A fast-track land suitability for avocado in Morocco

A comparison between available national and global datasets and next recommended steps

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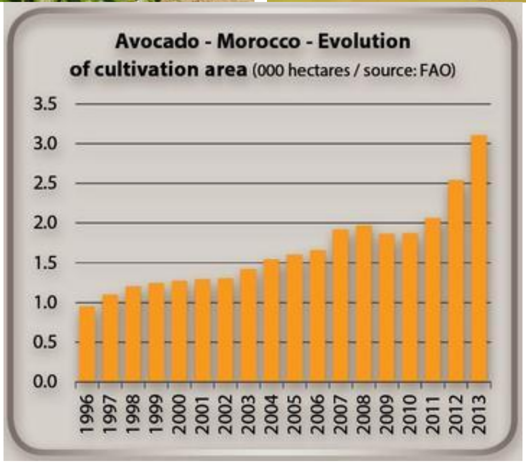


EXECUTIVE SUMMARY

Morocco offers suitable growing conditions for avocado. The specific ecological requirement of avocado is highly favored by the climatic, physiographic and soil properties of the country, thus offering a high potential growth in this region. FAOSTAT reported 54,576 ton of avocado harvested in 5,069 ha producing a yield of 107,666 hg/ha in the year 2019.

Agro-ecological zoning (AEZ) is the basis for planning rural and urban land-use planning. The process separates similar areas with potential for crop cultivation taking soil characteristics, land cover, and climatic features into consideration. AEZ has long been used in FAO's assessments and projects to answer key questions related with land suitability for cultivation of crops. Geospatial analysis, Geographic Information System (GIS) and Remote Sensing (RS) offer tremendous opportunities to better plan agriculture related activities. Conducting Agro-Ecological Zoning analysis in the context of Morocco, have the potential to provide key information to better identify land suitability for the key crops such as avocado in Morocco.

The objective of this assessment is to (1) assess land suitability at national level using available global data and (2) compare the land suitability for avocado cultivation using local and global datasets for the regions of Rabat, Sale and Kenitra in Morocco to be compared with a previous local level assessment for those three regions conducted under the project Mapping of the Agricultural land use for Morocco by Moussadek and Iaaich (2020).

National level assessment was carried out using global climatic data (maximum & minimum temperature, average annual precipitation), physiographic data (slope, aspect) and soil properties (pH). These data were overlaid against the suitability threshold for avocado and were categorized into (a) not suitable (b) suitable and (c) optimum suitable classes. At the end, a final suitability layer was obtained combining all the data. Main results from this assessment show that 11.2%, 30.8% and 35.4% of total area in the regions of Loukkos, Gharb and Zemmour, respectively, are suitable for the avocado production.

The local level assessment was done combining geospatial information on land cover, physiographic (slope and aspect) and soil properties (texture and drainage). These data were overlaid against suitability thresholds of avocado, sub-categorized into suitability classes and finally combined to obtain final suitability layer, identical with the procedure used for national level assessment. The result from this assessment show that 34.1%, 26.1% and 21% of total land in the regions of Loukkos, Gharb and Zemmour respectively, are suitable for avocado production.

Comparing the results from national and local assessments, it shows a difference of almost 23%, 4% and 15% in land suitability for the regions- Loukkos, Gharb and Zemmour respectively. In addition, the national level assessment provided additional information about land suitability outside the pre-defined regions. The assessment showed region of Casablanca Settat and Beni Mellal Khenifra had more than 40% (15,000,000 ha) of its total land suitable for avocado. Due to such high differences, the assessment proposes a random stratified sampling layer for cross validating the assessment results in the field.

Recommendations for future improvement include (1) conducting a field validation in the three priority regions with random stratified samples, (2) adding more data information into the land suitability analysis for different avocado plantation types and varieties, (3) include socio-economic analysis, (4) adding accessibility to roads and market-hub to the suitability analysis, (5) consideration of climate scenario information and (6) further consultation with national partners and stakeholders.

1 INTRODUCTION

Agro-ecological zoning (AEZ) is the basis for planning agricultural land use in both rural and urban areas. AEZ has long been used in FAO's assessments and projects to answer the key question related with land suitability of crops. The AEZ process separates areas with similar productivity of crop on basis of land cover, physiographic properties (like slope, aspect), soil properties (like pH, drainage, texture, salinity) and climatic features (temperature, evapotranspiration, rainfall). This not only helps in identifying key crops but also helps in crop rotation, which helps to sustain soil productivity in the long run.

Geospatial analysis, Geographic Information System (GIS) and remote sensing (RS) offer tremendous opportunities and support to better plan and prepare the agricultural activities. The usability of these tools is even more pronounced in the wake of climate change, in which the assessment is done using future projected climatic scenario. Conducting agro-ecological zoning analysis in Morocco helps to identify key information related with land suitability for its high potential crops such as avocado.

Avocado is a crop for high potential growth in Morocco and its specific ecological requirement is highly favored by the climatic, physiographic and soil properties of Morocco (Moussadek and Iaaich, 2020). It is also one of the major fruits grown in the country, with 107,666 hg/ha of yield in total of 5,069 ha area harvested to produce 54,576 ton of avocado in the year 2019 (FAOSTAT, 2019).

The present analysis assesses the land suitable for avocado, using both global and local level data in the regions of Rabat, Sale and Kenitra of Morocco. These three regions were indeed assessed for the land suitability of avocado in the project *Mapping of the Agricultural land use for Morocco* by Moussadek and Iaaich (2020).

The main objectives of the assessment are:

a) Assessing the land suitability at national level using available global and open-source datasets

b) Comparing the land suitability for avocado cultivation using local and global datasets for the regions of Rabat, Sale and Kenitra.

2 DATA SOURCES

Global open-sourced and local data described in Table 1 were used for the assessments. The global data were accessed from Google Earth Engine with scripts to select, process, and extract climatic and physiographic data. Soil properties were extracted from the Harmonized World Soil database. The local data (physiographic and soil properties) were obtained from National Institute of Agricultural Research (INRA, 2000) of Morocco. Local land cover maps were obtained from the project *Mapping of Agricultural Land Use* by Moussadek and Iaaich (2020).

Table 1: The different data sources used for national and local level assessment

Datasets	Global Data		Local Data		
	Source/Provider	Spatial resolution	Source/Provider	Original spatial Resolution	Resampled spatial resolution
Minimum Temperature	ERA5 (Copernicus Climate Change Service)	9km	Not used	na*	na*
Maximum Temperature	ERA5 (Copernicus Climate Change Service)	9km	Not used	na*	na*
Average Precipitation	CHIRPS (UCSB/CHG)	1km	Not used	na*	na*
Slope	SRTMv4 (NASA/CGIAR)	30m	ASTER GDEM v003	30m	60m
Aspect	SRTMv4 (NASA/CGIAR)	30m	ASTER GDEM v003	30m	60m
Soil (pH for global data and texture & drainage for local data)	HWSD (FAO/IIASA)	1km	Soil Map of Central Morocco (INRA)	Vector file	60m
Land Cover	na*	na*	Mapping of Agricultural Land use project (Moussadek & Iaaich, 2020)	Vector file	60m

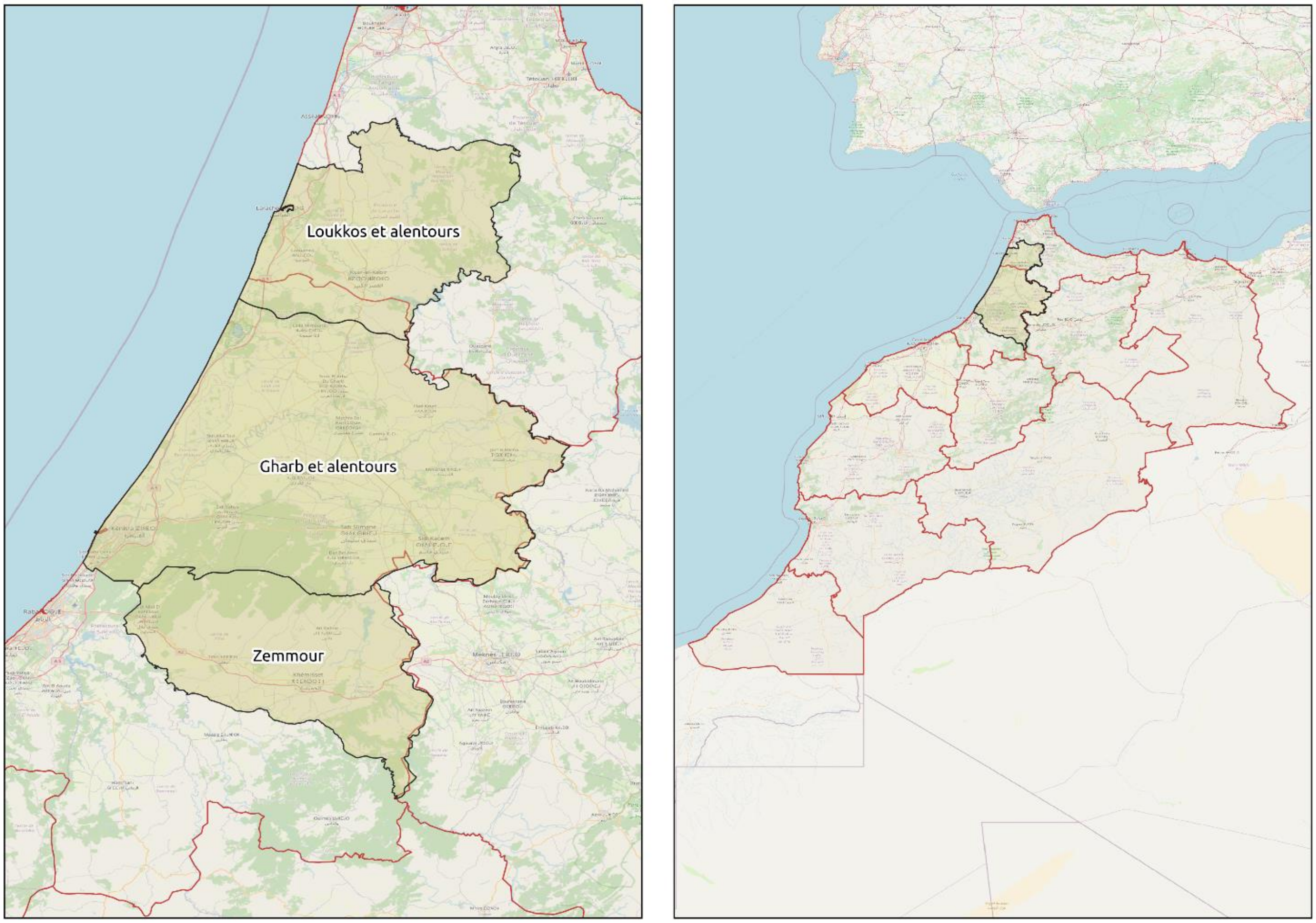
na*: not available or not used for the analysis

3 METHODOLOGY

Two assessments were conducted, at national and local levels. The methodological steps are provided at Figure 2.

3.1 Step 1: Defining an area of interest (AOI)

3.1.1 National level assessment



The area of interest used for the assessment is Morocco as shown in Figure 1 b). The administrative boundary was downloaded from the Database of Global Administrative Areas (GADM, 2018).

Figure 1: Areas of Interest for a) Local level assessment b) National level assessment

3.1.2 Local level assessment

The areas of interest used for this assessment are the regions of Rabat, Sale and Kenitra, comprising Loukkos, Gharb and Zemmour areas, as shown in Figure 1 a). The areas were obtained from the project[1].

3.2 Step 2: Crop specific parameters

3.2.1 National level assessment

The crop-specific parameters to assess optimum and absolute (sub-optimum) thresholds of each input layer for avocado were obtained from FAO – ECOCROP. This includes climatic (temperature, precipitation), physiographic (slope, aspect) and soil properties (pH) as described in Table 2.

[1] Mapping of Agricultural land use for Morocco (Moussadek and Laaich, 2020)

3.2.2 Local level assessment

The same crop parameters, as used with national level assessment, in terms of climatic, physiographic properties and soil properties, were used for local level assessment.

Table 2: Crop specific parameters for avocado (FAO-ECOCROP, 2013)

Parameters	Optimum Minimum	Optimum Maximum	Absolute Minimum	Absolute Maximum
Minimum Temperature	14 °C	na*	10°C	na*
Maximum Temperature	na*	40 °C	na*	45°C
Average Precipitation	500 mm	2000mm	2500mm	3000mm
Slope percent	< 2%	na*	na*	na*
Aspect	All except South & Southeast	na*	na*	na*
Soil pH	5	5.8	4.5	7
Soil Texture	balanced	na*	na*	Rough
Soil Drainage	balanced	na*	na*	high

na*: not available for the analysis

3.3 Step 3: Sub-classification of data into suitability classes

3.3.1 National level assessment

The suitability classes for the assessment, mentioned on Figure 1, is prepared based on crop parameters as described in Table 2. The prevailing condition thresholds are typically defined for optimum conditions where the crop growth is not constraint and can express its full potential, to moderate suitability where crop growth is somehow limited, to unsuitable conditions where specific values of a certain factor prevent the crop growth (irrespective from the values of the other parameters, that could be potentially suitable).

3.3.2 Local level assessment

The suitability classes for this assessment are identical with the national assessment, where suitability conditions are categorized into (a) Optimum Suitable (b) Moderate, and (c) Not suitable based on crop parameters as described in section 3.3.1.

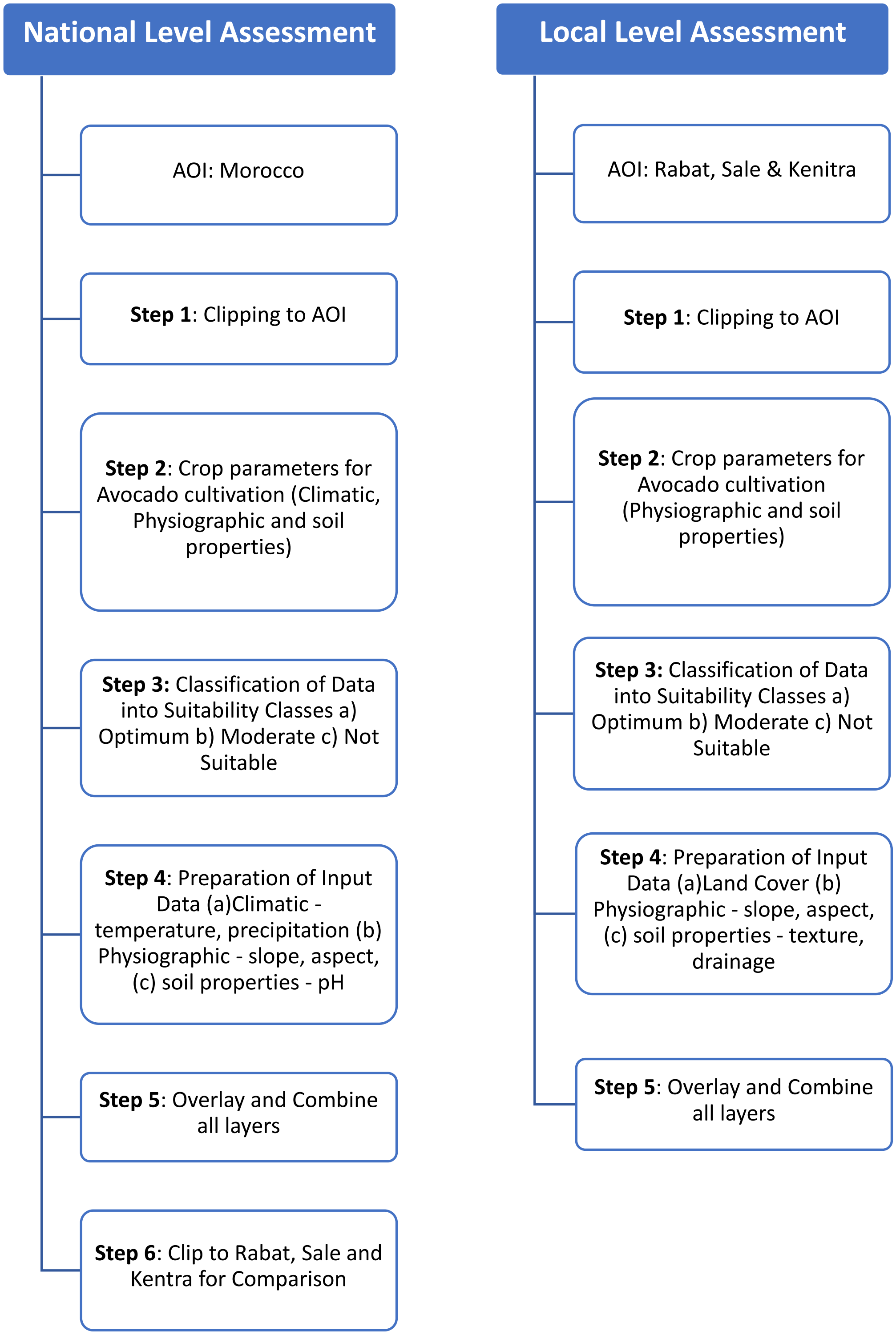


Figure 2: Methodological steps for national and local level assessment

3.4 Step 4 & 5: Preparation and combining the input data

3.4.1 Local level assessment

The various local datasets described in Table 1 and their corresponding suitability classes are presented in the section below.

3.4.1.1 Section 1. Landcover (Moussadek and Iaaich, 2020)

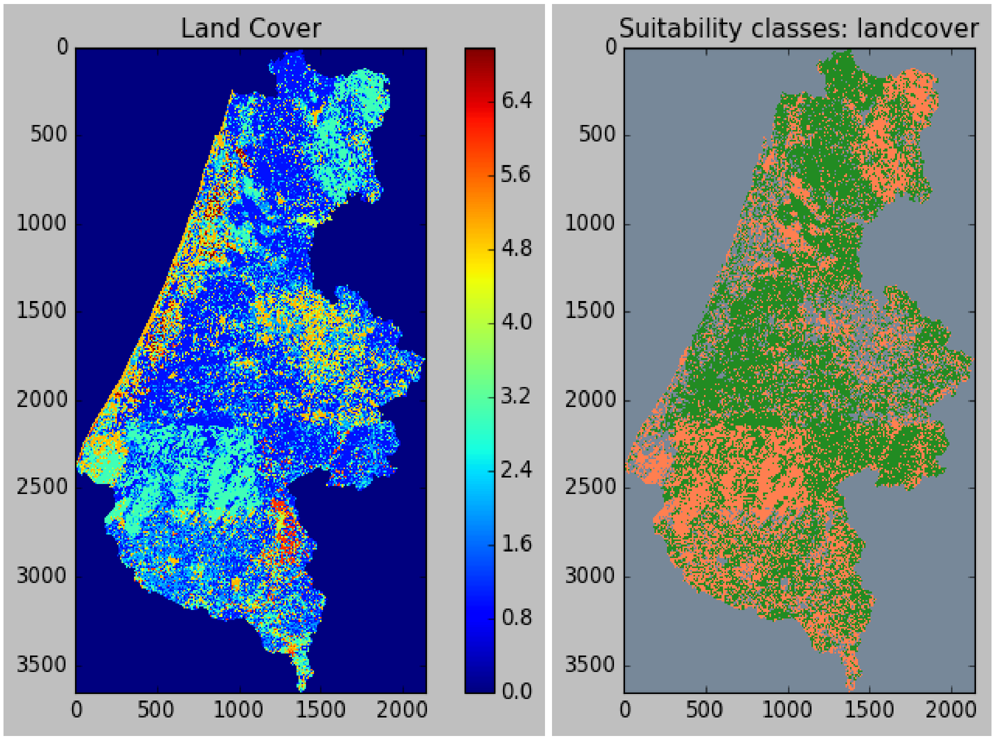


Figure 3: a) Land Cover b) Land Cover suitability class

Table 3: Land Cover classes

Values	Classes
1	Grandes Cultures et Maraichage/Field Crops and market gardening
2	Arboriculture /Arboriculture
3	Forêt/Forest
4	Etendue d'eau/Body of Water
5	Terrain Non Agricole/Non- agricultural land
6	Sol Nu/Bare ground
7	Agriculture sous Serres/Greenhouse agriculture

3.4.1.2 *Section 2. Physiographic Datasets*

3.4.1.2.1 Slope

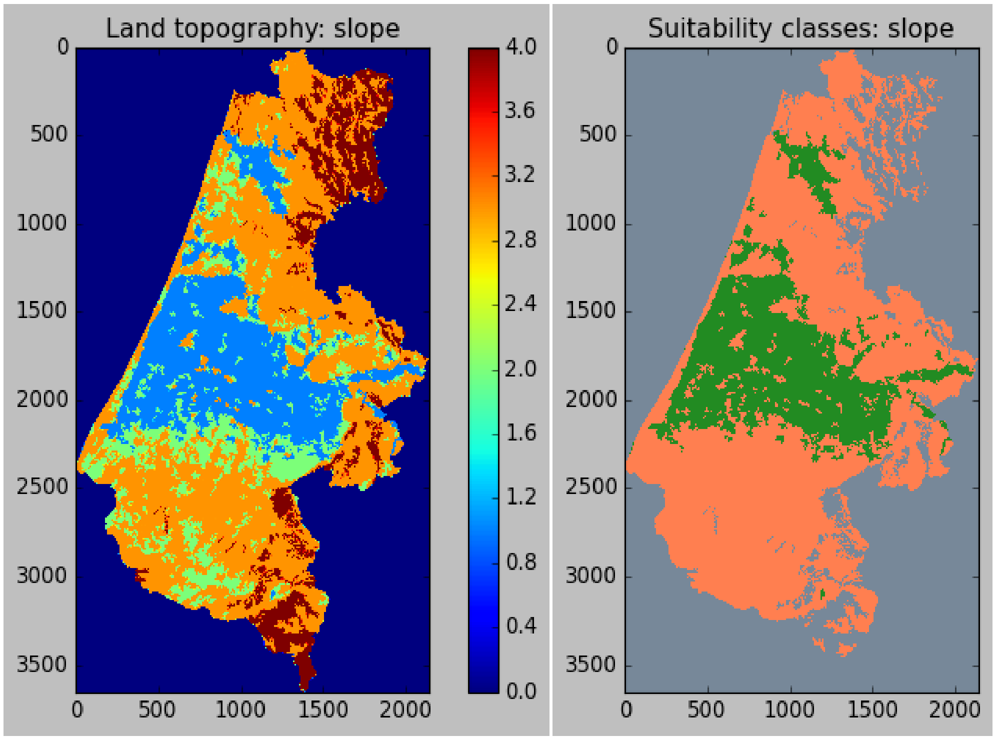


Figure 4: a) Slope percentage b) Slope suitability class

Table 4: Slope Classes

Values	Classes
1	< 2%
2	2% - 5%
3	5% - 15%
4	>15%

3.4.1.2.2 Exposure

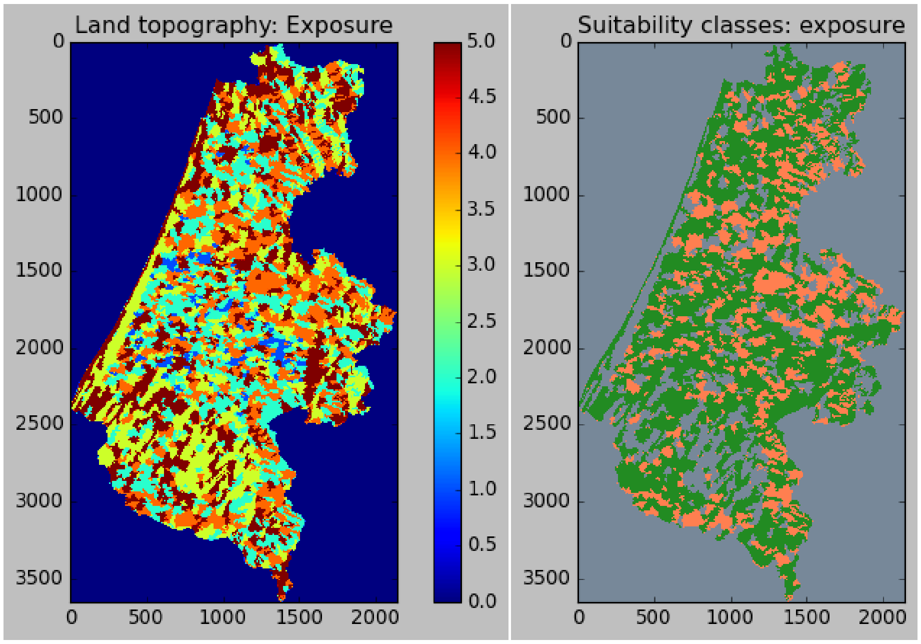


Figure 5: a) Exposure b) Exposure suitability class

Table 5: Exposure classes

Values	Classes
1	Plat
2	North & North-East
3	East & South-East
4	South & South-West
5	West & North-West

3.4.1.3 *Section 3. Soil properties*

3.4.1.3.1 Soil Drainage

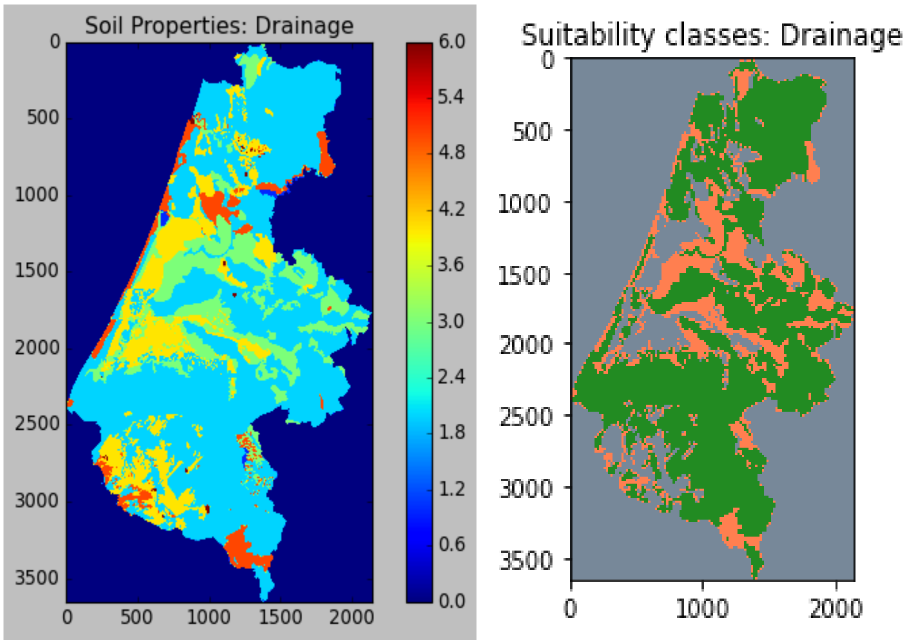


Figure 6: a) Soil Drainage b) Soil Drainage suitability class

Table 6: Soil Drainage classes

Values	Classes
1	Barrage
2	Bon/well
3	Faible/low
4	Mauvais/bad
5	Skeletal soil

3.4.1.3.2 Soil Texture classes

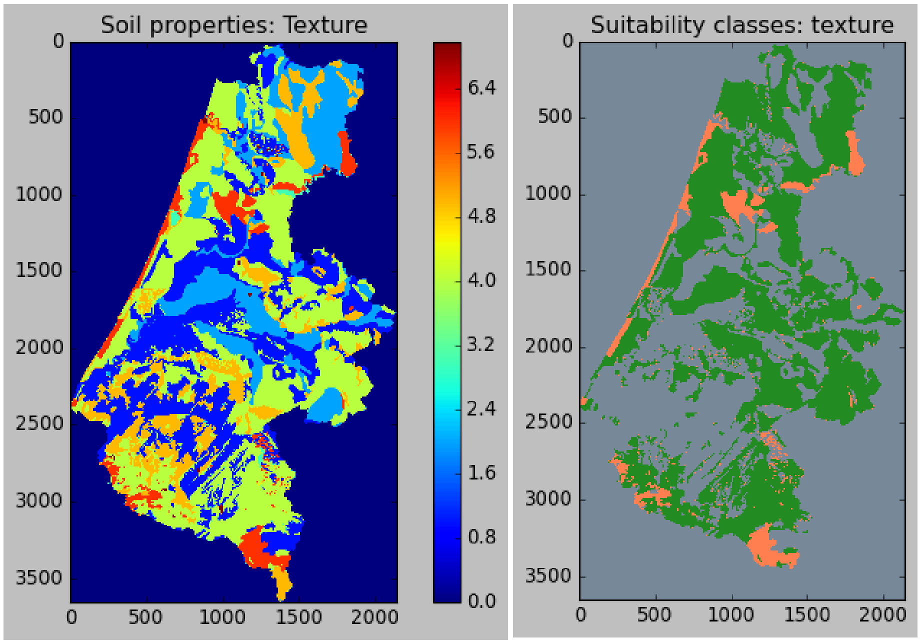


Figure 7: a) Soil Texture b) Soil Texture suitability class

Table 7: Soil Texture classes

Values	Classes
1	Argileuse/Clay
2	Balanced/Clay
3	Barrage
4	Equilibrée/Balanced
5	Sableuse/Sand Blaster
6	Skeletal soil
7	Urban Area

3.4.2 National level assessment

The various global datasets (Table 1), along with their corresponding suitability classes, have been analysed to provide the national level assessment and are presented at Annex 1. This includes climatic data (maximum and minimum temperature, average annual precipitation), physiographic data (slope and aspect) and soil properties (pH).

4 RESULTS

4.1 Results from the national level assessment

The result from national level assessment was obtained at 1km spatial resolution, due to the coarser input data described in Table 1. The result in figure 8 shows that north-eastern region of Morocco is highly suitable for avocado production. The suitability of North-eastern region (comprising Rabat, Sale and Kenitra regions) were also previously identified from Mapping of the Agricultural Land Use for Morocco project by Moussadek and Iaaich (2020). The result was further clipped to these three regions to make comparative assessment with local level data.

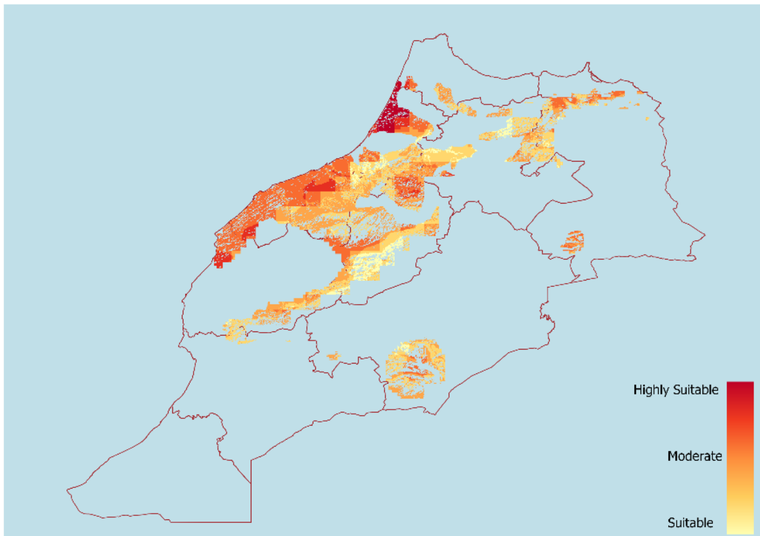


Figure 8: Avocado suitability layer for Morocco from national level assessment

The assessment also identified the regions of Beni Mellal Khenifra and Casablanca Settat as highly suitable for avocado with more than 40% (15,000,000 hectares) of its total area suitable for the cultivation. Other key regions identified through the assessment are presented in the Table 8.

Table 8: Regions suitable for avocado cultivation expressed in percentage

Regions	Percentage suitability in terms of total area
Beni Mellal Khenifra	38.6
Casablanca Settat	55.1
Draa Tafilalet	17.3
Fez Meknes	24.0
Guelmim Oued Noun	0.0
Marrakech Safi	23.6
Oriental	17.1
Rabat Sale Kenitra	34.8
Souss Massa	1.5
Tangier Tetouan Al Hoceima	4.2

4.2 Results from the local level assessment

The result from local level assessments was obtained at 60m spatial resolution. The result from the figure 9 show that the northern and central region of Rabat, Sale and Kenitra region, are highly suitable for avocado production. Spatial extend of suitability is seen more from the local assessment when compared with national assessment, especially in the region of Loukkos and Gharb region. Percentage of land suitability by the three regions were finally calculated. Table 9 shows 11%, 30% and 35% of total area in regions of Loukkos, Gharb and Zemmour respectively are suitable for cultivation.

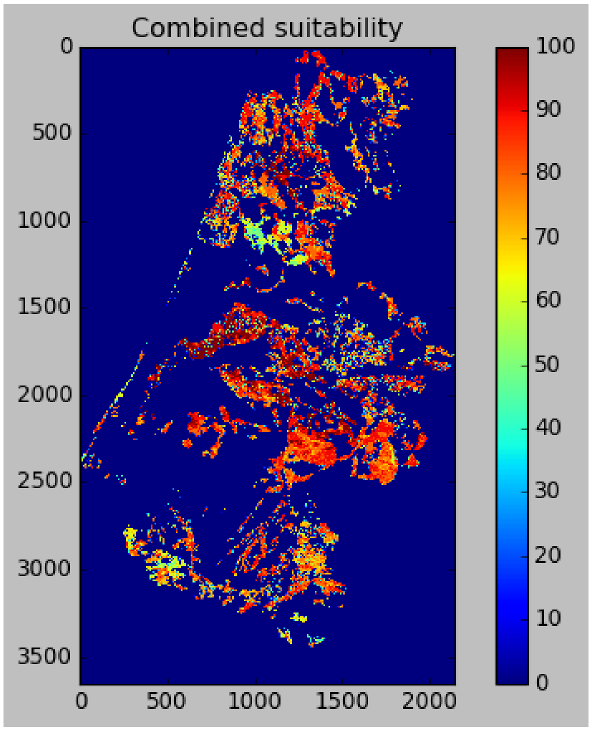


Figure 9: Suitability layer through local data

Table 9: Percentage suitability in three regions of interest

Regions	National Level Assessment
Loukkos	11.2%
Gharb	30.8%
Zemmour	35.4%

4.3 Comparison between local level, national level and previous assessments

A significant difference in terms of percentage of land suitable for avocado was observed through national Level assessments both in terms of spatial extend and average percentage as shown in Figure 10 and Table 10 respectively. In the region of Loukkos, the ational level assessment showed only a little over tenth and local assessment showed a third of its total area suitable for avocado production. Region of Gharb presented similar results in the land suitability percentage, where only a difference of 4% was observed between national and local assessments. Similarly, the region of Zemmour which initially showed 35.4% suitability of total area through national level assessment was later reduced to 21% through local level assessment.

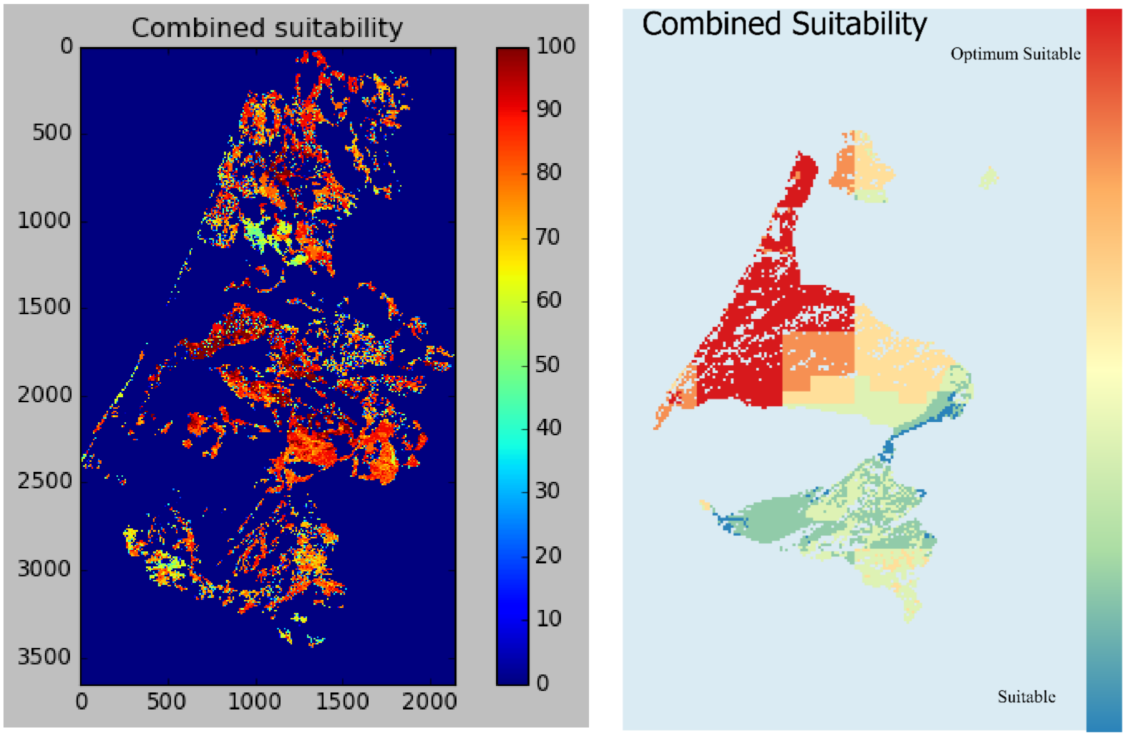


Figure 10: Suitability layer through a) local data b) national data

Table 10: Percentage of land suitable for avocado production through different assessments

Regions	National level assessment	Local level assessment	Previous assessment (Moussadek and Laaich, 2020)
Loukkos	11.2%	34.1%	26.1%
Gharb	30.8%	26.1%	29.6%
Zemmour	35.4%	21.0%	24.5%

4.4 Factors affecting the results in national level and local level assessments

The difference in results from national level and local level assessments ranged from 3% (in the region of Gharb) to 13% (in the region of Loukkos, refer to Table 10). This difference in results mainly arose due to the difference in scale of input soil data (texture and drainage properties in local assessment and pH in national assessment). The differences between results are explained with following factors:

1. Quality and scale of soil data used in the assessment

Quality of soil data (mainly through HWSD, refer Table 1) used in national level assessment is not detailed enough (in terms of scale) to consider the soil properties (like pH used in national level assessment). This also fails at capturing the details of soil properties spatially. Discrete but not finer and continuous in capturing the soil properties is one of the major reasons to explain the discrepancies between national level and local level assessment results.

2. Consideration of climatic parameters only in national level assessment

Climatic parameters (in terms of average annual precipitation and average maximum and minimum temperature) were only considered in national level assessment, as the data were derived from global open-sourced platform. These climatic factors were missing in local level assessment, owing to unavailability of these data locally, during the time of assessment. Only few areas in Morocco were found to be climatically suitable for avocado production (refer to Figure a), b) and c) at Annex 1). This is particularly true in the case of precipitation (Figure a (2) at Annex 1). This has resulted in considerable areas unsuitable for avocado production, incorporating climatic parameters.

3. Consideration of land cover data only in local level assessment

A detailed land cover map[2] was available at local level, which was used in the local level analysis. This avoided areas in urban, build up, water bodies and forest for assessing land suitability. On the other hand, land cover data was not used in national level assessment, which may have resulted in such differences in results.

4. Spatial resolution of output results (1 km for national level and 60m for local level assessment)

The spatial resolution may not have been sufficient enough to capture the suitability thresholds of avocado spatially and hence, may have missed the spatial extend of suitability coverage at 1 km spatial resolution in national level assessment. The local assessment (output result at 60m spatial resolution) have covered relatively more spatial extend of suitability, that resulted in higher suitability areas and national assessment missed to capture this suitability extent resulting in lower suitability areas.

4.5 Overall time spent and tools used for the assessments

The assessment was first performed with national level data. The scripts were prepared in Jupyter Notebook (refer to reference section); this also included pre-processing, processing of results through python scripts. The post processing was mainly done in Q-GIS in a stand-alone personal computer[3]. Later, the scripts were adapted to suit the local data requirements for local level assessment. The amount of time spent for the assessments is shown in Table 11.

Table 11: Amount of time spent in national and local level assessment

Activities	National level assessment (in days)	Local level assessment (in days)
Extracting input data	2	0
Preparing scripts	5	2
Pre-processing of input data	1	1
Running scripts with input data	1	1
Post processing of results	1	1
Report writing	5	5
Total (in days)	**15**	**10**

[2] Land Cover data derived from Mapping of Agricultural land use for Morocco (Moussadek and Laaich, 2020)

[3] Specification of personal computer used: RAM: 15.5 GiB, Processor: 1.8 GHz Intel Core i7

5 RECOMMENDATIONS

The assessment proposes to enhance this rapid land suitability analysis and contribute to provide improved actionable results through the following recommendations:

1. Undertake a field validation campaign,

   A proper cross referencing and validating is needed to take the assessment into confidence. For this purpose, it is proposed to randomly stratify and sample the area of interest with 300 field data locations to be visited by field enumerators. The sample points would be a combination of 3 suitability classes – a) Not Suitable b) Suitable, and c) Optimum Suitable as described in Methodology section.

2. Enhance the analysis with additional information about avocado plantation types and varieties (specific to Morocco),

   The assessment did not consider any specific avocado varieties nor any specific plantation types, which could open possibility for different suitability thresholds. The assessment proposes different varieties to be taken into consideration which could alter the suitability threshold. The thresholds used in this analysis could be reviewed by national experts considering suitable avocado plantation conditions.

3. Consider socio-economic dimensions into the analysis

   The assessment did not consider socio-economic dimensions into the assessments like accessibility to roads and nearby market-hubs, which helps in making the avocado cultivation economically viable and sustainable in the long run. Further consideration of socio-economic conditions such as related to farm types, employment opportunities, economic and social conditions would improve the assessment.

4. Consider inter-annual variability of climatic conditions into the analysis

   The assessment considered specific thresholds averaged with long-term averages (30 years) but it does not consider annual variability. Some of the regions may have stronger feasibility for production for a number of years and others may not. For example, precipitation is considered, even though most of the avocado production is within irrigated conditions. This is also to identify those areas where water requirements are higher.

5. Consider future climate scenario in the analysis

   The assessment only considered averaged historical climatic data. For the sustainability of the cultivation, the assessment proposes future climatic projection (possibly RCP 8.5, RCP 4.5, and RCP 2.6 scenarios to assess high, medium, and low climatic extremes in terms of precipitation and temperature) to be taken into consideration.

6. Further consultation with the national partners and stakeholders

   Climatic features, physiographic and soil properties are taken into consideration, but locally prevailing conditions and factors (if they exist) have been not considered. To make the assessment robust, consultation with national partners and stakeholders are a must. The assessment proposes such consultations with the national team to consider any overlooked factors. In addition, the analysis is performed using open-source software and codes. It can be easily transferred to national partners. Also, it is proposed to engage national partners, share, and transfer this kind of analysis and tools for sustainable land use analysis for avocado and other crops.

6 CONCLUSION

Variation in land suitability, both in spatial extend and average percentage of land, were observed through national and local level assessments. The national datasets showed coarser results, in terms of spatial extend of suitability, which was later improved with local datasets. The results in terms of percentage of land suitable, when compared with the project[4] were also different. For instance, the project result (refer to Table 10) showed the region of Gharb as the most suitable region for avocado production with 30% of its total area suitable for avocado production. However, the national level assessments and local level assessments showed Zemmour (with 35%) and Loukkos (with 34%) respectively, as the most suitable area for the avocado production. This difference is mainly explained with the coarseness of input data (in particular soil information). This is also very significant differences observed, even when proceeded with same methodology. For this reason, cross referencing and validation from field is a must to take the assessment into confidence.

The assessment only considered historic climatic data, physiographic data and few soil properties like texture, pH, and drainage. Salinity is also one of the limiting factors for avocado, but it was not considered owing to limited data availability. Local level assessment also did not consider any climatic factors. In these regards, it is necessary to reassess the methodology with quality data, for which consultation with national partners and stakeholders is needed. This also avoids any possible parameters that may have been overlooked in the assessment.

Socio-economic viability of the project is another important factor for the sustainability of the project. Such socio-economic analysis has not been considered in the analysis. Accessibility to roads and nearby market-hubs make important consideration for such economic analysis. The present assessment proposes such socio-economic analysis to be considered.

[4] Mapping of Agricultural land use for Morocco by Moussadek and Laaich (2020)

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ANNEX

ANNEX 1: NATIONAL LEVEL ASSESSMENT

1.1 Datasets and suitability classes for national level assessment

a) Precipitation

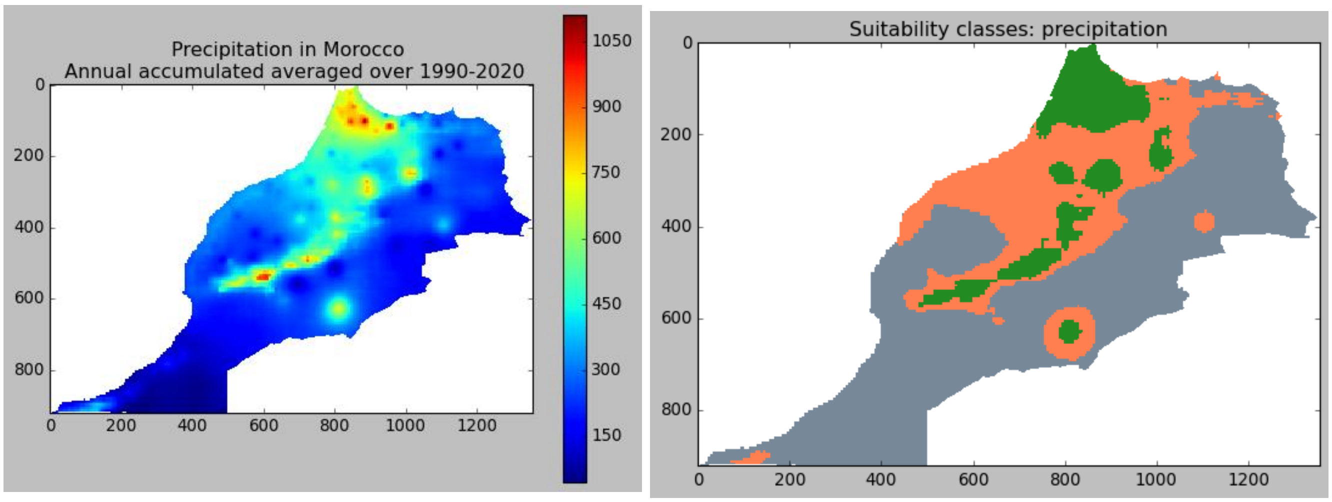


Figure: (a) 1) Precipitation 2) Precipitation suitability class

b) Maximum Temperature

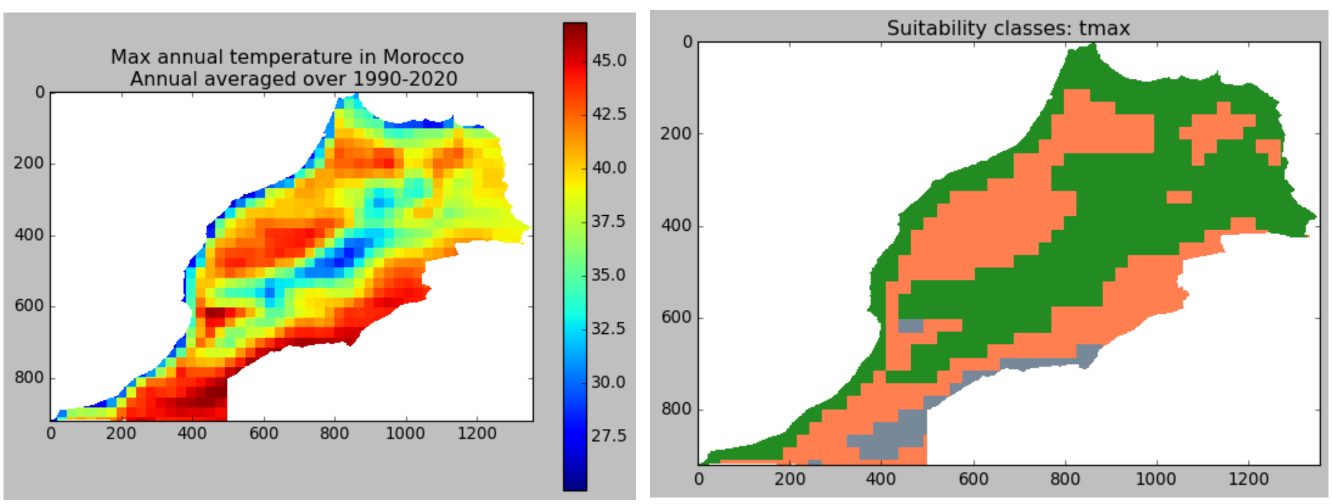
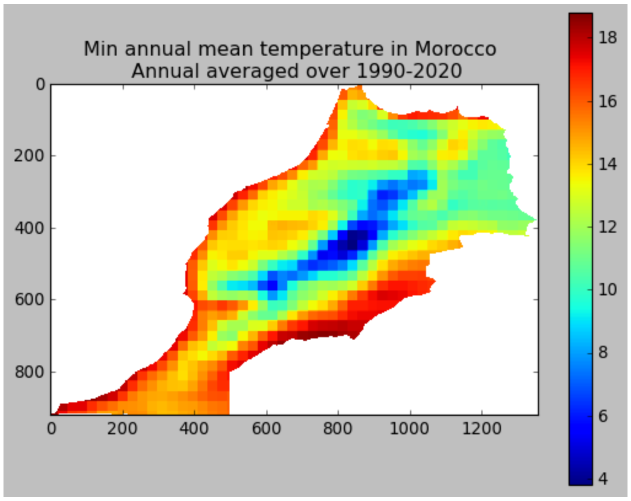


Figure: (b) 1) Maximum Temperature 2) Maximum Temperature suitability class

c) Minimum Temperature



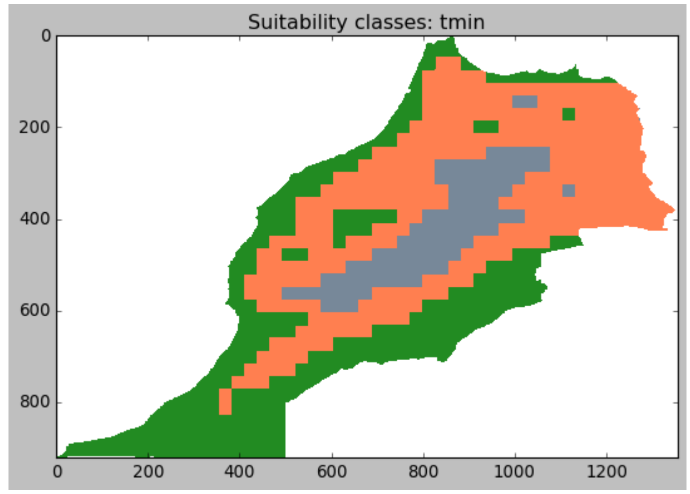
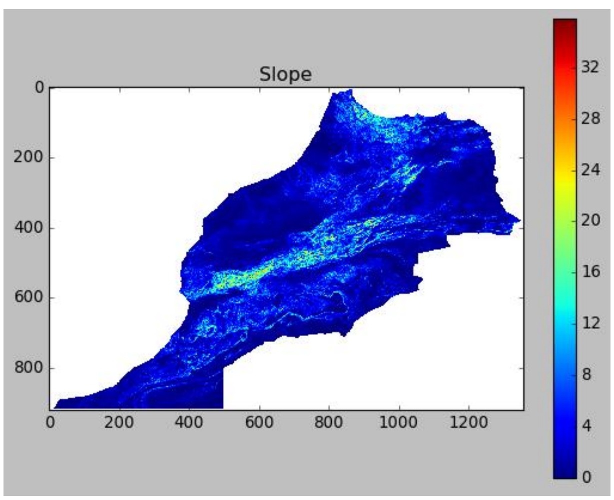


Figure: (c) 1) Minimum Temperature 2) Minimum Temperature suitability class

d) Slope



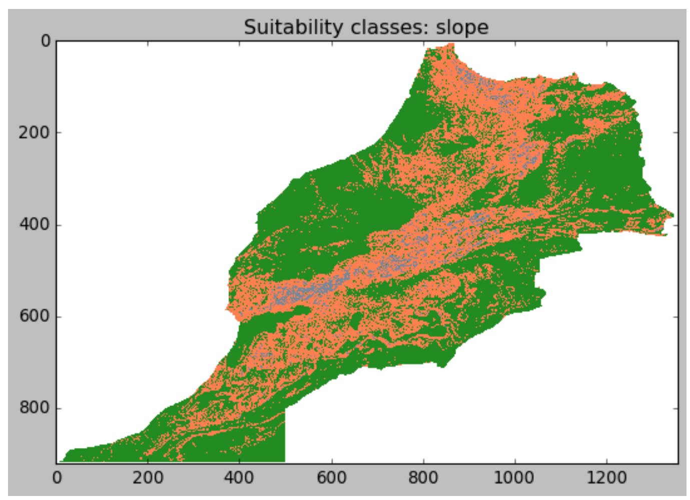


Figure: (d) 1) Slope 2) Slope suitability class

e) Aspect

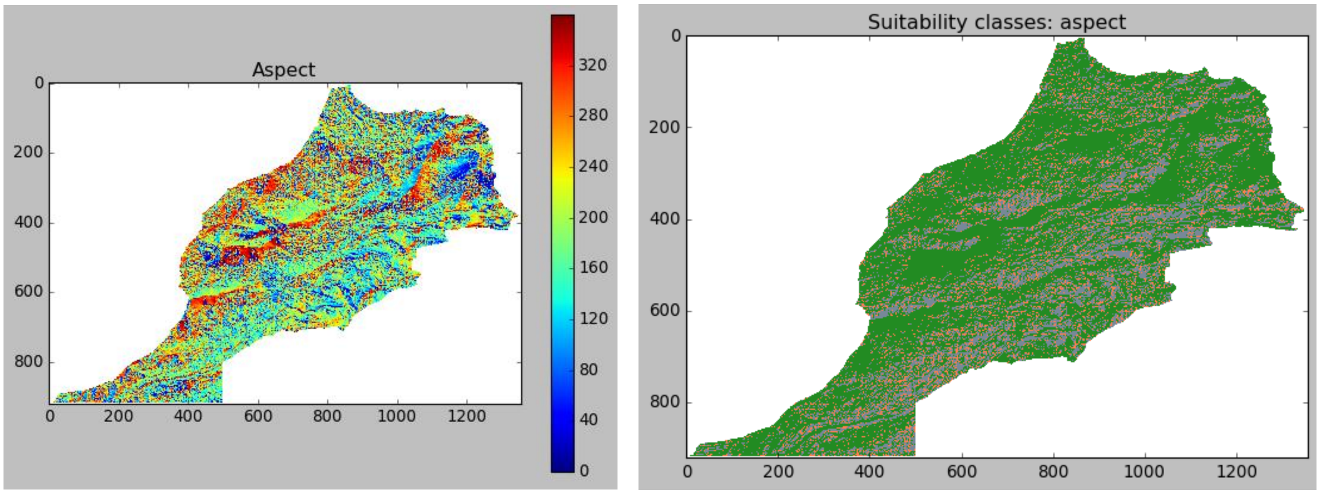


Figure: (e) 1) Aspect 2) Aspect suitability class

f) Soil pH

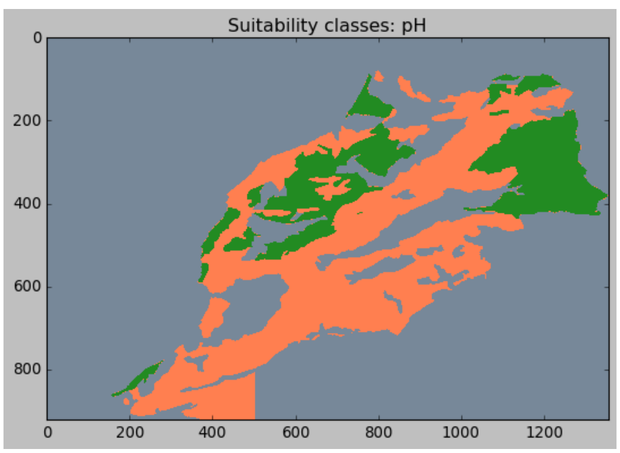


Figure: (f) 1) soil pH suitability class