



University of Thessaly
Department of Environmental Sciences



Agroclimatic zoning methodology for selection of suitable crop in water limited Mediterranean areas

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Agroclimatic Classification for sustainable production

✓ What are the Agroclimatic Zones?

Are land units supporting specific crops for long periods without degradation



✓ Agroclimatic classification is very useful for:

- Optimizing yield production
- Rational use of natural resources
- Sustainable rural development



Objectives of Agroclimatic zoning



- To identify rapidly & relatively high resolution suitable productivity zones for sustainable farming according to water limitations, microclimatic and soil features in water limited Mediterranean areas (Thessaly – Greece).
- To Investigate Earth Observation data & new geoprocessing tools, such Google Earth Engine web platform, for rapidly creating agroclimatic zoning.

The pilot area: Thessaly - Greece

Thessaly region lies in central Greece, occupying about 14000 Km².

The topography: 50% plain and 50% mountainous and semi-mountainous areas.

Intensive Agriculture sector:

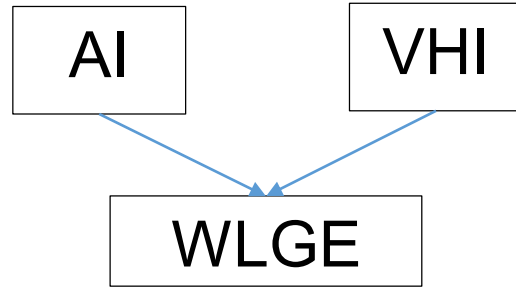
Annual crops: Cotton, maize, wheat, etc.

Tree crops: almond, olive, pistachio, vineyard, etc.

Livestock: Vetch, Clover, Forage Pea, etc



Flow chart of the agroclimatic zoning methodology



Combination of highly correlated Indices categories

Stage 1
Hydroclimatic zoning



GIS-Multicriteria Decision Making

Stage 2
Non Crop Specific Agroclimatic zoning



GIS-Multicriteria Decision Making

Stage 3
Crop Specific Agroclimatic zoning (Productivity zones)

Have been conducted: Evaluation, with the support of experts in the different stages of the methodology
Validation, of the productivity zones with the help of local farmers and stakeholders

Dataset and Geoprocessing tools


Hydroclimatic zoning database

- Landsat data: Period 2001-2022. 1538 images are processed.
- MODIS data: Potential Evapotranspiration product (500 m) & Land Surface temperature product (1 Km). Period (2001-2022). 1010 images in total are processed.
- Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). Period 2001-2022 (5 Km). 1584 pentad data, are processed.

Non crop specific agroclimatic zoning database

- Digital Elevation Model (DEM), Soil Map, Corine Land Cover (CLC) product in 2018

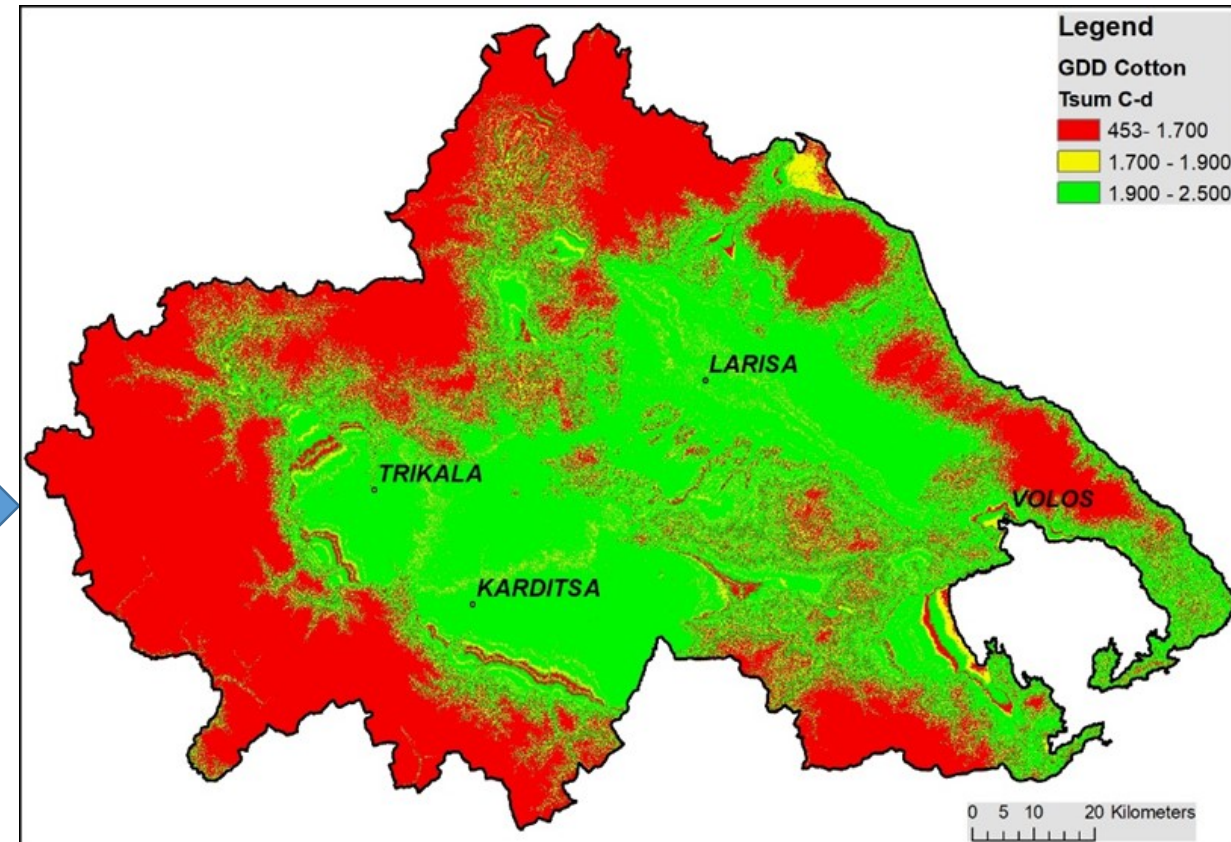
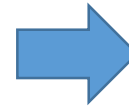
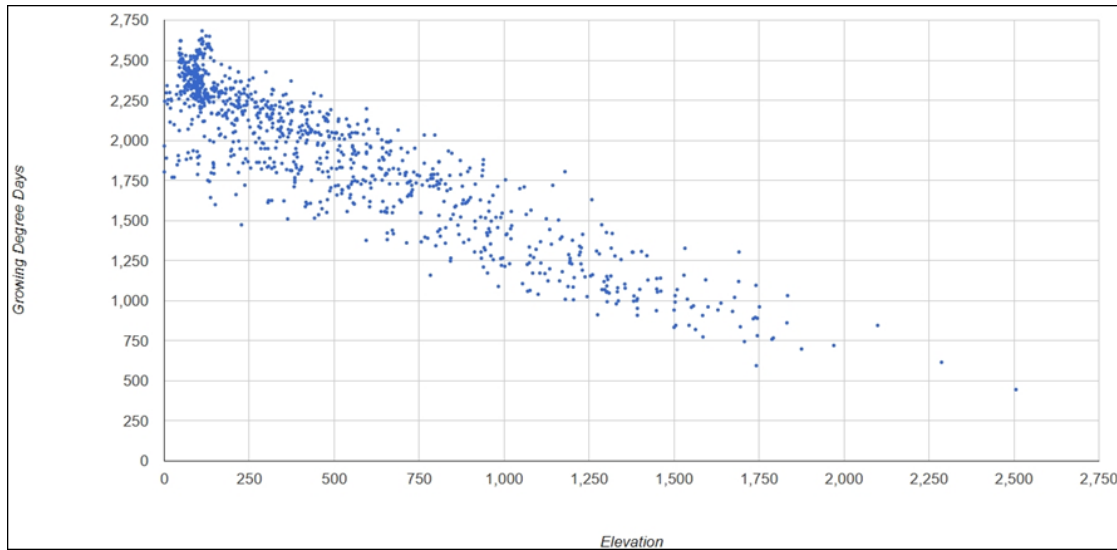
Crop specific agroclimatic zoning database

- 505/670 8-days Modis Land surface Temperature data
 - 172 CHIRPS (1981 to 2022)
- 
- ✓ The Google Earth Engine (GEE): computer-based platform dedicated to processing satellite imagery (Sentinels, Landsat, Modis, etc) and geospatial of datasets (climatic and elevation data).
 - ✓ SNAP toolbox & GIS software.

Downscaling Techniques

Machine learning algorithms.

- A correlation between the two variables: GDD and DEM
- Scatterplot by 1000 sample points collecting (randomly) from the study area.



1. Hydroclimatic Zones

- Temperature and rainfall: Climate parameters which determine the type of crops suitable for a give location.
- Crop growth is affected by water supply
- Identify areas under restriction in water.

Water Limited Growth Environment Zones (WLGE)



VHI: Vegetation Health Index

Represents overall Vegetation Health



AI: Aridity Index

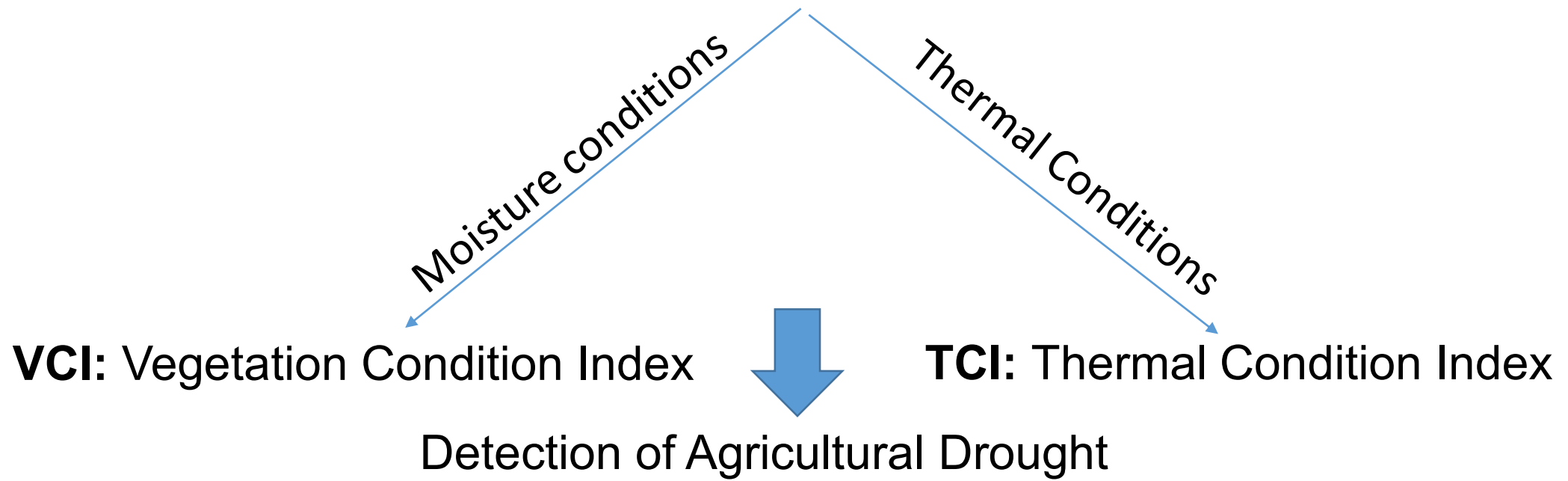
Represents Climatic Aridity – adequacy of rainfall

1. Hydroclimatic Zones

VHI: Vegetation Health Index

VHI:

- Monitor the impact of weather to vegetation.
- Reflects the vegetation stress caused by adverse climatic and hydrological factors



1. Hydroclimatic Zones

VHI: Vegetation Health Index

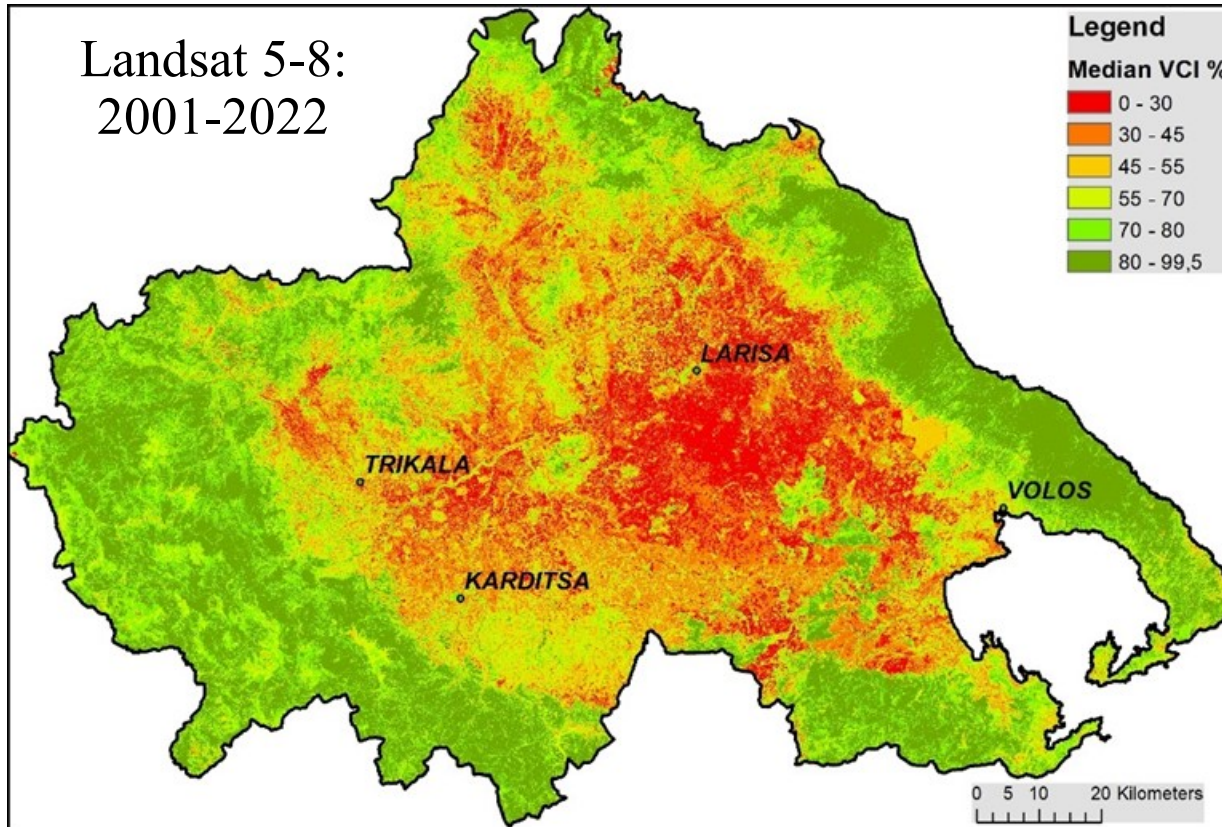
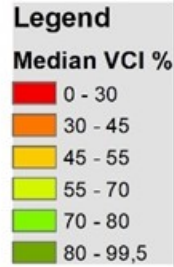
✓ VCI median for the 22 years period

$$VCI = 100 * \frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}$$

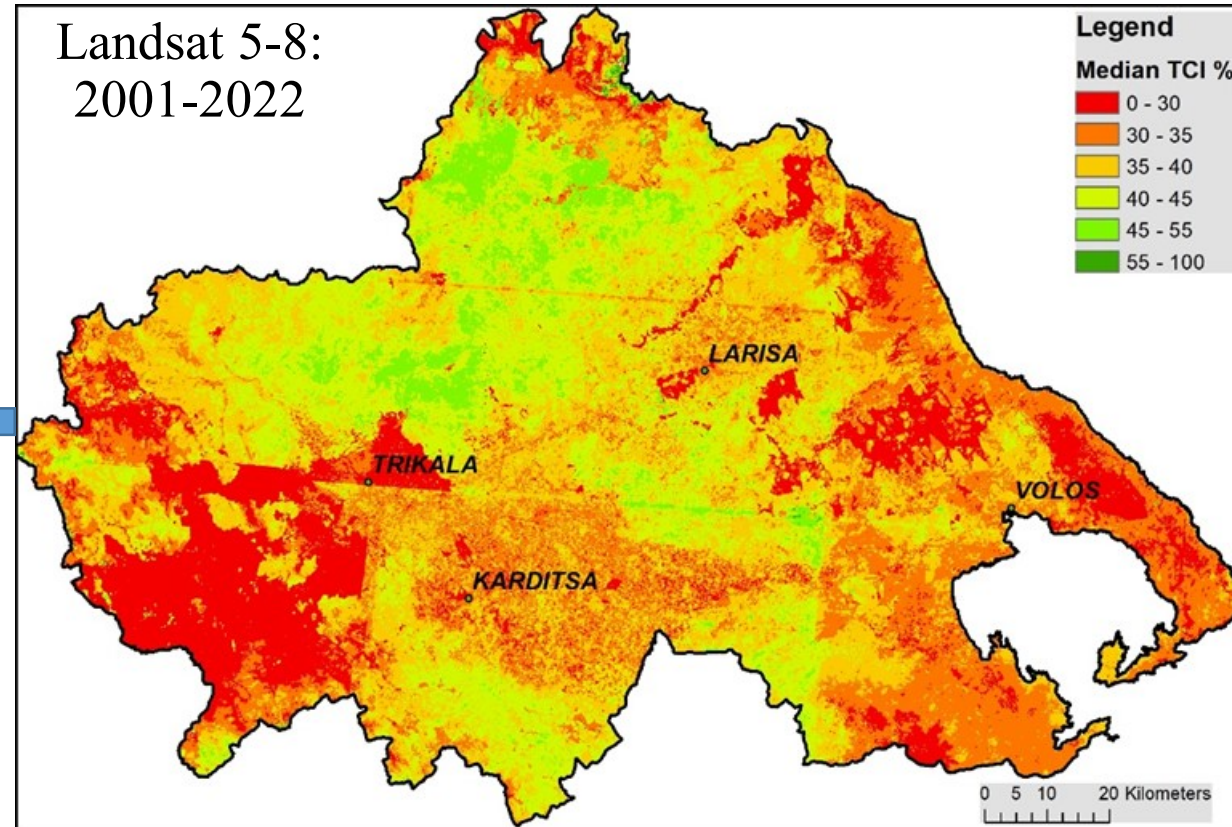
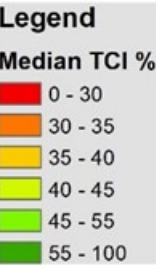
✓ TCI median for 22 years period

$$TCI = 100 * \frac{BT_{max} - BT}{BT_{max} - BT_{min}}$$

Landsat 5-8:
2001-2022



Landsat 5-8:
2001-2022



1. Hydroclimatic Zones

VHI: Vegetation Health Index

$$VHI = 0.5 * (VCI) + 0.5 * (TCI)$$

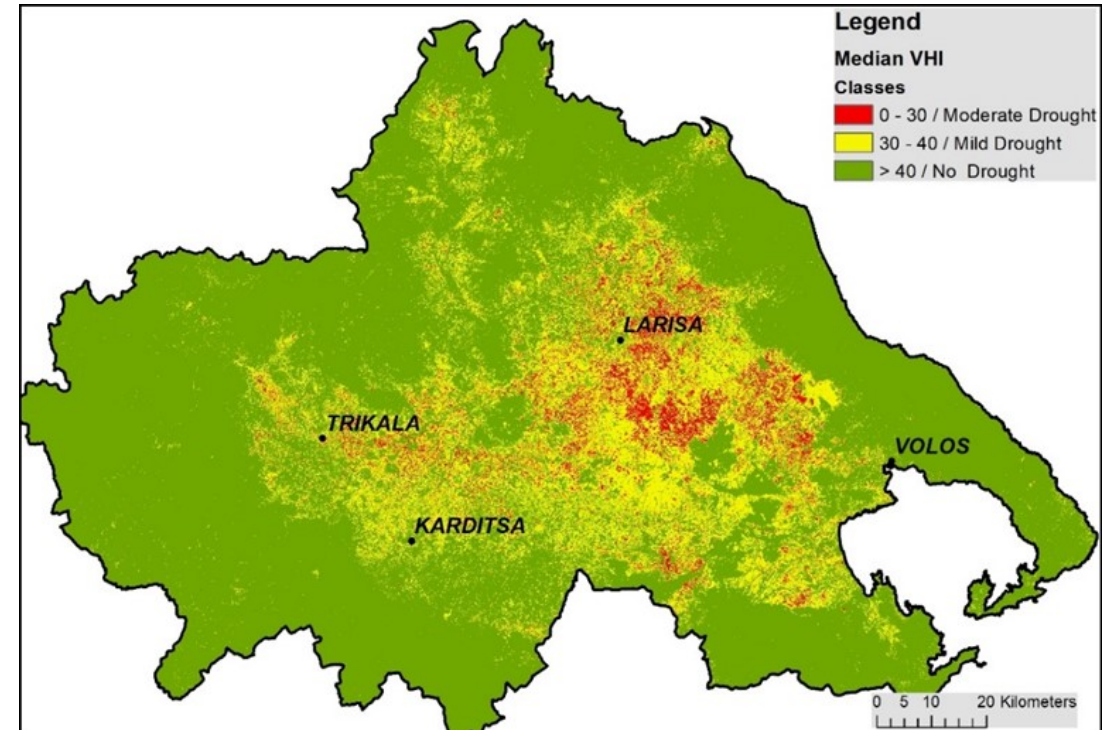
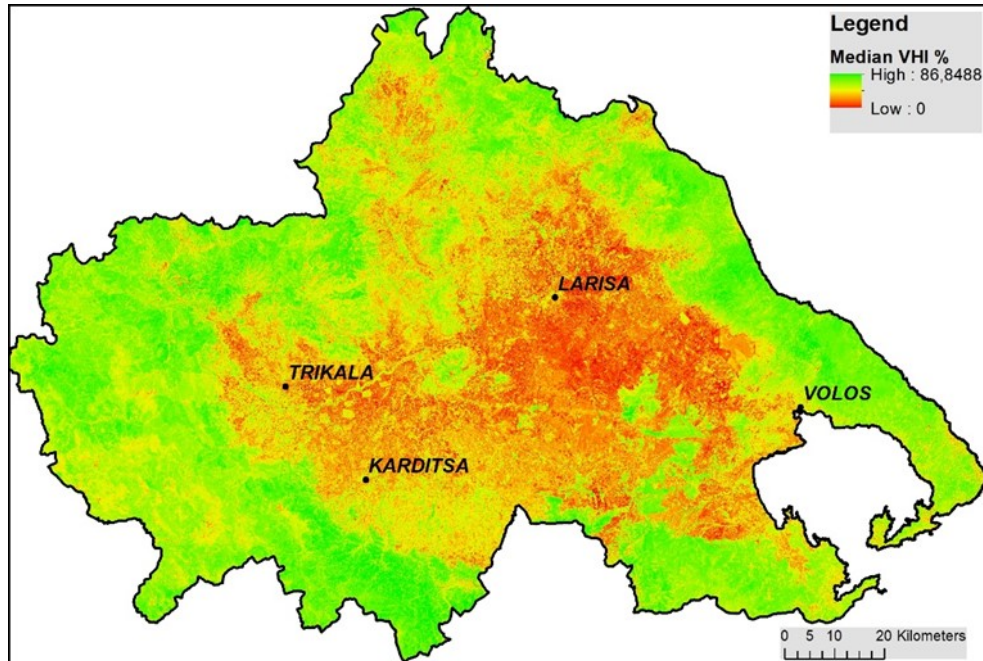
VHI values	Vegetative drought classes
<10	Extreme drought
<20	Severe drought
<30	Moderate drought
<40	Mild drought
>40	No drought

Classes:

Moderate Drought (red)

Mild Drought (yellow)

No Drought (green)



1. Hydroclimatic Zones

AI: Aridity Index

- ✓ **AI:** Represents Climate Drought & Determines the adequacy of rainfall for the crops water needs.
- ✓ **AI** is calculated in Multi-year basis using Monthly values

$$AI = \text{Precipitation} / \text{Potential Evapotranspiration}$$

- ✓ Precipitation: CHIRPS data
- ✓ PET: MODIS 8-day Potential Evapotranspiration product (MOD16A2)

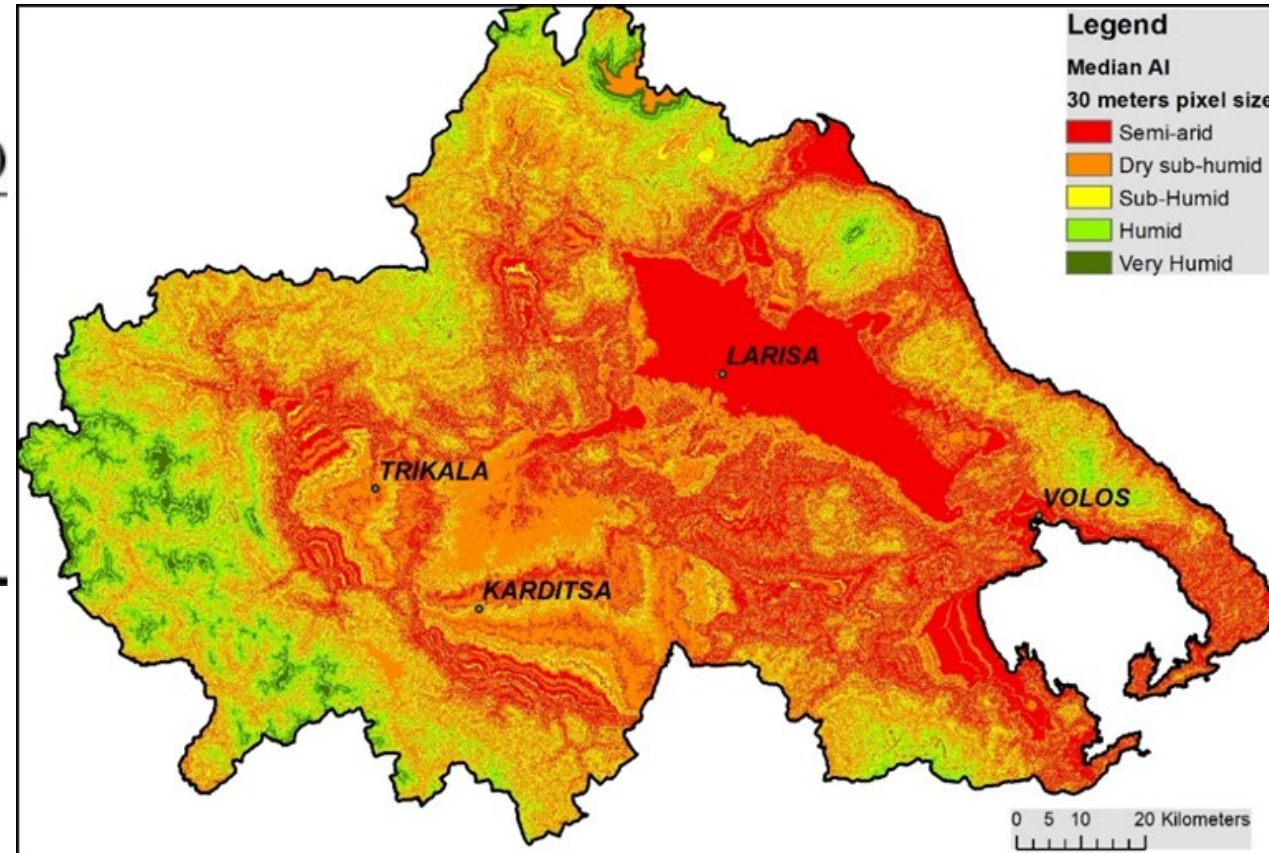
1. Hydroclimatic Zones

AI: Aridity Index

Aridity median Index for the 22 years

Classification	Aridity Index (AI)
Hyper-arid	$AI \leq 0.05$
Arid	$0.05 \leq AI < 0.20$
Semi-arid	$0.20 \leq AI < 0.50$
Dry sub-humid	$0.50 \leq AI < 0.65$
Sub-humid	$0.65 \leq AI < 0.80$
Humid	$0.80 \leq AI < 1.5$
Very humid	$1.5 \leq AI$

Semi-arid class dominates in the east part of Thessaly

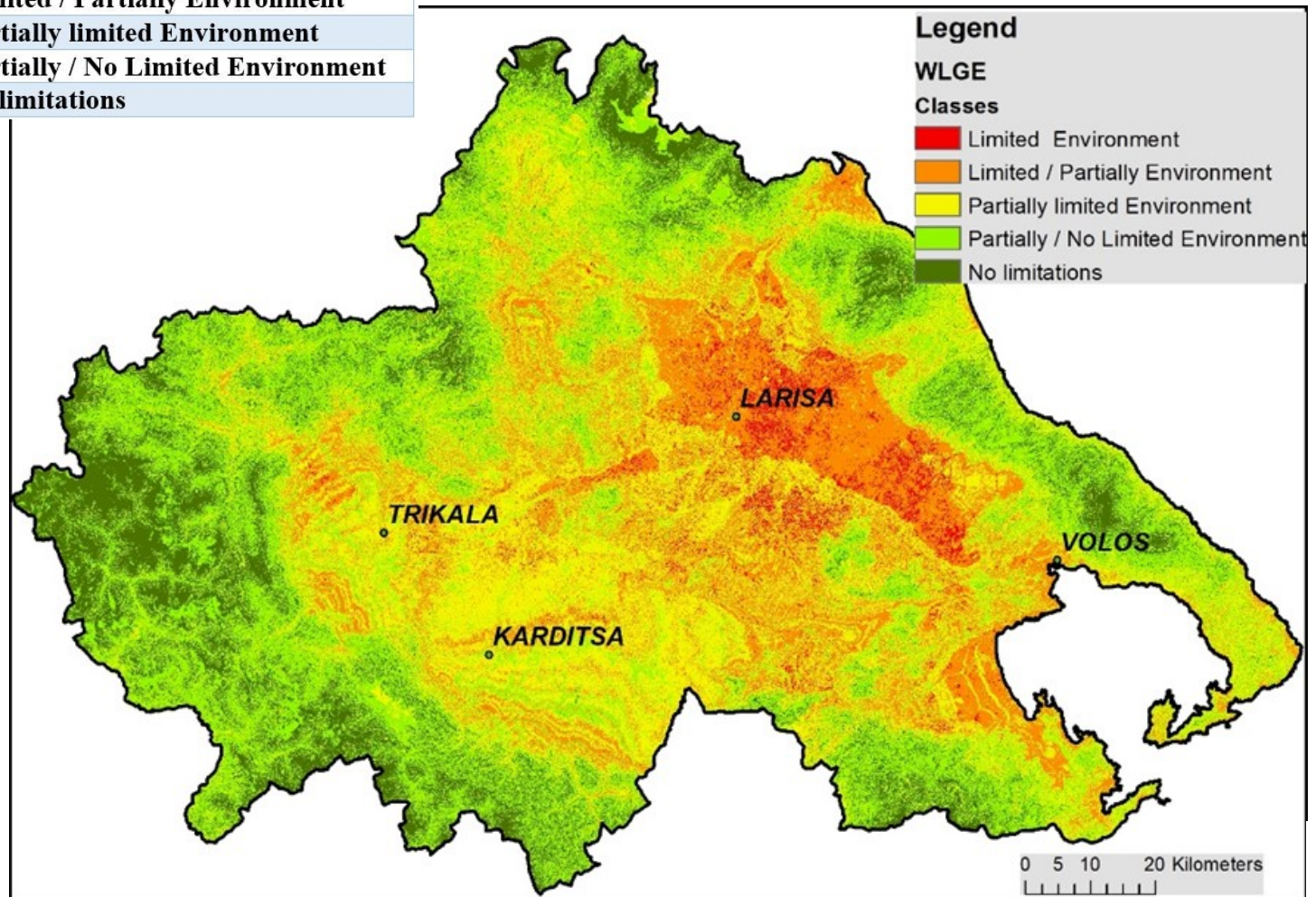


Median Aridity Index for the period 2001-2022, pixel size 30 m

1. Hydroclimatic Zoning

WLGE zones

Agricultural drought classes (VHI)	Aridity classes (AI)	WLGE classes
Extreme drought	Hyper-arid	Very Limited environment
Severe drought	Arid	
Moderate drought	Semi-arid	Limited Environment
	Dry sub-humid	Limited / Partially Environment
Mild drought	Sub-Humid	Partially limited Environment
No drought	Humid	Partially / No Limited Environment
	Very Humid	No limitations



2. Non crop Specific (General) Agroclimatic Zoning

➤ **Identification of Sustainable Production Zones in terms of:**

- Water Sufficiency
- Soil fertility
- Vulnerability - danger of desertification
- Elevation Restrictions

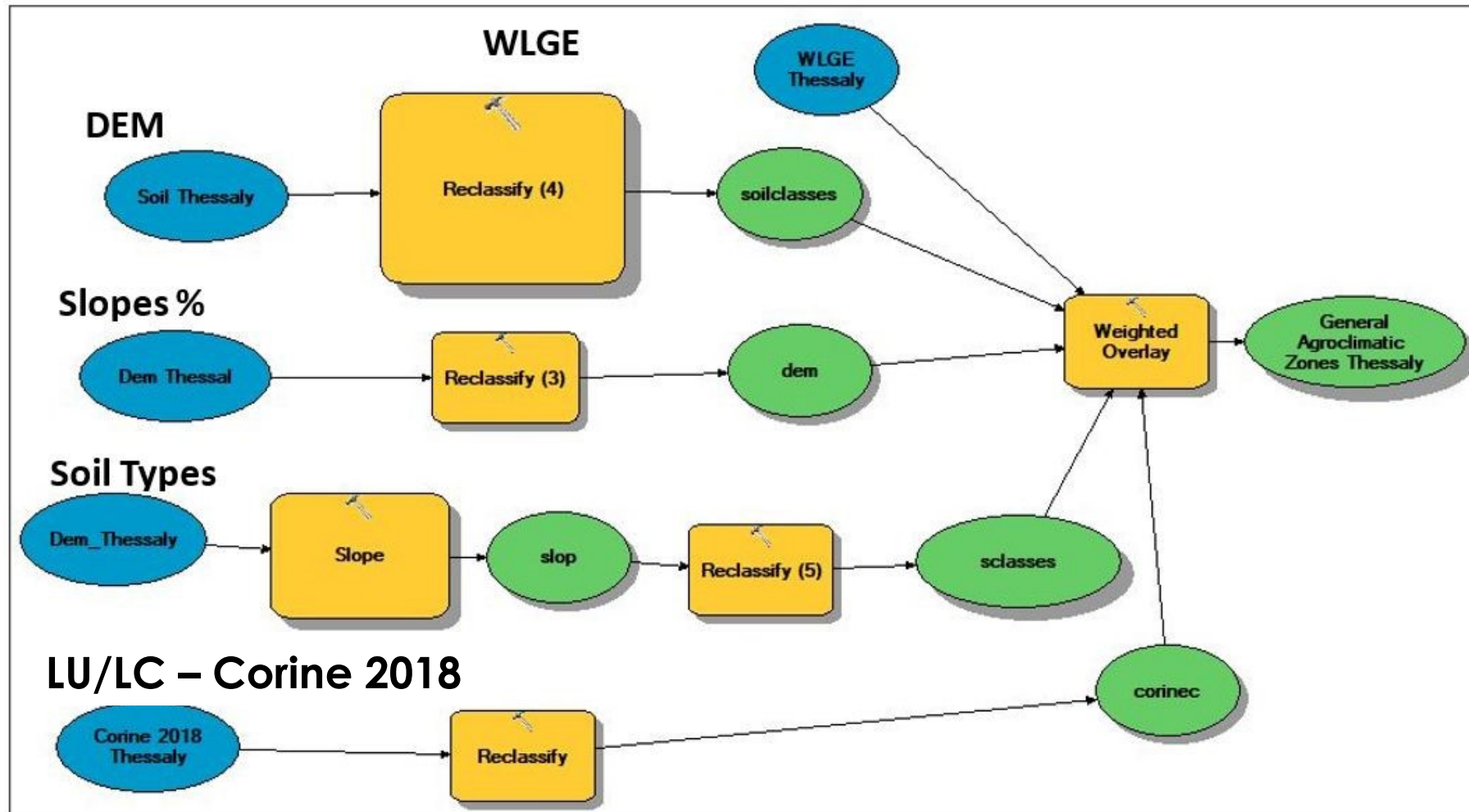
➤ **Input Data:** DEM + Slope + Soil + Land Use/Lan Cover + WLGE zone



A multicriteria model was applied

2. Non crop Specific (General) Agroclimatic Zoning

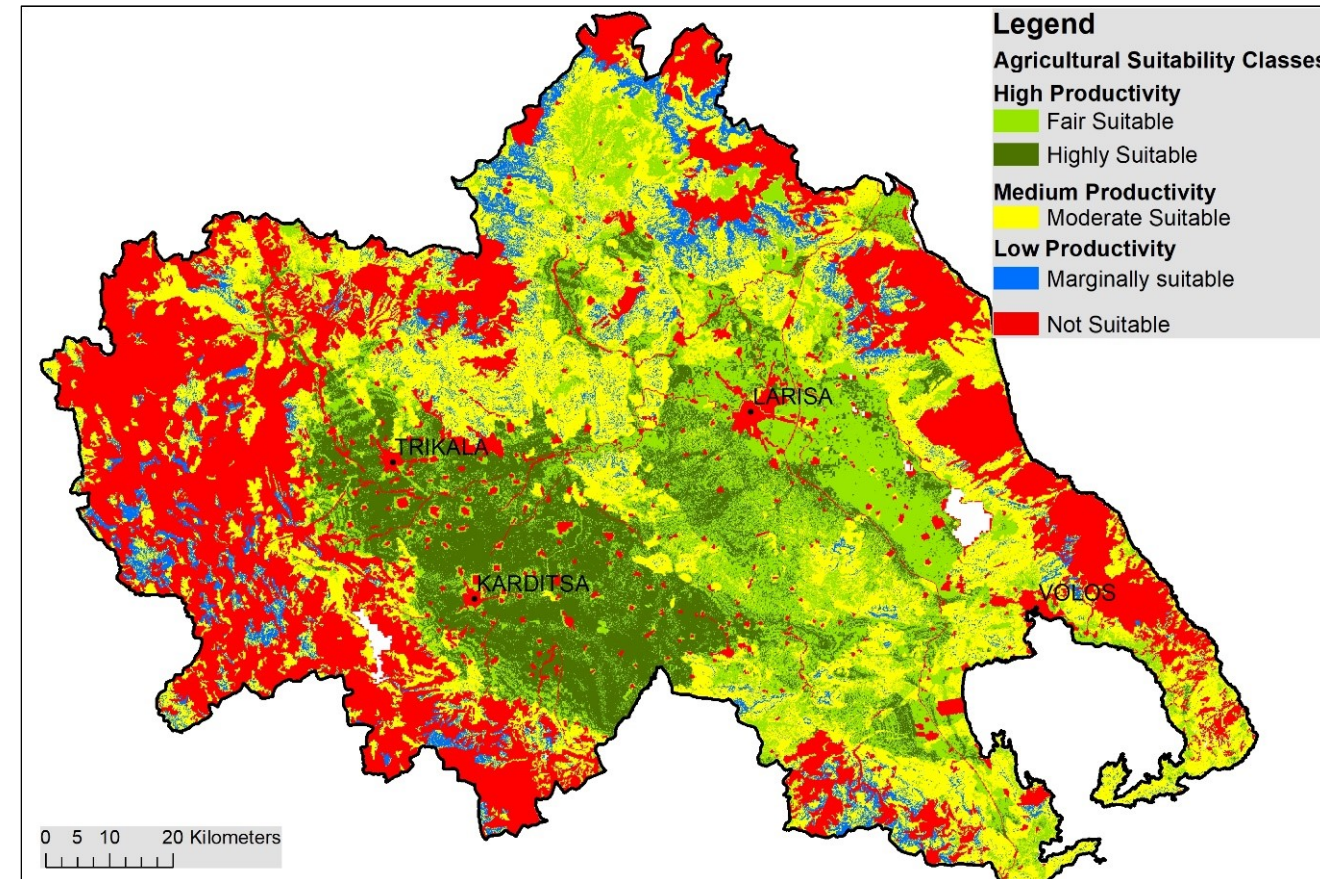
GIS Multicriteria Analysis



2. Non crop Specific Agroclimatic Zoning

Classification of 5 classes:

Suitability level	Suitability areas for agricultural production		Land Characteristics	Remarks
	Hectares	%		
Highly Suitable	205625	15,2	Gentle slopes, high soil moisture, with lower elevation	Most suitable for agriculture, favorable areas for intensive agriculture. Excess of water availability
Fair Suitable	250572	18,5	Gentle slopes with lower elevation, water deficiency	Suitable for agriculture, favorable areas for intensive agriculture but water shortage in summer period
Moderate Suitable	405950	30,0	Gentle to steep slopes with higher elevations, medium soil moisture	Suitable areas for farming practices with proper management
Marginally suitable	88648	6,6	Steep slopes with higher elevation	Less suitable areas for agriculture with careful farm management. Necessary protection from drainage and erosion
Not suitable	401369	29,7	Dense forests, Urban areas, water bodies, rocky lands	Not suitable for agriculture. Areas under vegetation, manmade structures, barren lands, etc.
Total	1352164	100		



3. Crop Specific Agroclimatic Zoning

➤ For annual crops wheat (non irrigated crop) – cotton (irrigated crop)

Should be estimated the High – Low productivity zones.

Three variables should be calculated: Growing Degree Days and Net Radiation for the Growing Season.

✓ **GDD:** Growing Degree Days $^{\circ}\text{C}$

✓ **Rn:** Net Radiation

✓ **Spring precipitation**



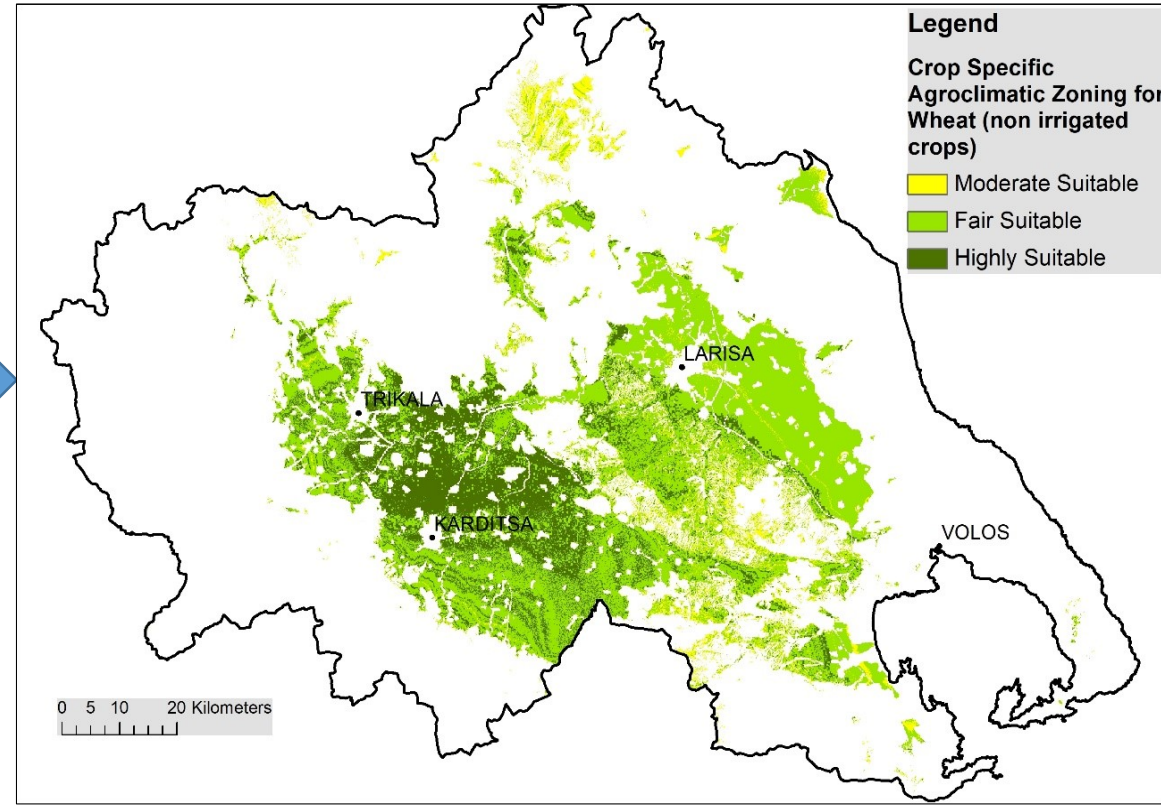
High-Low Productivity Zones

Those Indices control the growth environment of the crops

3. Crop-Specific Agroclimatic Zoning for annual winter crops (Wheat)

For the winter crop- wheat- a multicriteria analysis model was performed. A limited number of factors has been considered: altitude, slopes, GDD, spring precipitation and land use-land cover & Non-Crop specific agroclimatic zones.

Suitability level	Suitability areas for agricultural production		Land Characteristics	Remarks
	Hectares	%		
Highly Suitable	95160	26	Gentle slopes, high soil moisture, with lower elevation.	Most suitable for wheat crop. High productivity. Excess of water availability.
Fair Suitable	231841	63.4	Gentle slopes with lower elevation, water deficit.	Suitable for wheat crop, but potential water shortage in spring period. High-medium productivity.
Moderate Suitable	38788	10.6	Gentle to steep slopes with higher elevations, medium soil moisture.	Suitable areas for wheat crop in hilly and semi-mountainous zones with potential water shortage. Medium Productivity
Total	365789	100		

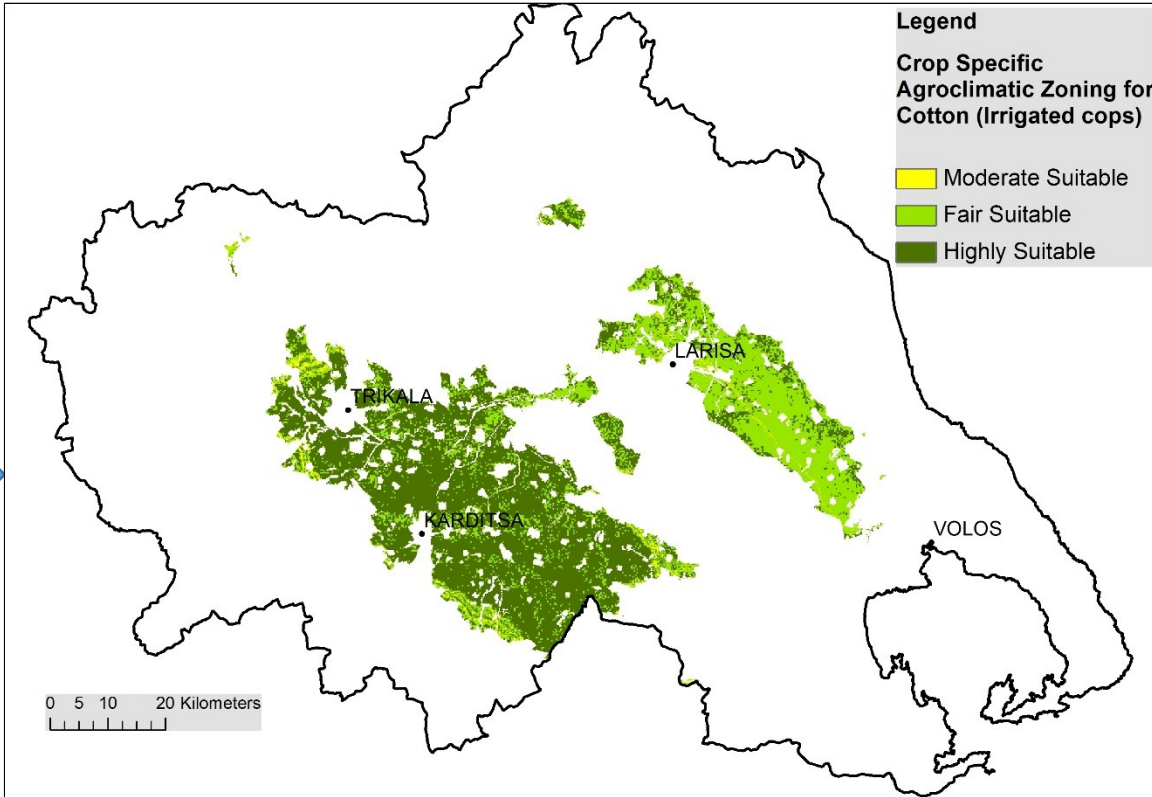


The most appropriate zones for wheat crop cultivation concerning the sustainable use of natural resources

3. Crop-Specific Agroclimatic Zoning for annual summer irrigated crops (Cotton)

For the summer irrigated crop –cotton- a multicriteria analysis model was performed. A limited number of factors has been considered: altitude, slopes, GDD, spring precipitation and non-crop specific agroclimatic zones. Greater influence (weight factor) being given to irrigated areas.

Suitability level	Suitability areas for agricultural production		Land Characteristics	Remarks
	Hectares	%		
Highly Suitable	135281	37	Gentle slopes, high soil moisture, with lower elevation	Most suitable for Cotton crop. High productivity. Excess of water availability
Fair Suitable	77672	21.2	Gentle slopes with lower elevation, water deficiency	Suitable for cotton crop, but potential water shortage in summer period. Need for farmer sustainable management practices. High productivity
Moderate Suitable	4731	1.3	Gentle to steep slopes with higher elevations, medium soil moisture	Suitable areas for cotton crop in hilly areas. Medium productivity
Total	217684	100		



The most appropriate zones for cotton crop cultivation concerning the sustainable use of natural resources

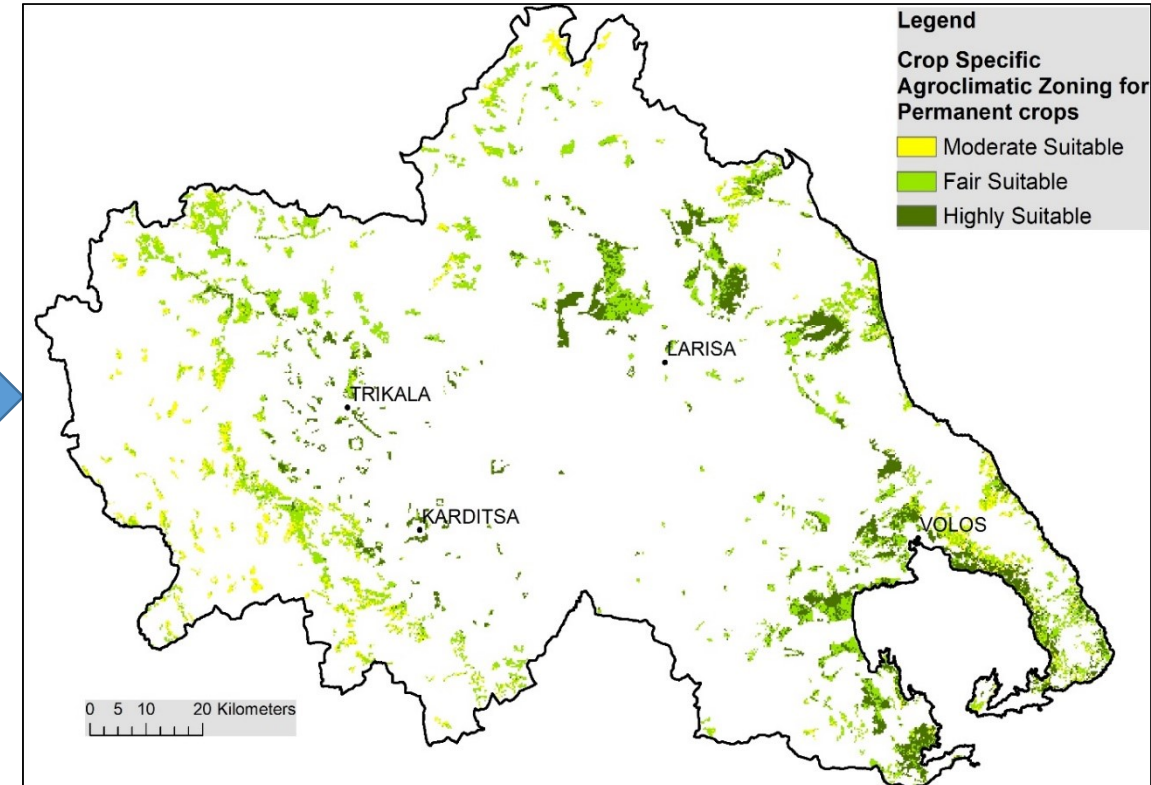
3. Crop-Specific Agroclimatic Zoning for Permanent crops (Olive trees, orchards, vineyards)

For the permanent crops a multicriteria analysis model was performed.

A limited number of factors has been considered: altitude, slopes and non-crop specific agroclimatic zones.

Land-cover class types, such as: vineyards, fruit trees, olives, complex cultivation patterns were considered as the most suitable zones for permanent crops.

Suitability level	Suitability areas for agricultural production		Land Characteristics	Remarks
	Hectares	%		
Highly Suitable	44161	30	Gentle slopes, with lower elevation	Most suitable for permanent crops. High productivity. Excess of water availability.
Fair Suitable	77867	53	Gentle to steep slopes in lower to medium altitude areas	Suitable for permanent crops, but potential water shortage in summer period. Need for farmer sustainable management practices. High-medium productivity.
Moderate Suitable	24971	17	Gentle to steep slopes with higher elevations, medium soil moisture	Suitable areas for permanent crops in steep slopes and medium to higher elevations. Good productivity.
Total	147000	100		



The most appropriate zones for permanent crops concerning the sustainable use of natural resources

3. Crop-Specific Agroclimatic Zoning

for Livestock crops (Oats, Vetch, Ray-grass Italie, Forage pea)

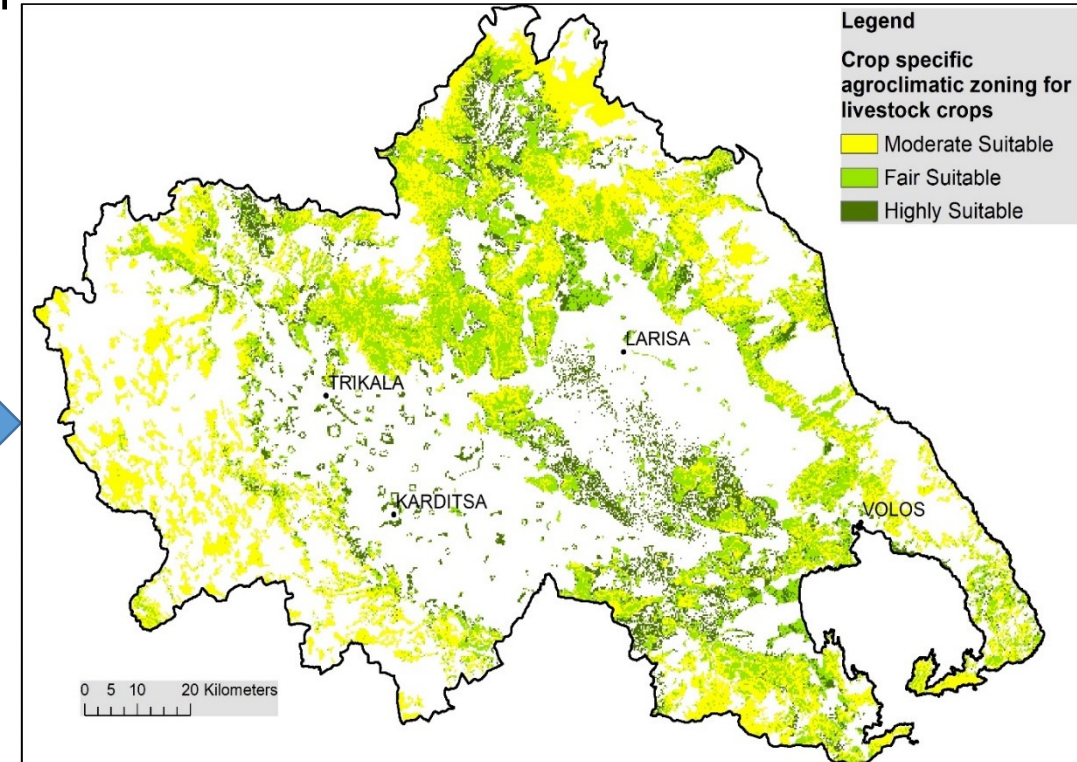
For the animal feed production crops a multicriteria analysis model was performed.

A limited number of factors has been considered: altitude, slopes and non-crop specific agroclimatic zones.

Land-cover class types, such as: pastures, grasslands, agroforestry areas, were considered as the most suitable zones for livestock production.

Land-cover type non-irrigated areas with more than 12% slopes have been classified as suitable areas for grazing

Suitability level	Suitability areas for agricultural production		Land Characteristics	Remarks
	Hectares	%		
Highly Suitable	79975	14,7	Gentle slopes, with lower elevation at agroforestry/grassland zones and at non-irrigated areas with slopes more than 12%.	Most suitable for livestock crops. High productivity. Excess of water availability in higher elevations.
Fair Suitable	199374	36,7	Gentle to steep slopes in semi-mountainous areas.	Suitable for livestock crops, in low to medium altitude 150-500 but potential water shortage in summer period. Need for farmer sustainable management practices. High-medium productivity.
Moderate Suitable	263235	48,5	Gentle to steep slopes with higher elevations, medium soil moisture.	Suitable areas for livestock crops in steep slopes and medium to higher elevations. Good productivity.
Total	542584	100		



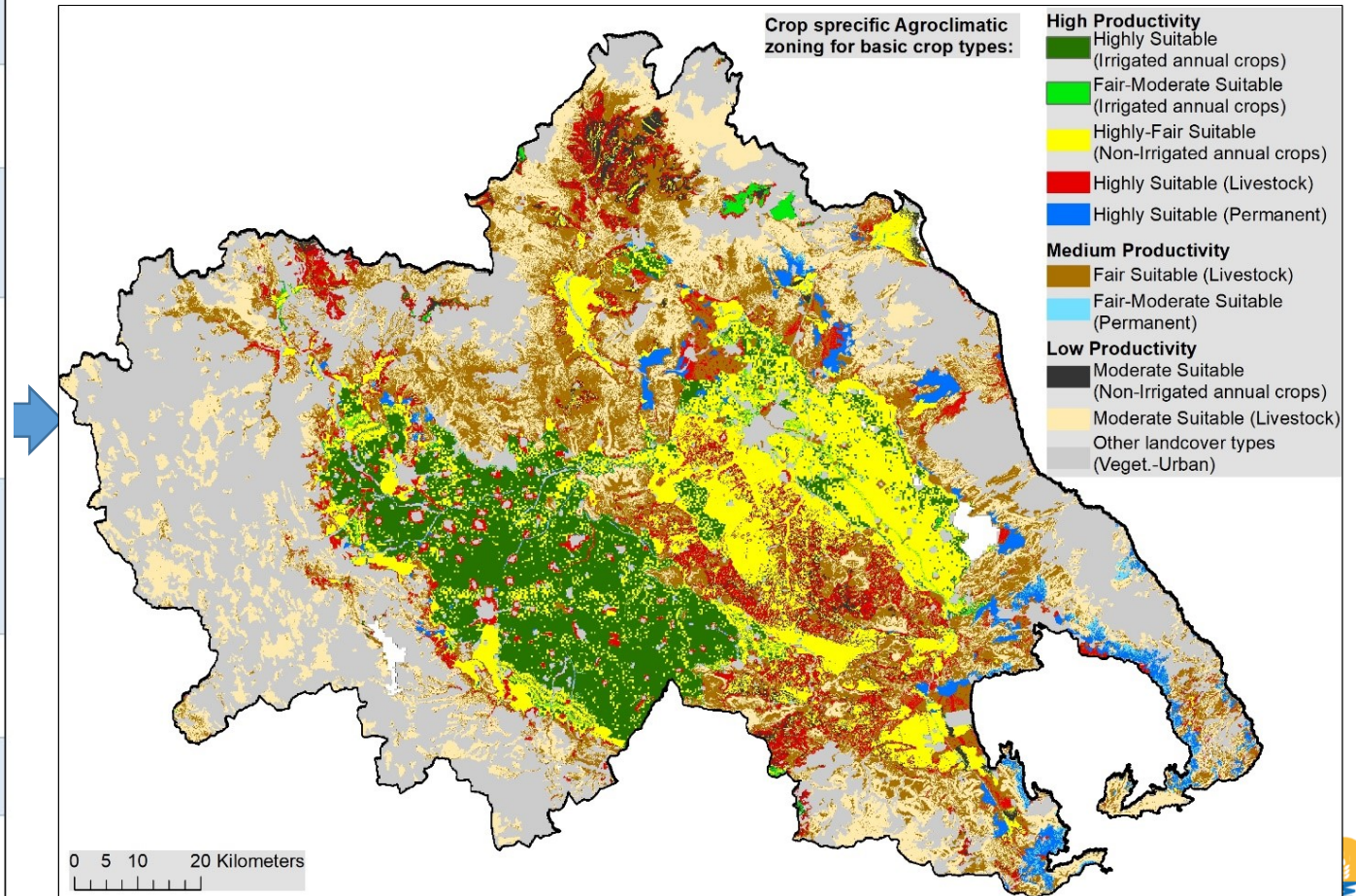
The most appropriate zones for Livestock crops cultivation concerning the sustainable use of natural resources

3. Integrating crops- specific productivity zones in the Thessaly Region

Crop Suitability level	Suitability areas for agricultural production		Land Characteristics	Remarks
	Hectares	%		
Irrigated crops, Highly Suitable (Cotton, etc.)	135281	10.0	Gentle slopes, high soil moisture, with lower elevation.	Most suitable for Irrigated crops (cotton, etc.). High productivity. Excess of water availability
Irrigated crops, Fair-Moderate Suitable (Cotton, etc.)	9476	0.7	Gentle slopes with lower elevation, water deficit.	Suitable for Irrigated crops (cotton, etc.), but potential water shortage in summer period. Need for farmer sustainable management practices. High-medium productivity
Non-Irrigated crops, Highly-Fair Suitable (Wheat, etc.)	191720	14.2	Gentle slopes, with lower elevation, water deficit.	Suitable for Non-Irrigated crops (wheat, etc.), but potential water shortage in spring period. High productivity
Non-Irrigated crops, Moderate Suitable (Wheat, etc.)	37085	2.7	Gentle to steep slopes with higher elevations, medium soil moisture.	Suitable areas for Non-Irrigated crops (wheat, etc.), in hilly and semi-mountainous zones with potential water shortage. Medium productivity
Livestock, Highly Suitable	79983	5.9	Gentle slopes, with lower elevation at agroforestry/grassland zones and at non-irrigated areas with slopes more than 12%.	Most suitable for livestock crops. High productivity. Excess of water availability in higher elevations.
Livestock, Fair Suitable	198891	14.7	Gentle to steep slopes in semi-mountainous areas.	Suitable for livestock crops, in low to medium altitude 150-500 but potential water shortage in summer period. Need for farmer sustainable management practices. High-medium productivity
Livestock, Moderate Suitable	261807	19.4	Gentle to steep slopes with higher elevations, medium soil moisture.	Suitable areas for livestock crop in steep slopes and medium to higher elevations. Good productivity
Permanent, Highly Suitable	28327	2.1	Gentle slopes, with lower elevation.	Most suitable for permanent crops. High productivity. Excess of water availability. High productivity
Permanent, Fair-Moderate Suitable	5709	0.4	Gentle to steep slopes in higher elevations, medium soil moisture.	Suitable areas for permanent crops in steep slopes and medium to higher elevations. Good productivity.

The combination of the four prevailing crops was performed in order to create a consolidated map containing the suitability zones

Productivity Zones



Conclusions

- ✓ The continuous technological advancement in new satellite systems has steadily increased the reliability of remote sensing data and methods, such as agroclimatic zoning, leading to the identification of suitable productivity zones.
- ✓ The resulting fine-resolution productivity zones (30x30 m²) could help farmers to select suitable crops within each agroclimatic zone, and to address socio-economic considerations, leading to viable and resilient agriculture.
- ✓ Relatively easy to process and transferable almost everywhere in the world via the Google Earth Engine (GEE) platform.