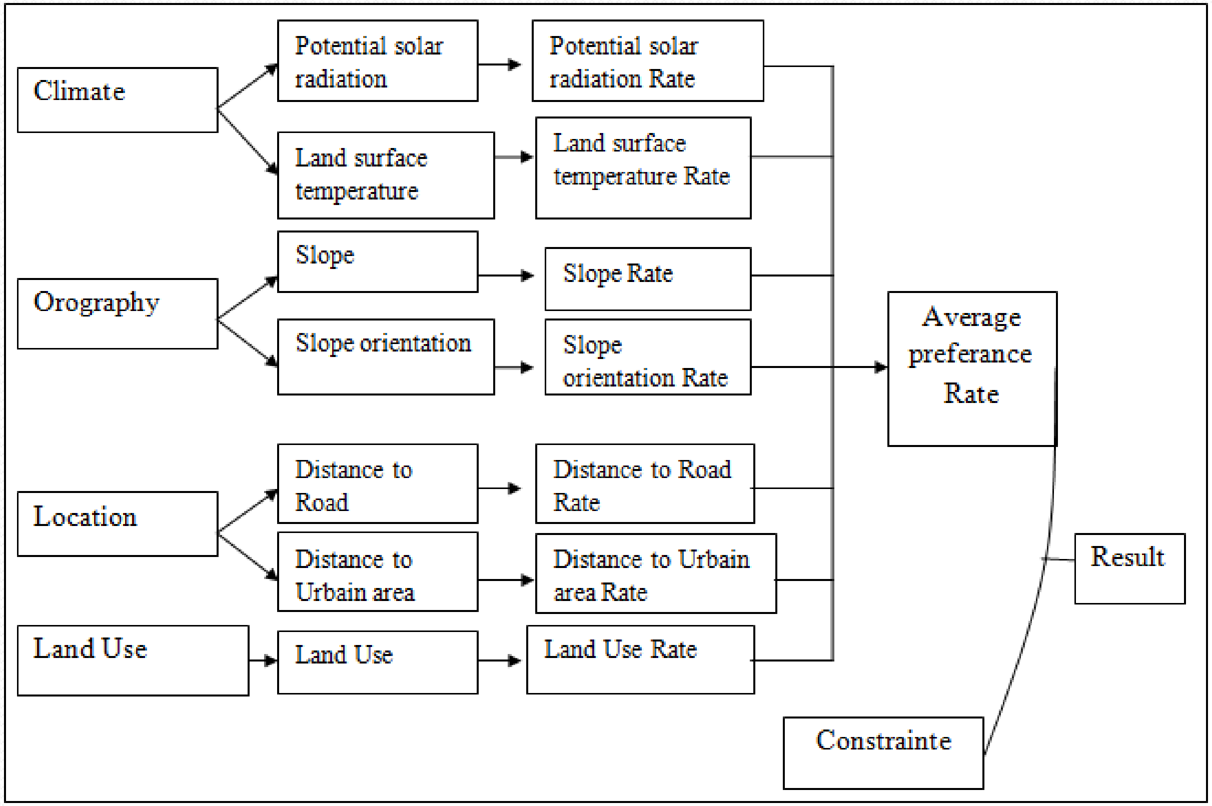
- Convert the brightness temperature into the land surface temperature (*S*) :

$$S = \frac{TB}{1 + (\lambda + \frac{TB}{\rho})\ln\varepsilon}$$

where:

S	=	land surface temperature
λ	=	wavelength of emitted radiance
ε	=	emissivity
ρ	=	$h * \frac{c}{\sigma}$
h	=	Planck's constant
c	=	light velocity
σ	=	Stefan Boltzmann constant

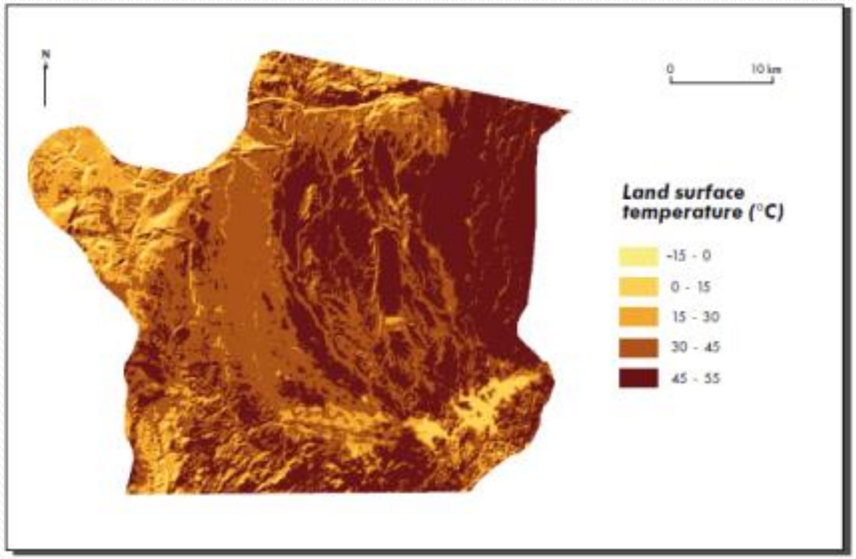
Solar Geographic Information System model

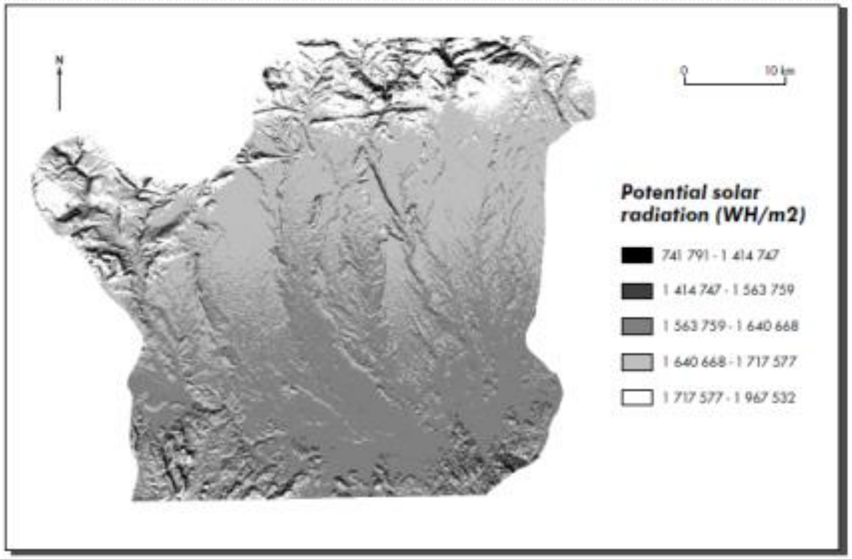


$$S = \sum_{i=1}^{n} W_i X_i \times \prod_{j=1}^{m} C_j$$

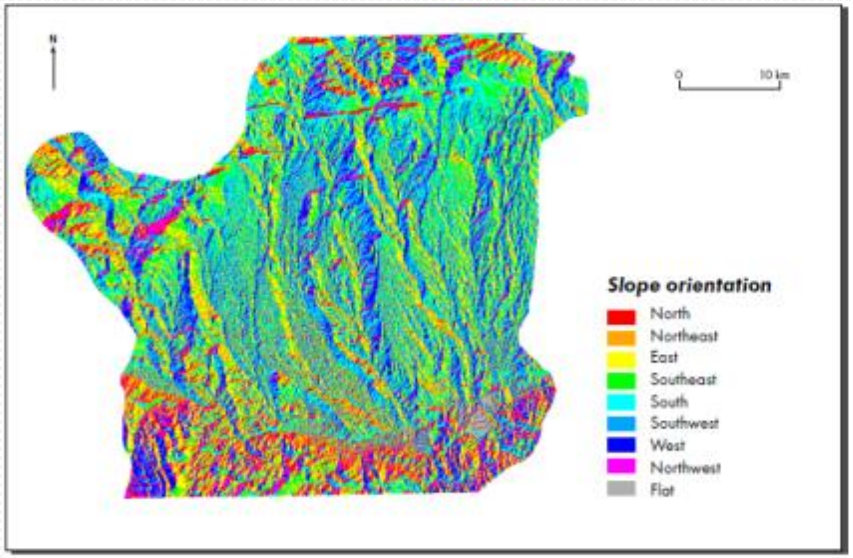
Layers results

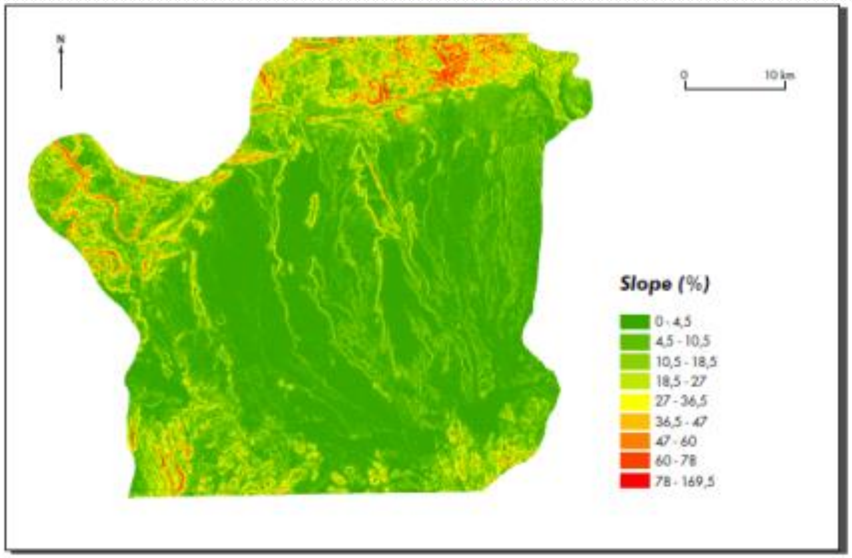
Layers results



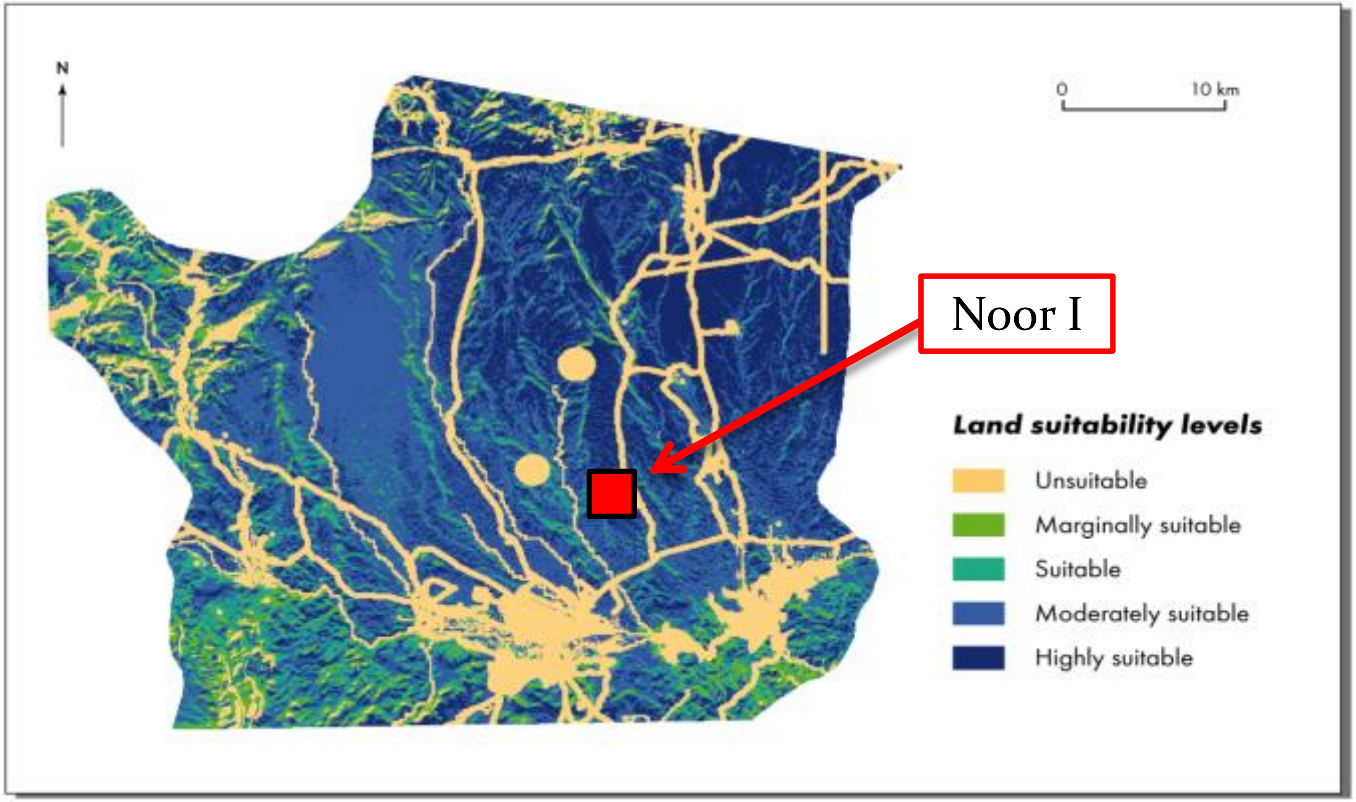


Layers results





Final result : Land suitability



Comparaison to other Mediterranean case studies

	Ouarzazate, Morocco	Murcia, Spain	Granada, Spain	Karapinar region,Turkey
HighlySuitable	23%	3%	5%	14%

Conclusion

- The majority of the land in Ouarzazate has a high suitability for photovoltaic farm installation;
- The high potential solar radiation, the land surface temperature and the orientation towards the south are unsurprisingly the key factors that increase the suitability of a land;
- The integration of GIS and MCDM techniques provides the decision maker with an innovative approach to sitting problem.

Thank you for your attention