LAND COVER CHANGE DETECTION IN CRETE ISLAND, GREECE, USING DIFFERENT COMBINATIONS OF BIOPHYSICAL INDICES IN CHANGE VECTOR ANALYSIS

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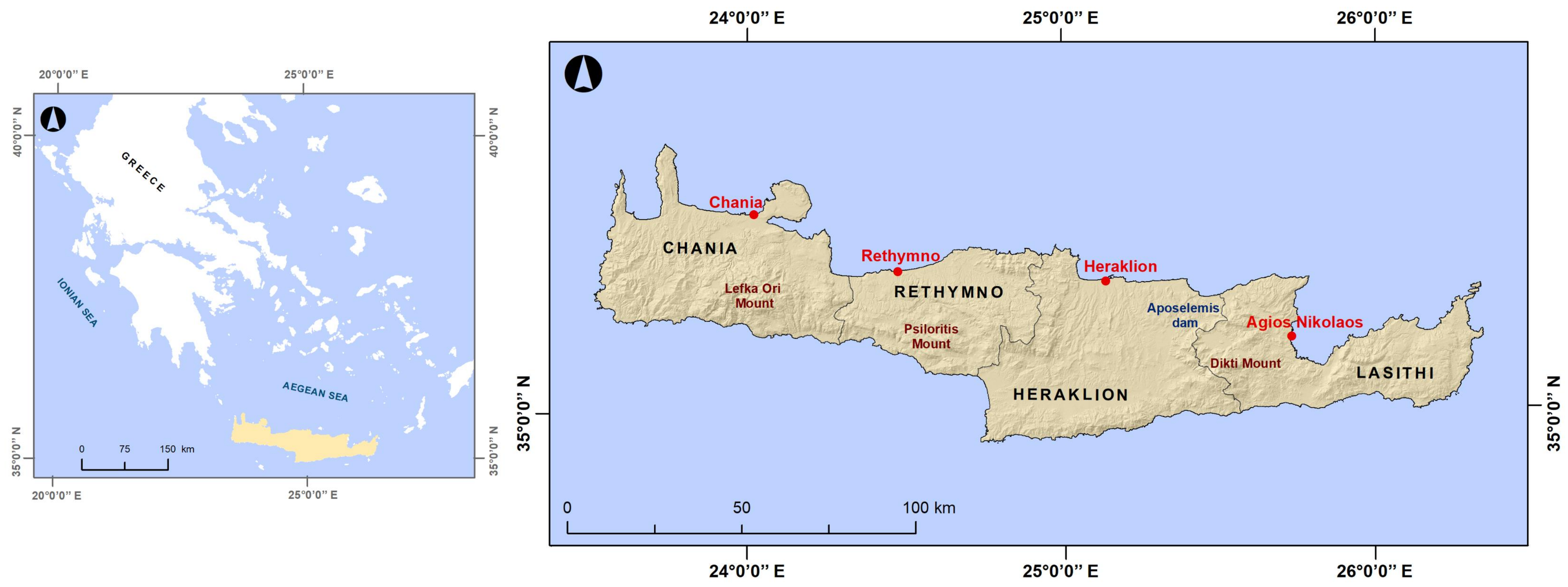
Abstract

Land cover describes the general biophysical state of the surface providing also information about other aspects of the land, such as soils and water. Changes in land cover may have noticeable impact on the ecosystem biodiversity, water resources, climate system and socio-economic sectors. Therefore, the need for detecting these changes is more and more imperative, especially given the emergence of unbalances caused by natural and anthropogenic driving forces like climate change, intensive agriculture and wrong land management decisions. Land cover changes are mainly represented by changes in the biophysical properties of land surface. These properties can be measured by remote sensing-derived indices representing both the vegetation and soil conditions of a given region. In this research effort, by applying a change detection technique like change vector analysis (CVA), the relationship between the dynamic changes in such indices and land cover changes in Crete Island, Greece, was assessed and mapped for the time periods of 1999–2009 and 2009–2019. Vegetation indices such as normalized difference vegetation index (NDVI) and tasseled cap greenness (TCG), and soil indices such as albedo and tasseled cap brightness (TCB), were estimated by Landsat satellite images captured in 1999, 2009 and 2019. Based on two different index combinations (NDVI–albedo and TCG–TCB), CVA produced change results for each of the periods indicating the magnitude and type (direction) of changes, respectively. The most appropriate combination for land cover change detection in the study area was determined by an evaluation process resulting to the estimation of accuracy statistics (kappa index and overall accuracy). Although promising accuracy results were provided for both examined combinations, the change maps produced by the combination of NDVI–albedo were found to be more accurate.

Study area



Data

Satellite/sensor	Date	Spatial resolution (m)
Landsat-5/TM	May 1999	30
Landsat-7/ETM+	May 2009	30
Landsat-8/OLI	May 2019	30

Methodology

1) The imagery data was pre-processed, including atmospheric and radiometric corrections as well as mosaicking of the obtained Landsat image tiles.

2) Spectral indices representing the biophysical properties (vegetation and soil) of the study area were prepared for 1999, 2009 and 2019:

   Vegetation indices: *Normalized difference vegetation index (NDVI)* and *Tasseled cap greenness (TCG)*

   Soil indices: *Albedo* and *Tasseled cap brightness* (TCB)

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}}$$

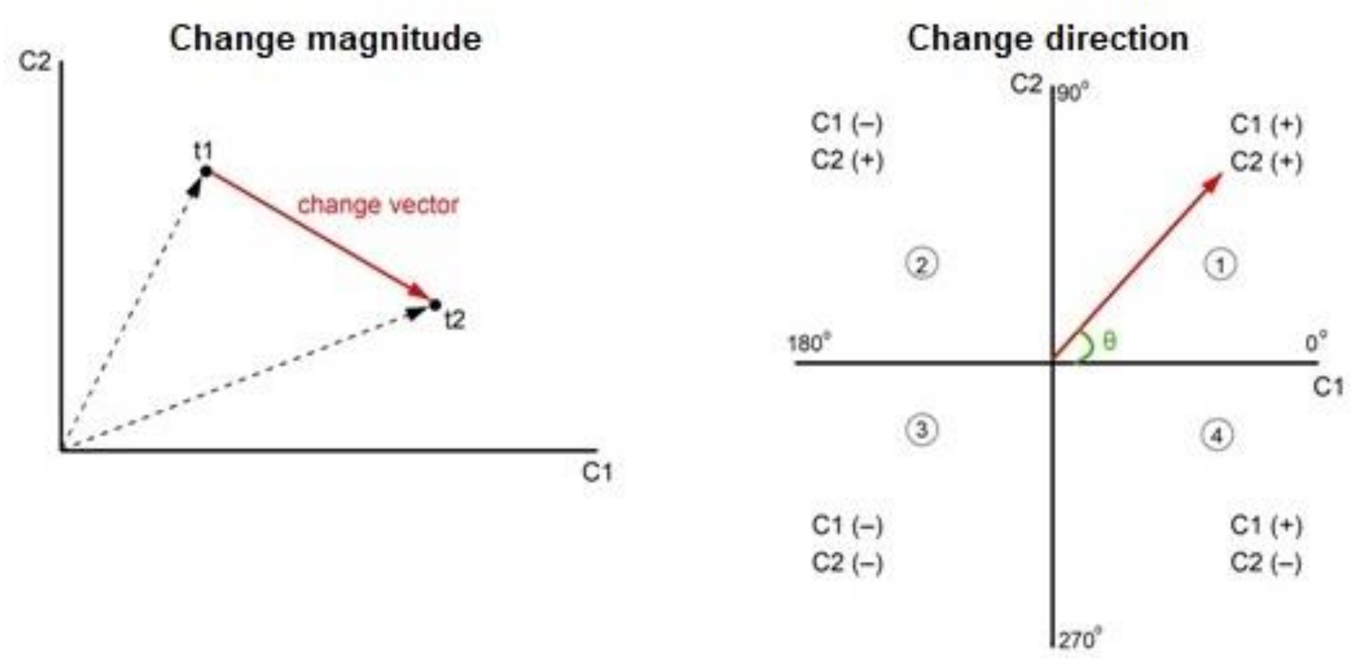
$$Albedo = 0.356\rho_{BLUE} + 0.130\rho_{RED} + 0.373\rho_{NIR} + 0.085\rho_{SWIR1} + 0.072\rho_{SWIR2} - 0.0018$$

   where ρ_{NIR}, ρ_{RED}, ρ_{BLUE}, ρ_{SWIR1} and ρ_{SWIR2} are the reflectance values at the relative Landsat bands.

   Similarly to albedo, using different coefficients, *TCG* and *TCB* were produced.

3) Implementation of *change vector analysis (CVA)* for land cover change detection in the periods of 1999–2009 and 2009–2019 based on the index combinations of NDVI–Albedo and TCG–TCB.

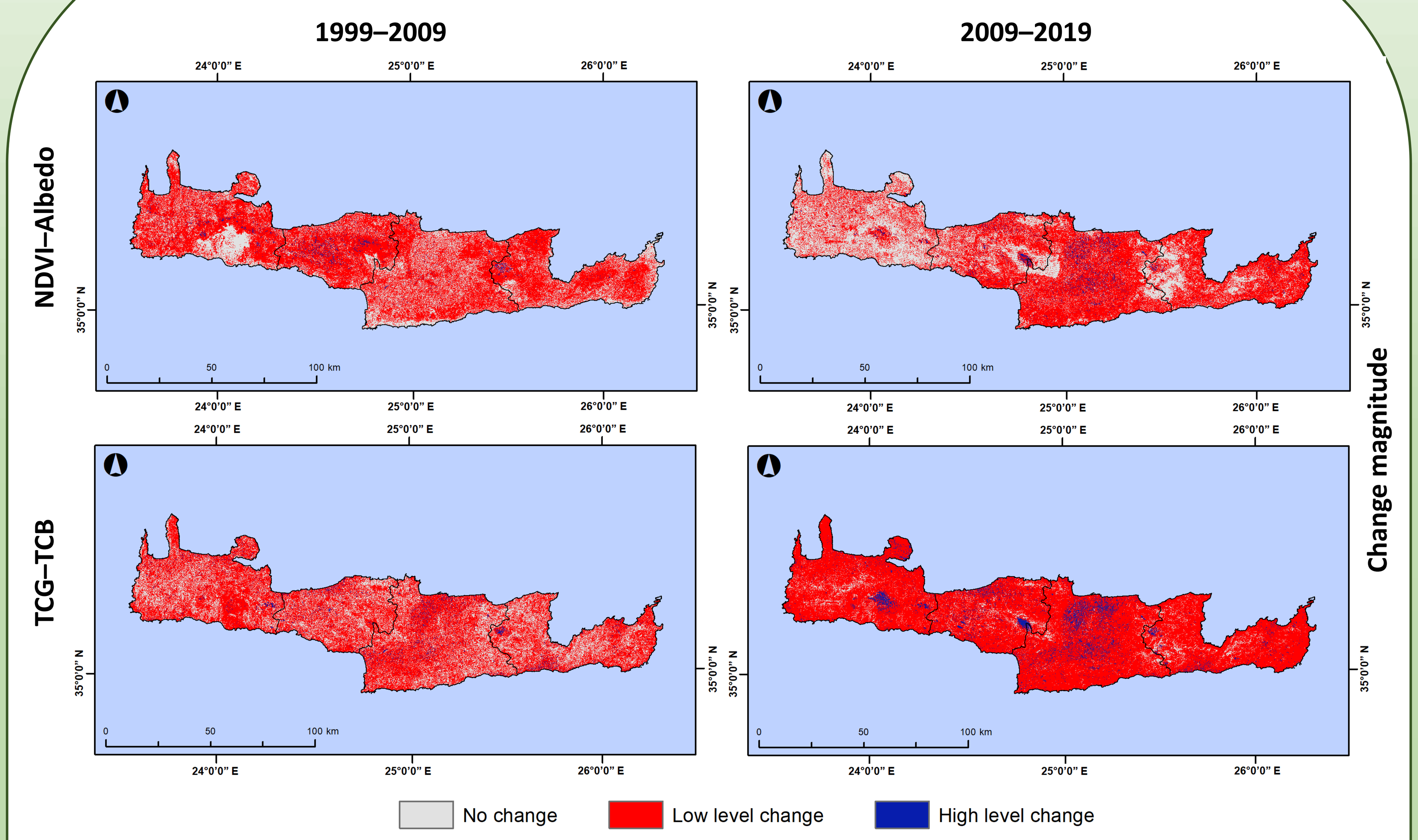
   CVA is a change detection technique presenting the change as a vector in a two-dimensional space. Based on metric difference between two input components, it enables the assessment of the magnitude and direction of changes among two dates.

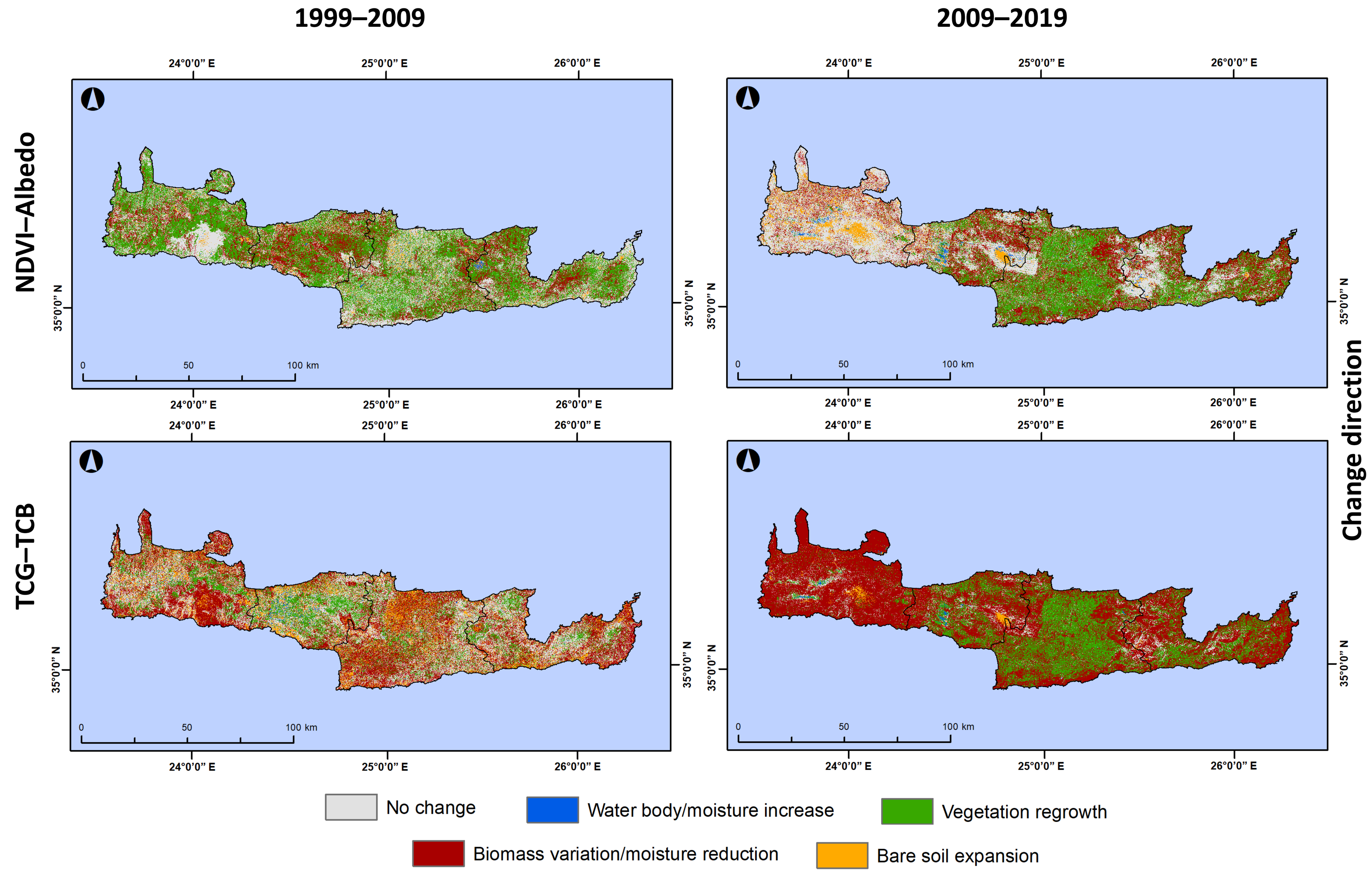


$$\Delta M = \sqrt{(C1_{t2} - C1_{t1})^2 + (C2_{t2} - C2_{t1})^2} \qquad tan\theta = \frac{C1_{t2} - C1_{t1}}{C2_{t2} - C2_{t1}}$$

where $C1_{t1}$, $C1_{t2}$, $C2_{t1}$ and $C2_{t2}$ are the values in components 1 and 2 at dates *t1* and *t2*, and $tan\vartheta$ is the tangent of angle ϑ.

Results





Accuracy assessment: Detailed land cover maps by supervised classification of imagery data as reference data were compared with CVA results by confusion matrices in order to calculate accuracy statistics.

Time period	Index combination	Change/no change (magnitude)		Type of change (direction)	
		Kappa index	Overall accuracy	Kappa index	Overall accuracy
1999–2009	NDVI–albedo	0.672	0.954	0.637	0.887
	TCG–TCB	0.663	0.943	0.590	0.861
2009–2019	NDVI–albedo	0.686	0.960	0.637	0.896
	TCG–TCB	0.641	0.938	0.605	0.880

Conclusions

- The study area was mostly affected by low level changes for both index combinations in both periods.
- Remarkable increase to the extent of high-level changes between the two periods.
- Increase to the extent of unchanged part for NDVI–Albedo, and decrease for TCG–TCB.
- In the period of 1999–2009, vegetation regrowth at the largest part of the study area for NDVI–Albedo, and biomass variations (or moisture reduction) for TCG–TCB.
- In the period of 2009–2019, decrease to the extent of above vegetation regrowth, and increase to the extent of above biomass variations.
- In the period of 2009–2019, the spatial concentration of vegetation regrowth was totally removed from the western to central part of the island.
- More areas of bare soil expansion for TCG–TCB in the period of 1999–2009.
- Large areas of bare soil expansion on massifs for both index combinations in the period of 2009–2019.
- Among the two kinds of results, higher accuracy for the change/no change (magnitude) than the change type (direction).
- Among the two time periods, higher accuracy for the changes occurred in 2009–2019 than those in 1999–2009.
- Among the two index combinations, NDVI–Albedo with more accurate results than TCG–TCB, indicating that NDVI–Albedo constitutes the most appropriate index combination for detecting the land cover changes in the study area.
- Valuable results for planning and implementation of land management strategies in order to diminish the expansion of land degradation risk in agricultural land.

"5DARE" research project

Websites: *https://www.ims.forth.gr/en/project/view?id=193*
https://www.5dare.tuc.gr/en/home/

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