Studying soil erosion rates through landscape fragmentation. A case study from Crete, Greece.

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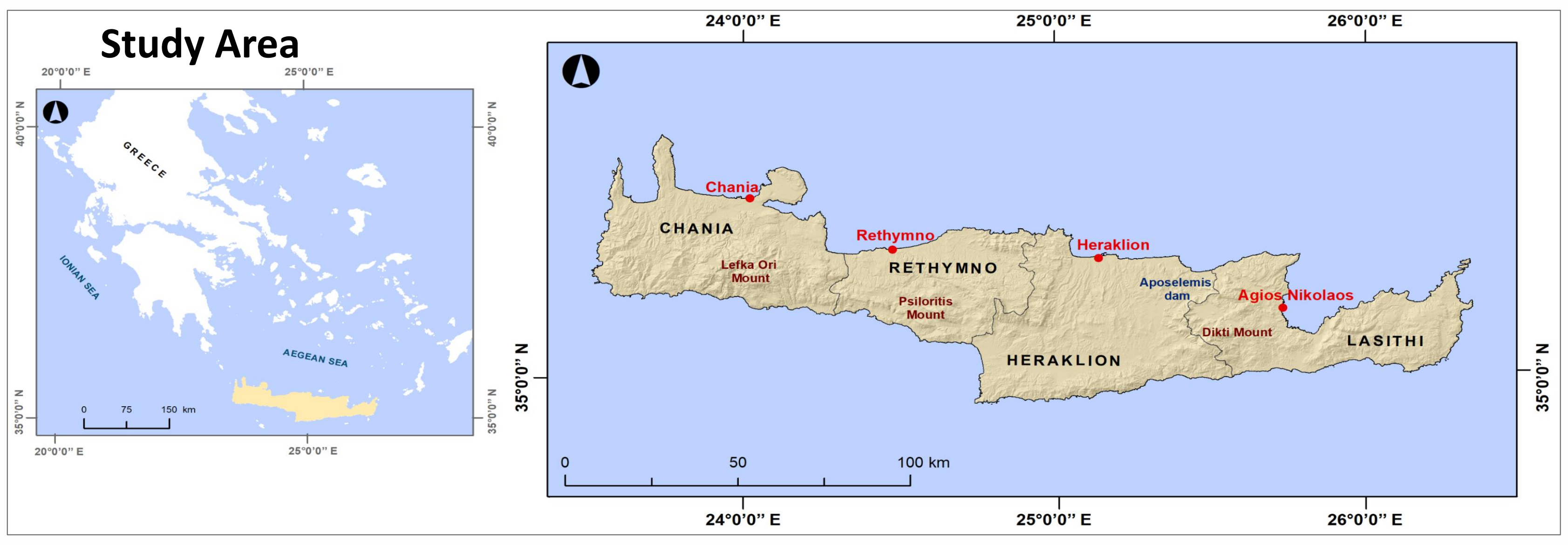
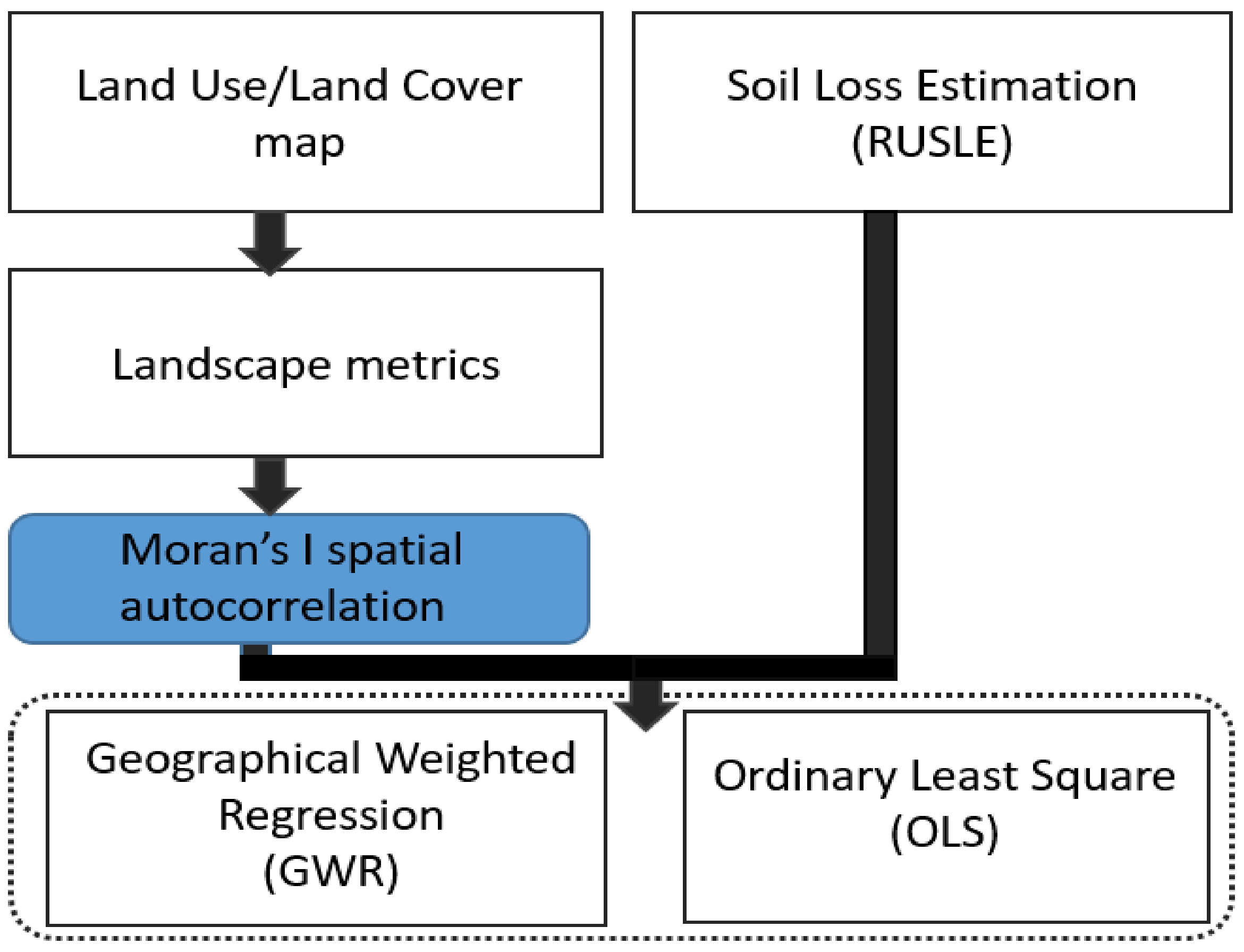
Abstract: The regular patterns of soil erosion tend to change at different scales of observation, affecting the mechanism of soil erosion and its evolution characteristics. Fragmentation and land loss are two critical, interrelated processes that influence the entire landscape. In this study, we examine how the relationship between landscape fragmentation and soil loss is diversified in different scales and contexts. Thus, different Earth Observation (EO) products, in terms of spatial analysis, such as Landsat 8, Sentinel 2 and Planetscope imageries are utilized to search the influence of scale effect in fragmentation rate. Land use / Land Cover (LULC) maps were developed in different scales through the use of sophisticated classification algorithms. Following, FRAGSTATS software was employed to calculate spatial metrics in order to capture important aspects of landscape patterns such as edge density, largest patch index, number of patches, contagion etc. In this context we calculated fractal dimensions and Moran's I spatial autocorrelation statistics and used them to represent the degree of landscape fragmentation. Soil loss data, estimated in different scales were incorporated in the overall study as derived from RUSLE (Revised Universal Soil Loss Estimation) soil loss estimation model. Ordinary least square (OLS) and Geographical Weighted Regression (GWR) methodologies were applied in order to correlate both spatially and quantitatively soil loss rates with landscape fragmentation The results denoted the fact that the combining use of GWR and not spatially extended research areas are ideal for collating landscape metrics and soil erosion phenomena. The overall approach can be used as a road map in order to extract crucial conclusions about landscape's diachronic evolution and how this is affected both from natural and anthropogenic interventions

Study Area



Methodology



Land Use/Land Cover map

Soil Loss Estimation (RUSLE)

Landscape metrics

Moran's I spatial autocorrelation

Geographical Weighted Regression (GWR)

Ordinary Least Square (OLS)

- **RUSLE (Revised Universal Soil Loss Estimation)** is an empirical equation that enumerates the average annual soil erosion in tons /ha/year.

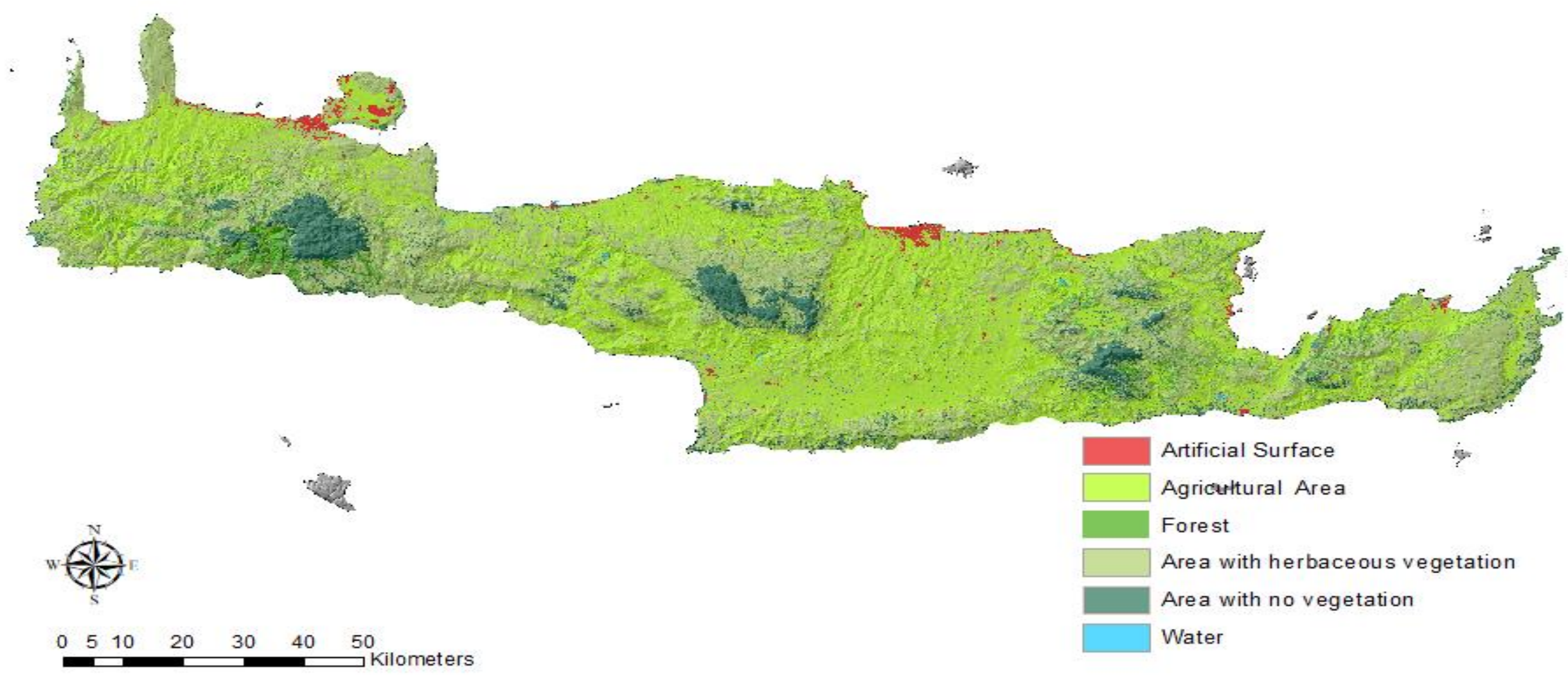
$A = R*K*LS*C*P$

where, A estimated average annual soil erosion (ton/ha^{-1}/year^{-1}),
R rainfall erosivity factor ((MJ mm ha-1 h^{-1} year^{-1}),
K = soil erodibility factor (t MJ^{-1} ha^{-1} mm^{-1}),
L slope length factor (dimensionless),
S slope steepness factor (dimensionless),
C cover management factor (dimensionless),
P supporting practices (dimensionless),

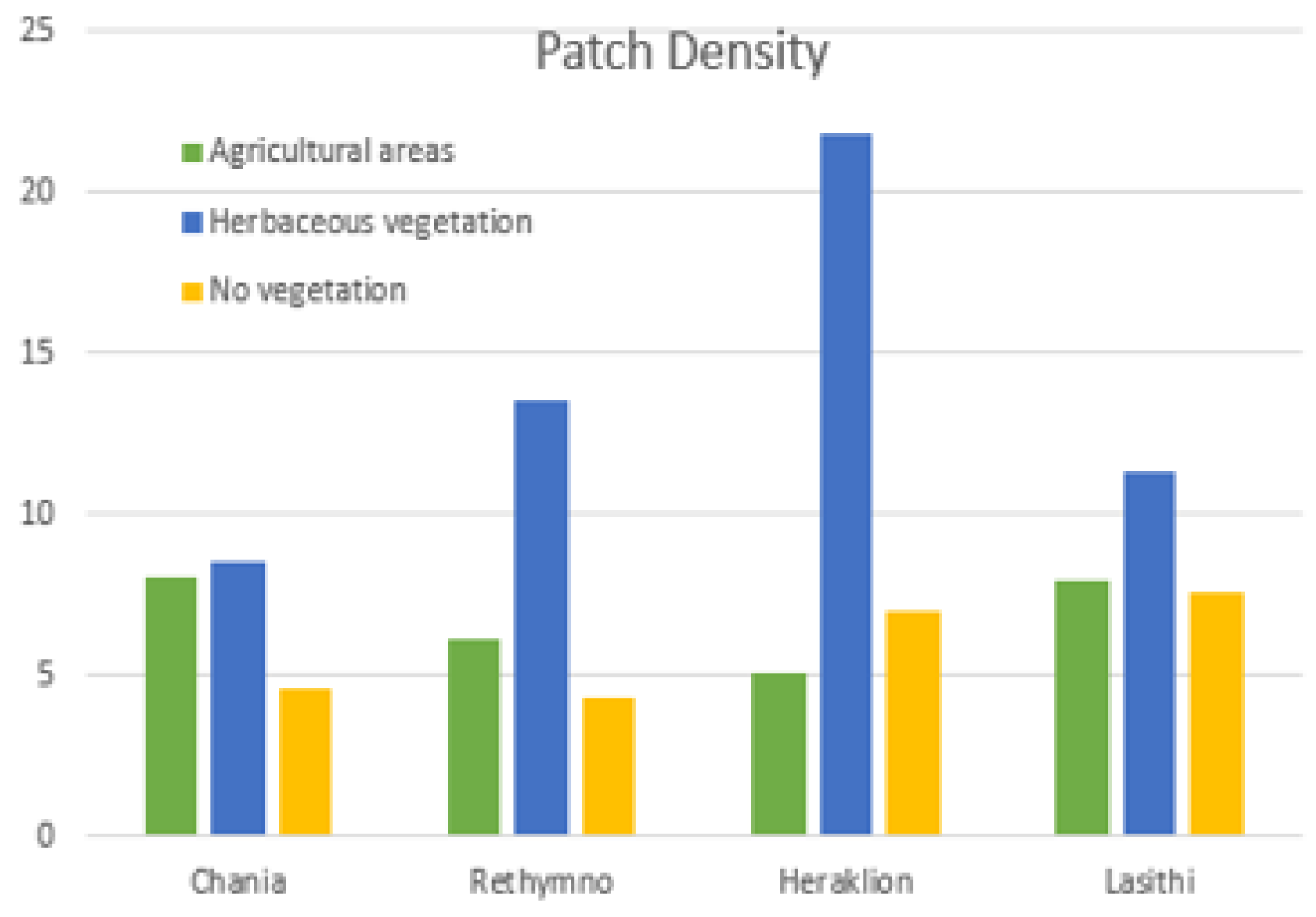
- RUSLE was estimated for 2019 for Crete and its individual Prefectures: Chania, Rethymno, Heraklion and Lasithi

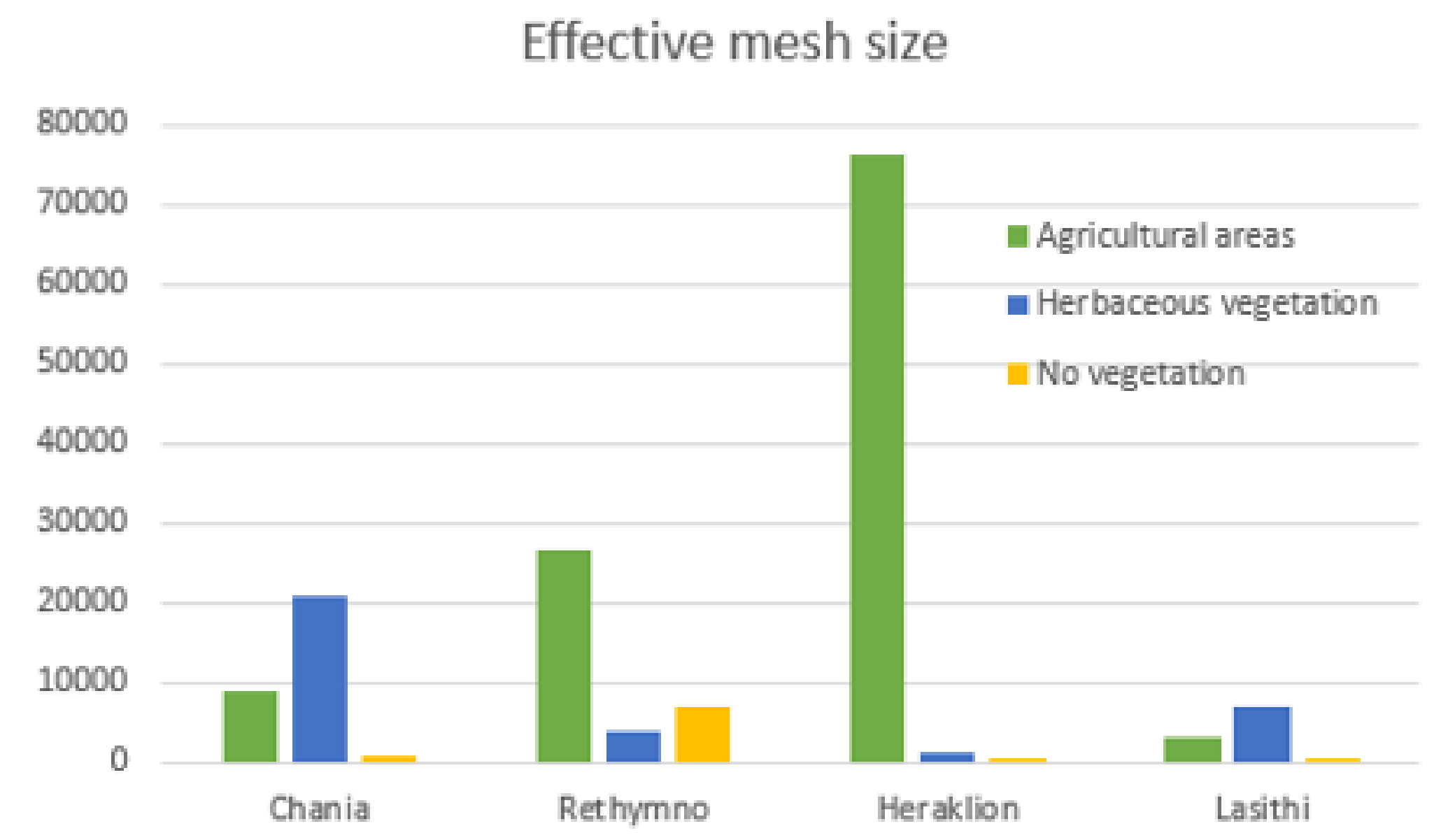
#	Area	Mean Soil Loss (tn/ha/yr)
1	Chania	25.67
2	Rethymno	15.74
3	Heraklion	10.19
4	Lasithi	10.51
5	Crete	16.42

- **Supervised classification (maximum likelihood)** was applied on Landsat 8 images to develop Land use/Land Cover(LULC) map of 2019. 6 (six) final classes were developed for Crete: Artificial Surface, Agricultural Area, Forest, Areas with herbaceous Vegetation, Areas with no Vegetation, Water.



- **Landscape Metrics :** Various landscape metrics (number of patches, patches density, cohesion, LPI, LSI, Effective mesh size, Aggregation Index) were estimated in Fragstats environment. The metrics were estimated both for Prefecture and island level. ***Moran's I*** spatial autocorrelation methodology was utilized to all landscape metrics variables for evaluating how clustered or random the observed patterns are. The results denoted that all the landscape metrics were randomly allocated.
- Following, both ***Geographical Weighted Regression (GWR***) and ***Ordinary Least Square (OLS)*** methodologies were applied to estimate the spatial and quantitative correlation of soil loss / soil erosion (dependent variable) with the landscape metrics (independent variables). Sensitivity analysis was performed in order to select the independent variables that are more correlated to soil loss. Patch density and effective mesh size (independent variables) were selected as the more correlated.
- *Patch density* has the same basic utility as number of patches as an index, except that it expresses number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size.
- *Effective mesh size* is based on the cumulative patch area distribution and is interpreted as the size of the patches when the corresponding patch type is subdivided into S patches, where S is the value of the splitting index.





- **Results/Conclusions:**
- The results denoted the fact that the spatial correlation of landscape metrics is higher in shorter spatial coverage areas (Prefecture level) compared to larger (island level). Specifically, for GWR method the R square values is higher to 0.5 for all Prefectures of Crete, reaching 0.77 for Lasithi.
- OLS methodology resulted to high R square values only for Lasithi (0.72) and less for Chania (0.35). Concerning Rethymno and Heraklion, the R square values as estimated from OLS are negligible. Lasithi is a fragmented landscape (high patch density, low effective mesh size) where low soil loss rates were estimated for 2019.
- In addition, for both methodologies, no correlation is estimated between landscape metrics and soil loss in Crete (island level).

R square			
#	Area	GWR	OLS
1	Chania	0.58	0.35
2	Rethymno	0.76	0.02
3	Heraklion	0.5	0.003
4	Lasithi	0.77	0.72
5	Crete	0.0266	0.026

- **Future work:** The research team will integrate more metrics in the overall methodology and will also work in watershed level (selected catchments in Crete). For this purpose high resolution images (PlanetScope) have been already acquired and analyzed in terms of Land use /Land cover.

"5DARE" research project

Websites: *https://www.ims.forth.gr/en/project/view?id=193*
https://www.dare.tuc.gr/en/home/

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the project is received funding from: