MSc Thesis proposal

“Seagrass mapping and monitoring along the coast of Crete, Greece”

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INTRODUCTION

1.1. Summary

The seagrasses, a unique group of aquatic plants growing submerged in sea water, create unique, complex, extremely diversified and productive ecological systems in the littoral coastal zones between 0-50 meters in shallow waters all over the world (Hogarth, 2007), and serve as a valuable environmental indicators for the marine ecosystems health. The seagrasses contribute significantly to the balance of littoral ecosystems and are referred to as the "constructors" of ecosystems, being a component of marine ecosystems of high importance.

The seagrass *Posidonia oceanica* (*Fig.1*) is a key species to inhabit littoral of the Mediterranean Sea and is widely spread along the coasts of Crete (Dumay, 2002). *P. oceanica* plays an important role in a number of geomorphological and ecological processes such as followings: nutrient recycling through the reducing the degree of water movements and thus providing sediments stability, provision of food for herbivorous fauna as well as helter zones for fish and other marine organisms (Francour *et al*, 1999).

Fig.1. Seagrass Posidonia Oceanica.

The purpose of this MSc thesis to focus on a seagrass mapping (case study of *Posidonia oceanica* meadows) along the Cretan coasts, Greece. The current research aims to apply methods of remote sensing and GIS-based spatial analysis for environmental monitoring of marine ecosystems. The technical implementation is based on *ENVI*, *Erdas Imagine* and *ArcGIS* software using broadband RS data.

1.2. Background and significance

Seagrass play vital roles in the marine ecosystems of the world ocean, being a habitat for numerous marine species, source of primary production and food for fish and turtles, which give them special environmental characteristics and value (Noralez, 2010). Globally, about 58 seagrass species are recognized (*Fig.2*), belonging to two orders (*Hydrocharitales* and *Najadales*), four families (*Hydrocharitaceae*, *Posidoniaceae*, *Cymodoceaceae* and *Zosteraceae*), and 12 genera (*Enhalus*, *Thalassia*, *Halophila*, *Posidonia*, *Syringodium, Halodule, Cymodocea, Amphibolis*, *Thalassodendron*, *Zostera*, *Heterozostera* and *Phyllospandix*) (Kuo & McComb, 1989). Seagrass meadows produce enormous quantities of organic matter (leaves, epiphytes), which constitute the basis of the food web both within and outside the ecosystem (Gobert *et al*, 2006).

Fig. 2. Global seagrasses distribution.
Source: Green & Short 2003

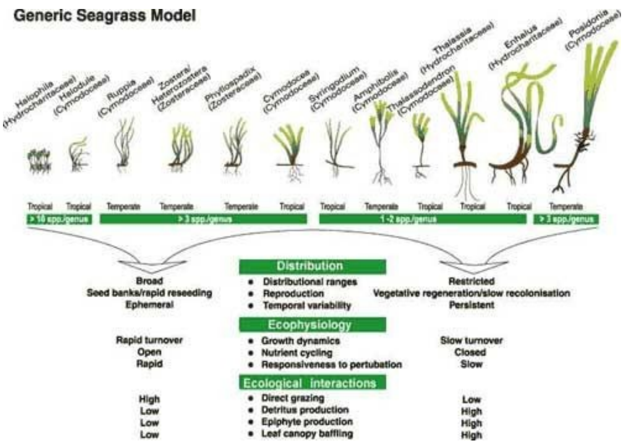


Fig.3. Various morphology in different seagrasses. Source: *http://www.ozcoasts.org.au/indicators/seagrass_species.jsp*

Among the common known species in Greece there are *Posidonia oceanica* (L.) Delile, *Cymodocea nodosa* (Ucria) Ascherson, *Zostera noltii* Hornemann and *Halophila stipulacea* (Amoutzopoulou-Schina, 2005). These species differ in morphological and phenological features (*Fig.3.*) as well as in structure and dynamics. *Cymodocea nodosa* is considered the pioneer species of *Posidonia oceanica* beds, the latter species forming the last stage. When *P. oceanica* beds regress, *C. nodosa* often replaces them (Den Hartog, 1977); as a result, *Posidonia oceanica*, *C. nodosa*, and *Z. noltii* do not form mixed persistent stands (Buia, 1991).

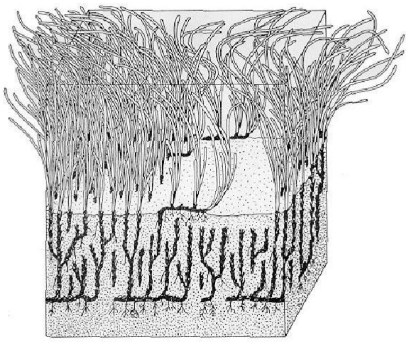


Fig. 4. Scheme of matte structure of P.Oceanica. Source: Pergent, 1990

The endemic Mediterranean seagrass *Posidonia oceanica* is a main species in marine coastal environment of Greece forms the largest, the most widespread, homogeneous and dense meadows between 5 and 40 m depth (Hartog 1970), making a “matte” (*Fig.4*), a monumental construction made by the growth of rhizomes with entangled roots and entrapped sediment (Francour *et al*, 2006). Representing one of the most productive Mediterranean ecosystems, it usually serves as a perfect biological indicator for assessing the quality of waters and environmental health (Boudouresque *et al*, 1989). Some authors (Guidetti, 2008, Montefalcone, 2009) illustrated it with research on status and population dynamics of *P. oceanica* for the evaluation of the meadow health status.

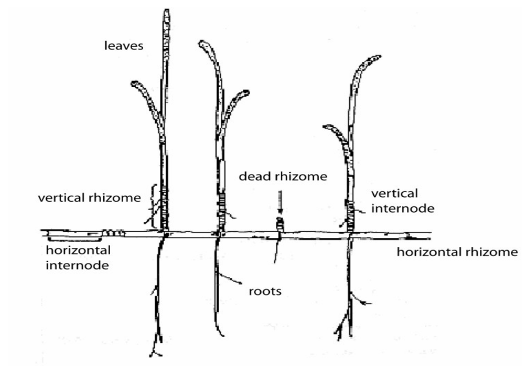


Fig.5. Structure and components of seagrass. Source: Di Carlo, 2004

There are some significant particularities in the phenology of the seagrass. First, the distribution of the seagrasses changes with the water depth: it is noticed (Dural, 2010) that the highest flowering density is usually in the 4-7 m depth. *Posidonia oceanica* flowers appeared in shallow stands in September while and in stands deeper than 15 m in November. This time delay is caused by the different maximum summer temperatures at those depths (Buia, 1991). Then, there are also some particularities in the seagrass phenology at different depths, because the plants in the isolated meadows in the shallower waters had short and falciform leaves, compared to the ones in the deeper and central areas (Dural, 2010). In *P. oceanica* flower abundance is related to the structure of the meadow and the maximum flower density is usually found in the densest stands, while the occurrence of flowering is regulated by environmental factors (Buia, 1991). Finally, there are some modifications in the phenology of the *Posidonia oceanica* during the flowering period which lasts ca 3 months: there is decrease of the number of leaves on the flowering shoots. A modification of the leaf growth also appears in flowering shoots: the oldest leaves are longer and the leaves induced during or after flowering are shorter and narrower than those of non-flowering ones (Gobert *et al*, 2001).

Meadows of *P. oceanica* are subjected to human activities, as they occur in coastal areas, where they can be affected both directly (Meinesz *et al*., 1991) or indirectly through the impact on the quality of waters and sediments (Duarte, 2002). *P. oceanica* is a long-living plant with a slow growth rate. Therefore, anthropogenic modifications of the coastal environment, happening more rapidly than the capacity of the plant to adapt to such changes, reduce its distribution area (Micheli, 2005). Some of the main drivers of seagrass decline are the location of the fish farming near the seagrass meadows. The negative effects of the sedimentation of waste particles in the farm vicinities on *P. oceanica* meadows are diverse and complex and are the main driver of benthic deterioration, accumulation of organic matter and seagrass decline (Holmer *et al,* 2008). The detailed research of the fish farm-induced decline of the seagrass meadows has been reported (Diaz-Almela *et al*) showing the relationships of fish farm organic and nutrient content in the sediments with dynamics of the key seagrass species (*P. oceanica*) in the Mediterranean Sea. In France *P. oceanica* (Linnaeus) Delile is a protected species since 1988 (Francour *et al*, 1999), and its presence is an indicator of a stable healthy environment. Other negative factors affecting growth and status of the seagrasses are environmental contaminants, e.g. thermal, sewage, dredging and chemical pollution as well as maritime works, e.g. trawling and anchoring of boats (Ribed, 2002).

Besides anthropogenic factors, the biochemical processes may strongly affect the status of the seagrass meadows up to complete disappearance, such as increased nutrient availability in the coastal zones, increased sedimentation, eutrophication, invasive macroalgae, rainfall, etc. (Holmer *et al*, 2009). Seagrasses are therefore, vulnerable fragile species, important for the marine coastal ecosystems, especially for the protection of the beach structure. *P.*

oceanica in particularly, is in the alarming state of regression due to the deterioration of the environment in the Mediterranean Sea (Ribed, 2002).

Due to their wide distribution, meadows size, easy collection and abundance as well as sensitivity to modifications of coastal zone, seagrasses in general, and *P. oceanica* in particular, are considered to be suitable indicator and descriptor for the environmental monitoring (Pergent-Martini *et al*, 2005).

Precise, correct and up-to-date information about the seagrass *Posidonia oceanica* distribution over the Cretan coast is necessary for the sustainable conservation of the marine environment and ecosystems in Greece, because identifying and mapping the main benthic bottom types and sea floor coverage is a necessary stage of any environmental coastal zone management (Pergent-Martin *et al*, 2006).

II. RESEARCH PROBLEM

Monitoring and cartography of the marine benthic ecosystems of seagrasses is essential for the evaluating the seagrass current distribution, analysis of its dynamics and changes over time as well as estimations the degree of deterioration of the meadows for the purpose of coastal management.

Seagrass vegetation have been spatially mapped and monitored in many studies using aerial photographs (Kendrick *et al*., 2000; Pasqualini *et al*., 1999), which is the most traditional remote sensing technique, often used as base maps for the seagrass meadows mapping (McKenzie, 2003).

Using space borne satellite imagery for the seagrass mapping is limited to some extent, due to the uncertainties of the spectral signature of the seagrass as well as some technical difficulties: e.g. the refraction of the light through water, sun reflection and angle affecting the quality of the images. However, satellite images are widely used for the seagrass underwater measurements, and they are more accurate, repeatable, versatile and informative comparing to aerial photos (Dekker *et al*, 2005). Satellite high-resolution remote sensing systems enable repeated temporal cover over the large remote areas and provide a cost-effective approach for mapping of such difficult for detection feature as underwater vegetation (Jensen *et al*, 1995) and provide more detailed and particular information on seagrass canopy, e.g. environmental condition of the seagrasses (Fyfe, 2003).

Spectral reflectance characteristics of the *Posidonia oceanica* seagrass enable its discrimination from other seafloor types as well as different vegetation communities. The spectral signatures of different species of tropical seagrasses have been studied (Thorhaug A. *et al*, 2007) at the case study of the Australian coastal ecosystems, and it is proved that they are well distinguishable from each other (*Thalassia testudinum, Halodule wrightii* and *Syringodium filiforme*).

The potential of image processing application of various types of photographs (colour, infrared, and black and white) for the seagrass monitoring has been studied previously (Pasqualini *et al*, 2001, Matarrese *et al*) and the image processing of normal colour aerial photographs has been successfully used in the littoral and marine environment including within seagrass beds (Kelly, 1980; Walker, 1989; Green *et al*, 1996). The using of the IKONOS multispectral imagery for the mapping of *Posidonia oceanica* has been studied by Fornes (Fornes *et al*, 2006). They reported successful application of the methods of the supervised classification towards seagrass mapping resulting in automated classification of the image pixels, so that seafloor is divided into four types: sand, rock, *P. oceanica* and unclassified. Validation of the results has been performed using acoustic survey and shown pretty high (84%) accuracy. Other research (Calvo *et al*, 2003) reports experience of the CZCS images application towards the case study of the *P. oceanica* monitoring along the Italian coast with the best results of the neural-based classification using Isodata method. The authors suggest the critical resolution of the four meters for the extraction of information within the study area, yet for dense *P. oceanica* meadows lower resolution can be suitable as well (Calvo *et al*, 2003).

In case of *Posidonia oceanica* beds aerial and satellite remote sensing methods are particularly well suited to surveying shallow waters (Pasqualini *et al,* 1998) and can both include false-colour infrared images, to distinguish the marine plant formations, and black and-white photographs to follow the temporal evolution of the seagrass beds over several decades (Pasqualini *et al*, 2001).

The current work of the case study of *P. oceanica* seagrass mapping is proposed to be done using raster imagery and remote sensing techniques using different band combination in the images. The research will explore spatial extent and species diversity of the seagrass using satellite high-resolution imagery over the long-term period, to analyse dynamics in environmental changes.

2.1. Research objective

This MSc thesis aims to explore the application of the remote sensing technologies for seagrass mapping and spatial-temporal monitoring using the integration of satellite data and knowledge about the coastal environmental over the northern Greece, to discriminate seagrass at the species level and map the temporal dynamics of their distribution over the last 10 years (2000-2010).

The main research objective is monitoring of seagrass (*Posidonia oceanica*) over time along the northern coast of Crete island in selected locations, using methods of remote sensing techniques and spatial GIS analysis.

2.1.1. General objective

The main objective of this study is to investigate the distribution of seagrass along the coast of Crete over 10-year period, using remote sensing techniques.

1) Mapping the distribution of *Posidonia oceanica*
2) Monitoring the health and absence/presence of *Posidonia oceanica* meadows as well as how remote sensing can help estimate these health indicators

2.1.2. Specific objectives

1. To apply broadband RS data (*Landsat TM* images) for the seagrass monitoring.
2. To use supervised classification for the thematic mapping in the case study of seagrass distribution along Cretan coasts.

2.2. Research questions

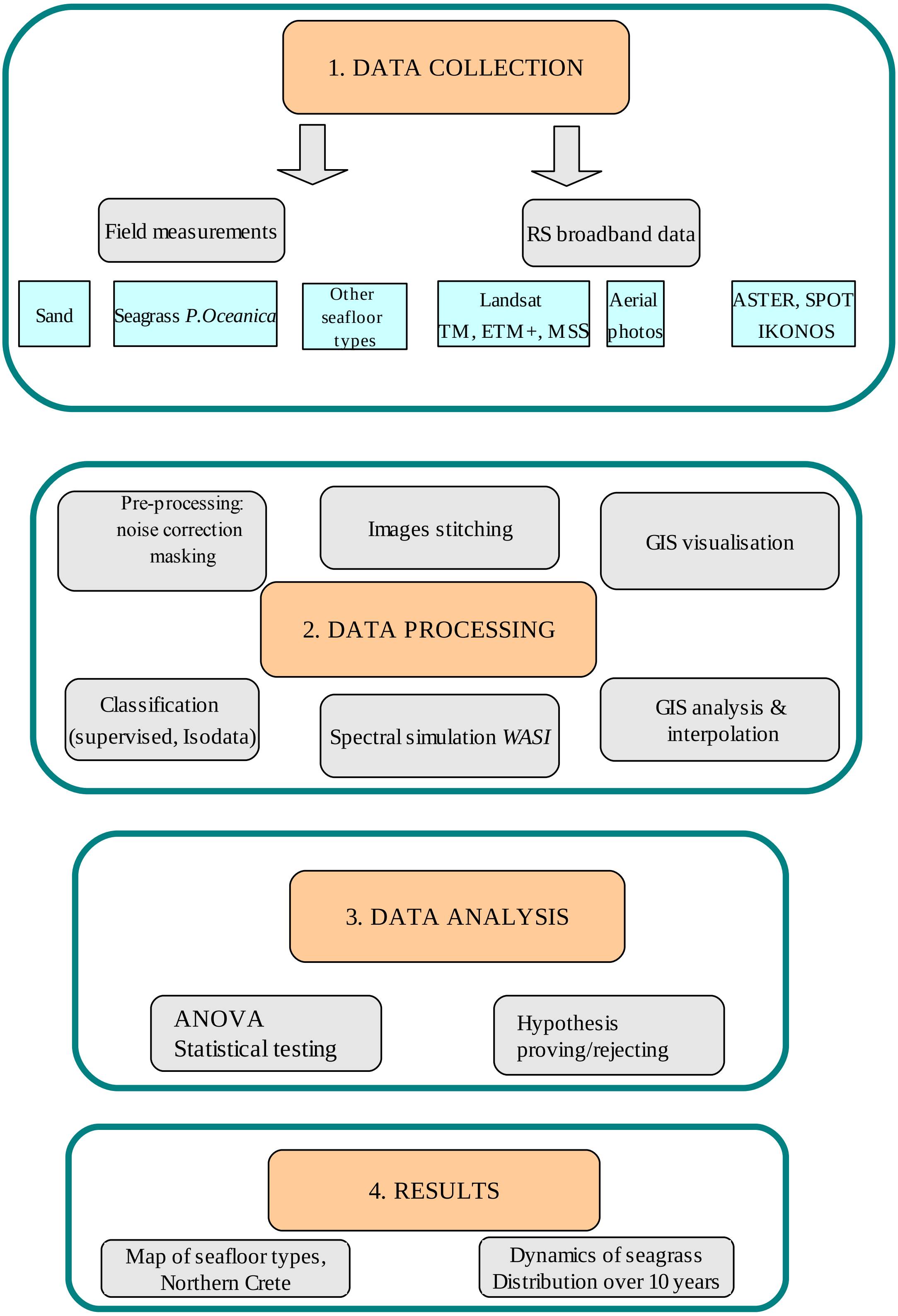
1. At selected sites along the Cretan coast (*Heraklion, Agia Pelagia and Xerokampos*): is *Posidonia oceanica* spectrally distinct from other seafloor cover types based on broadband satellite remote sensing (i.e. aerial photograph, ASTER, LANDSAT, SPOT)? The broadband RS data will be used for discriminating different seafloor cover types and to study reflectance properties of seagrass for detecting areas of its location. Application of the optical radiative transfer model *WASI* is suggested to simulate RS sensors (ASTER, SPOT, MERIS, LANDSAT, etc). The Water Colour Simulator *WASI* is a software tool for analyzing and simulating the most common types of spectra (Gege, 2005), therefore is suitable for our case of seagrass spectral analysis. A statistical analysis using *WASI* will be used to test whether the broadband spectra are spectrally distinct and if *P. Oceanica* remains spectrally distinct with increasing water columns. While studying the heterogeneity of the seafloor we consider aerial photographs, in situ measurements and habitat suitability aspects (Bathymetric, Topology), because cover fractions vary and may prove to be too small compared to the resolution offered by satellite sensors.

2. Monitoring indicators and how remote sensing can be applied for estimation of these health indicators:

- application of RS to estimate the structure of the matte: intermatte channels, dead matte, homogeneity, compactness, and thickness of the matte
- phenology of the seagrass: acquisition date imagery may obscure changes in the health of meadows.
- application of RS for estimation of the “number of leaves per shoot”
- application RS for estimation of the biomass of *Posidonia oceanica*

3. Detection dynamics in changes of the seagrass distribution along Crete during the past 10 years using series of *Landsat* satellite images for 2000-2010 time periods

2.3. Research scheme



2.4. *Hypotheses testing*

I. A statistical testing will be used to compare between the spectral responses of the different seagrass types, whether it is spectrally distinct and at least one pair is statistically different at every spectral band.

Hypothesis Ho: seagrass aquatic vegetation types are not spectrally distinct, which means *Ho:* $\mu_1 = \mu_2 = \mu_3 = \ldots = \mu_n$.

The alternative *Hypothesis Ha* claims the opposite statement: seagrass aquatic vegetation types are spectrally distinct, i.e. *Ho:* $\mu_1 \neq \mu_2 \neq \mu_3 \neq \ldots \neq \mu_n$.

The distribution of the spectral responses at every spectral band is assumed to be normal as well as the equality of the statistical variances.

II. The next research question is to find out whether there are any changes in the spatial distribution of the seagrass within the research area. Therefore, the statements will be the followings: *Hypothesis Ho*: there are no changes between its spatial distributions. *Hypothesis Ha:* the areas has reduced their area, i.e. how has the seagrass distribution changed during the research period of 10 years?

The hypothesis testing is suggested to be carried out using the ANOVA statistical test. The purpose of ANOVA test is to visualize in an effective and quick way the spectral differences between seagrass species and their spatial distribution. The key hypotheses of the research thus will be tested to prove whether the results of the research are meaningful and correct.

2.5. *Research approach*

Seagrasses can be mapped using various approaches, from field measurements to remote sensing, but the most popular method of mapping is based on the last one due to the restrictions of working at depth.

Using remote sensing for the mapping of seagrasses is explained by the fact that remote sensor detects the substratum and vegetation growing on it. Comparing to the analysing of the terrestrial plants, aquatic ones cannot be detected using red edge of the spectrum, as these wavelengths are significantly absorbed by water (Kirk, 1994), as well as by spectral scattering and absorption by phytoplankton.

Some remote methods of marine mapping use active hydroacoustic sonar sensors that send towards a sea-floor a pulse of sound energy and then collect the return echoes for analysis. Yet this method requires specialised equipment and is mostly used in the depth waters, for the bathymetric measurements. Therefore, broadband imagery will be used for the current case study. The imagery will be corrected atmospherically and for water-column-effects. Reflectance spectra of the seagrass canopy at different depths of the water-column will be analysed for the spectral signature. The results of the analysis of imagery series will be compared for the detection of multi-year dynamics in seagrass distribution. Imagery from sensors with high spatial resolution (ca 5 m, such as *ASTER*, *Landsat 7*, *QuickBird*), though not improving significantly the accuracy of large seagrass meadows, comparing to estuarine areas (Malthus, 2003), are better suitable for the objective and scale of detailed mapping of underwater ecosystems, so that these imagery will be used if available. *In situ* measurements of benthic reflectance seagrass will be collected using a field spectrometer during the fieldwork in Crete. For the validation of the classification results and to determine presence or absence of seagrass near the coast, the underwater photographs of the seafloor will be taken during the fieldwork.

The images processing will include usual steps of the remote sensing techniques, i.e. calibration, masking from land and cloud, atmospheric correction, sea surface glint and depth effects correction (Matarrese *et al*). At the classification phase the dataset training for the supervised classification methods is included, as well as its control and trial of different classification approaches (Unsupervised, K-means or ISODATA; Supervised, Maximum Likelihood). At the final stage, there is overall accuracy assessment of the results using ground truth data.

III. MATERIALS AND METHODS

The research is suggested to be technically based on *ENVI* and/or *Erdas Imagine* software for the processing and analysing hyperspectral images (*SPOT*) and *Landsat TM*. Additionally, *ArcGIS9.3* software will be used as a general tool for the spatial analysis and cartographic presentation and *GIS*-based spatial analysis, to detect zones for depicturing seagrass areas (general mapping); afterwards raster processing techniques will be applied for the detection of seagrass zones (using *ENVI* and/or *Erdas Imagine*).

The research data will include scenes from *Landsat TM* and *ETM+* covering research period of 10 years in the same year time, taken from *USGS GloVis*, http://glovis.usgs.gov/, *NOAA* and other available open geospatial resources. Examination of the satellite imagery provides with vital information of coastal areas of the most recent changes in mangrove forests, as well as mangrove areas in poor conditions or partially damaged. The available images processed are suggested to form a mosaic-like covering of the whole of the research area in order to cover the northern part of the Cretan coast. The *Landsat* data is considered (Mattarrese *et al*) to be more appropriate than those from *ASTER*, as the properly placed spectral bands of *Landsat* sensor enable to produce more accurate maps with correct results. Therefore, the main set of images is *Landsat*. Field data acquired on the ground are necessary addition to any cartographical work involving aerial and satellite photographs, to solve specific problems of interpretation (Pasqualini *et al*, 1998). Therefore, this work includes sampling *in-situ* measurements of the seagrass. The sampling stations are suggested to be in three separate locations on the northern part of Crete, because the northern coast is much more suitable for the seagrass due to the annual mean water temperatures and geological factors, i.e. seafloor conditions and sediments. The field campaign will be carried out during the September-October period 2010. Seagrass different species, their locations and characteristics will be recorded and added to the GIS project using their coordinates. Besides, the relationships between the seagrass species distribution and the geological-environmental conditions of the selected areas will be studied.

3.1. *Study area*

General area: Island of Crete, Greece (Fig.6).

Seagrass sampling will be performed at three stations at a depth of 6-7 meters, which include the following selected areas:

1. *Heraklion, 35°20'N 25°8'E*
2. *Agia Pelagia, 36°20'N 22°59'E*
3. *Xerokampos, 35°12'N 26°18'E*

Fig.6.Study area: locations of measurements. Source: Google Earth.

3.2. *Data available and Data to collect*

The research is based on the available satellite data from the open sources and fieldwork *in-situ* measurements of seagrass distribution on the Crete Island. The available imagery is listed below (see Table 1) and will be added new ones in the course of the research. The spatial resolution of *Landsat ETM+* image is 30 m in the visible and near infrared bands (bands 1-5 and 7); the spatial resolution of *ASTER* 15 m for the visible and near-infrared bands. *IKONOS* acquires data in 3 visible channels and NIR, with spatial resolution of 1-4 meters. *ASTER* and *IKONOS* images are suggested to be included as soon as available, in addition to the *Landsat*.

Table 1. Available data covering the research of interest.

№	*Image source*	*Data*	*Name*
1	Landsat ETM+	2005/May/04	WRS2p181r035L71181035_035_20050504_ETM-GLS2005
2	Landsat TM	2006/Nov/07	WRS2p181r036L5181036_036_20061107_TM-GLS2005
3	Landsat ETM+	2005/Apr/25	WRS2p182r035L71182035_035_20050425_ETM-GLS2005
4	Landsat	2000/Jul/09	WRS2p181r036_7dx_20000709_ETM-GLS2000

№	*Image source*	*Data*	*Name*
	ETM+		
5	Landsat TM	1987/Jun/10	LandsatWRS2p183r035p183r035_5dx_19870610_TM-GLS1990
6	Landsat ETM+/ Earth Sat	1999/Aug/08	071-261Mosaic_LandsatN-35N-35-35ETM-EarthSat-MrSID_19990808-20020624
7	Landsat ETM+/ Earth Sat	1999/Aug/08	071-260Mosaic_LandsatN-35N-35-30ETM-EarthSat-MrSID_19990808-20020617
8	Landsat ETM+	2000/Jun/30	WRS2p182r036_7x_20000630_ETM-EarthSat
9	Landsat MSS / Earth Sat	1975/Jul/26	LandsatWRS1p196r35_2m_19750726_MSS-EarthSat
10	Landsat TM / Earth Sat	1987/Jun/10	012-807LandsatWRS2p183r35_5t_19870610_TM-EarthSat
11	Landsat ETM+	2000/Jun/30	LandsatWRS2p182r036_7dx_20000630_ETM-GLS2000
12	Landsat ETM+	2005/Apr/09	LandsatWRS2p182r036L71182036_036_20050409_ETM-GLS2005
13	*In-situ* measurements	2010/Sep-Oct	Underwater still imagery and video footage

The research includes fieldwork for the *in-situ* measurements of the seagrass along the northern coast in chosen locations.

3.3. *Data analysis and modelling*

The spatial data analysis is based on the classification and investigation of the distribution of the seagrass, *Posidonia oceanica* within the research area in selected locations along the coasts of Crete. The *in-situ* measurements are based on the underwater still imagery and video footage, which enable detailed measurements and provides ground truth data. The general locations of the sampling sites and routes will be selected on the basis of existing knowledge of seagrass locations of the Greek colleagues and available data or maps covering the research area. Besides results of the fieldwork measurement and satellite imagery we will widely use aerial photographs from *Google Earth* as open source and reliable data, which enable to visualise area of interest in a most detailed and up-to-date way. The other advantages of the *Google Earth* application is high resolution (15 meters in land areas but lower in the oceans).

Benthic video footage will be collected using an underwater digital video camera *Olympus ST 8000* camera, to detect each type of habitat area for classification, e.g. “sand”, “rock”, “*P. oceanica*”, other seagrass species, etc.

3.3.1. *Sampling design*

The sampling design aims to well represent the absence or presence of seagrasses within the study area. To ensure even yet random selection of sampling sites and to prevent subjectivity in research, we will use transect sampling method, which means that the photographs will be taken along the research path. Transect method is nowadays a predominant sampling technique in the case studies of seagrass monitoring (Shortis *et al*, 2007) enabling the occurrences of the seagrass to be recorded and counted in a systematic way, and the distribution of seagrasses to be properly identified, without location bias.

The photos will be captured using an underwater camera *Olympus ST 8000* (Fig.7) at five minutes interval along the path. GPS attached will allow to make georeferencing and timing of the images; camera will be kept horizontally by a leveller. Data will be taken in proper weather conditions: sunny, serene and cloud-free days with glassy sea state. The locations of the route will be randomly selected to ensure most dense coverage of the research area.

Fig.7. Olympus camera ST 8000

The necessary materials and equipment will include the following items:

- Boat
- GPS
- Three underwater camera, Olympus ST 8000, suitable for photographing up to up to 33 foot depths and high-resolution 12.0-Mpixel image sensor (Fig.7)
- Measurements quadrate frame for measurements of the density of seagrass, 40*40 cm, Fig 8.
- diving equipment if necessary

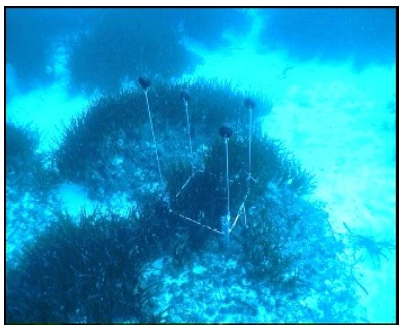


Fig.8. Measurement frame

3.3.2. *Methodology*

As the current research is located in shallow waters 7-8 meter, underwater mapping of seagrass leaf coverage will be carried out directly by taking photos of squares of ca 1 m^2 each. Data collected during the fieldwork, i.e. seagrass distribution, density and measurements of health indicators, will be added into a GIS dataset for further assessment and statistical analysis. The images will be stitched into a mosaic single one, covering each research paths.

One of the ruling factors for the seagrass locations is bathymetry and depth, and the research sampling would be incomplete without bathymetric data measurements. To receive three-dimensional data we will use 3 cameras which enables us to read info about the depths, using photogrammetric principles.

Among the most important environmental characteristics of the seagrass ecosystems we consider 3 following ones: i) health of meadows, ii) seafloor types where species of *P.oceanica* preferably grows, and iii) aspects of suitability, i.e. bathymetry. We propose the following methodology for the estimation of these features, which is mainly based on the already existing methods of seagrass measurements and monitoring, proposed by other authors, applying them to the case study of Cretan littoral environment.

i). *Ground observations for seafloor cover types*

Fieldwork measurements of the seafloor cover types will be made using available underwater video camera's *Olympus ST 8010,* which will be mounted under the boat to capture video footage/still imagery. The records made using these cameras will be made along each path. The data received will contain information on seagrass presence or abundance within the study area, different species and the nature of the sea floor bottom (rocks, sandy, etc.). Seafloor types will be classified using received seafloor imagery, based on colour, texture and pattern.

ii). *Ground observations for health of meadows*

Health of meadows can be well estimated on the basis of the following parameters, most characteristic for the state of the seagrass meadows:

- ✔ shoot size: length, width, rhizome and root diameter

- ✔ biomass, nutrient content
- ✔ density of the meadows

These measurements can be made directly using measurements quadrate frame and taking samples of seagrass for laboratory analysis (i.e. nutrient content or biomass). The sampling area is divided in equal-sized spots and the samples of seagrass are taken from each of them. The *P.oceanica* density in the areas covered by seagrass will be estimated using measurement frame in spots of ca 1*1 m along the path route, which will enable assessment of *P. oceanica* percentage cover over different locations at various depths (3-5-7 m).

iii). Ground observations for habitat suitability aspects (bathymetry)

Georeferenced imagery will be achieved by using three cameras which enable acquiring of stereo imagery: the horizontal 60~65% overlapping distance of the images, a stereo base, allows to have a 3-D stereo-model of terrain elevation. Therefore, three cameras will be aligned and set apart at a necessary distance in order to create suitable, corresponding to the seafloor depth.

In the RS part of the research the supervised classification will be applied to satellite *Landsat* images received previously from the open sources. The seagrass areas will be detected using different bands combinations, masked and studied for the estimation of the changes in the areas. The raster-based mapping includes supervised classification with training sites of seagrasses (10-15 set areas) in different bands for each photograph by classification a series of polygons characteristic of each of the sea floor bottom types: sandy surface, seagrass bed for each species including *P.oceanica* (meadows), patchy seagrass bed and algae on rock, rocks, muddy surface, etc. On the basis of the image processing and classification, applied to the period 2000-2010, the marine bottom types between 10 m depth will be mapped, including the location of the limit of the seagrass meadows provided on the basis of the available bibliographical and field data.

The main research tasks will be completed using *WASI*, *ENVI* and *Erdas Imagine* software, while general mapping and managing the *GIS*-project will be supported in *ArcGIS* architecture through the data exporting and conversion.

The overall accuracy will be calculated using the ground truth data as test areas.

IV. EXPECTED RESULTS

The research work is expected to result in series of raster thematic maps showing seagrass spatial distribution over the period of 10 years. The map of the seagrass locations within the research area is planned to illustrate the variation of seagrass adaptation towards different environmental and hydrological conditions along the Cretan coastline. The suggested methodology of the analysis of seagrass adaptation towards different hydrological conditions of coastal zones can be applied to other marine areas with growing seagrass.

Keywords:

Seagrass, *Posidonia oceanica,* remote sensing, monitoring, *Landsat TM*, Crete

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APPENDIXES

Previews of satellite images available for the research area

Fig.1. ***224-965LandsatWRS2p181r035L71181035_035_20050504_ETM-GLS2005***

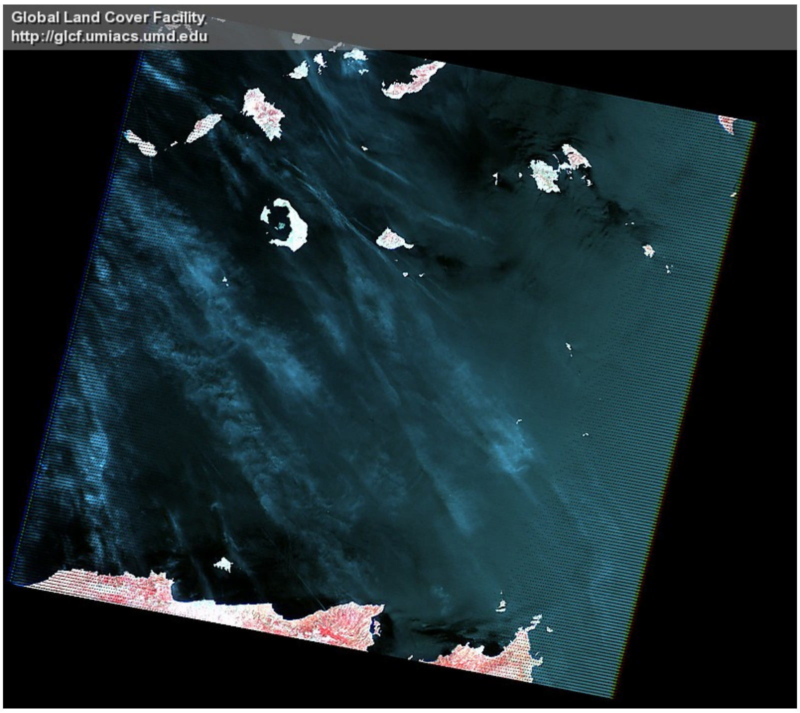

Fig.2. ***224-758LandsatWRS2p181r036L5181036_036_20061107_TM-GLS2005***

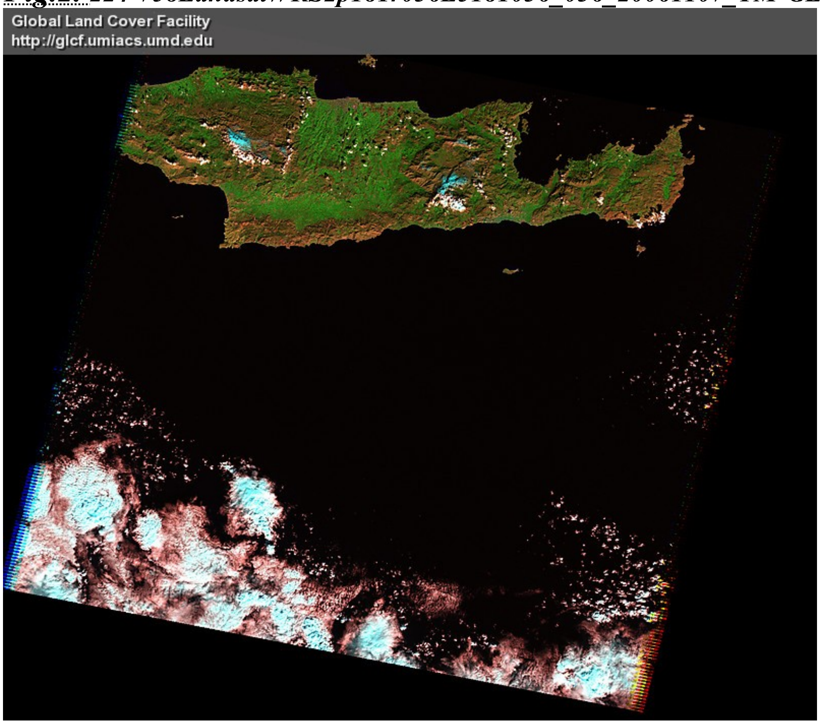

Fig.3. ***220-219LandsatWRS2p182r035L71182035_035_20050425_ETM-GLS2005***

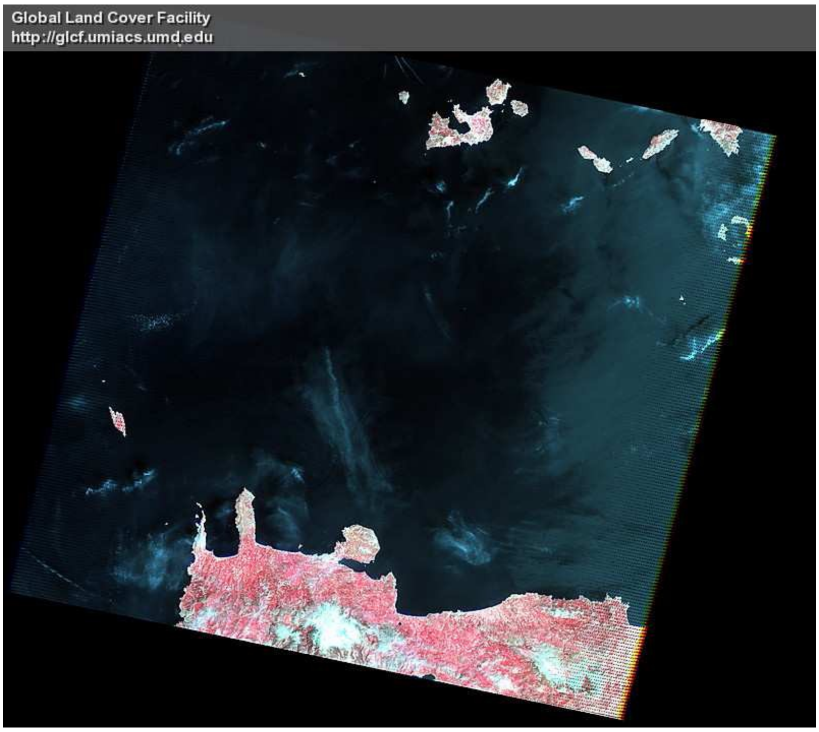

Fig.4. ***213-654LandsatWRS2p181r036_7dx_20000709_ETM-GLS2000***

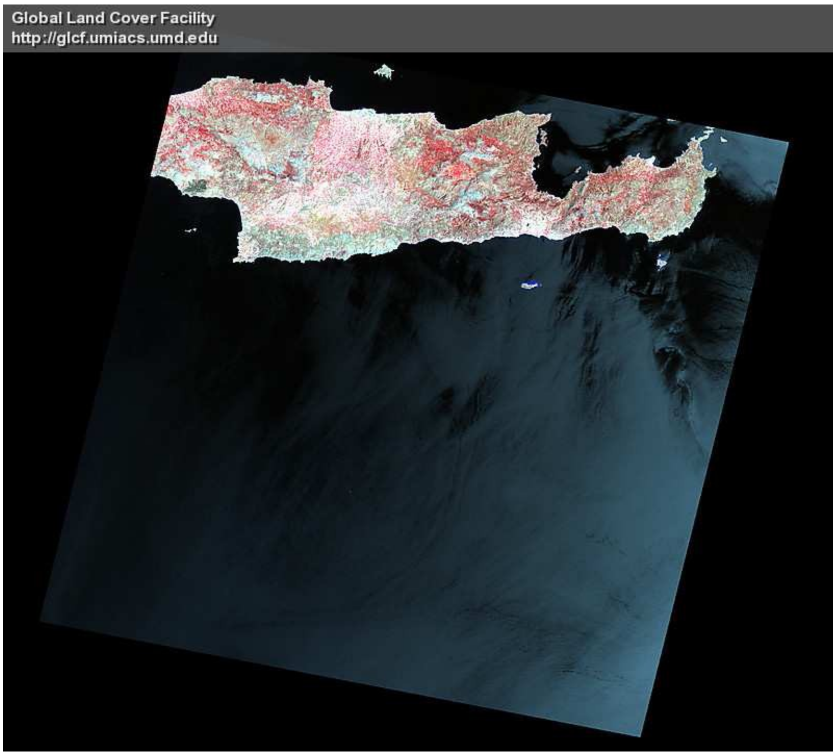

Fig.5. ***205-039LandsatWRS2p183r035p183r035_5dx_19870610_TM-GLS1990***

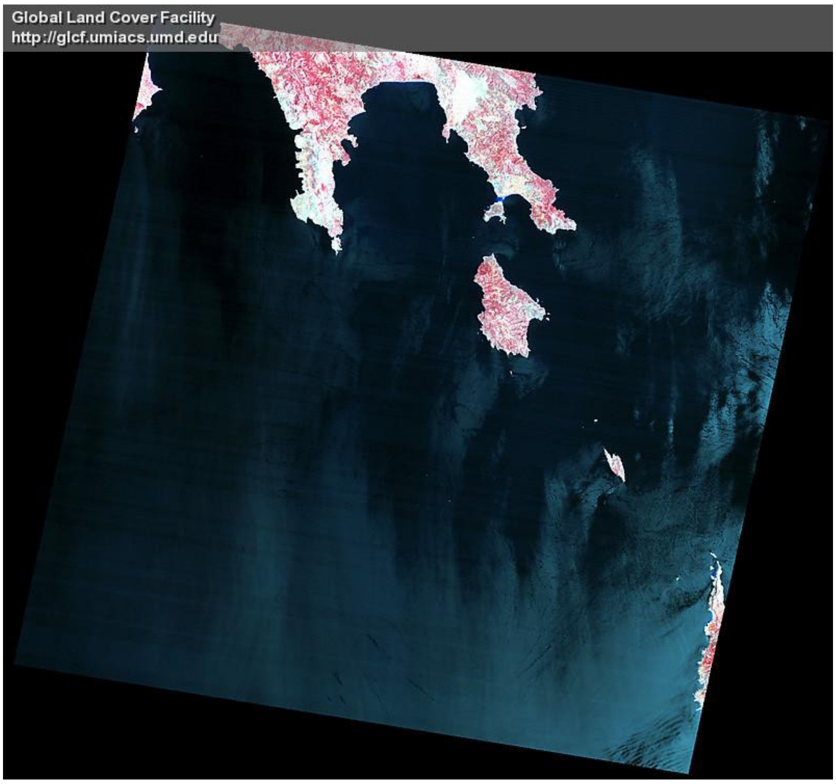

Fig.6. *071-261Mosaic_LandsatN-35N-35-35ETM-EarthSat-MrSID_19990808-20020624*

Fig.7. *071-260Mosaic_LandsatN-35N-35-30ETM-EarthSat-MrSID_19990808-20020617*

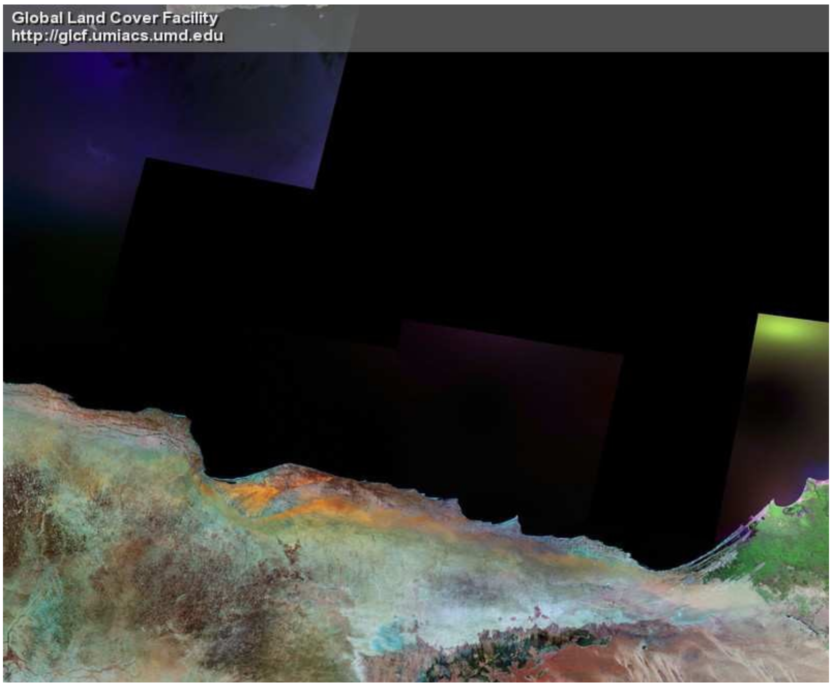

Fig.8. *036-913LandsatWRS2p182r036_7x_20000630_ETM-EarthSat-Orthorectified*

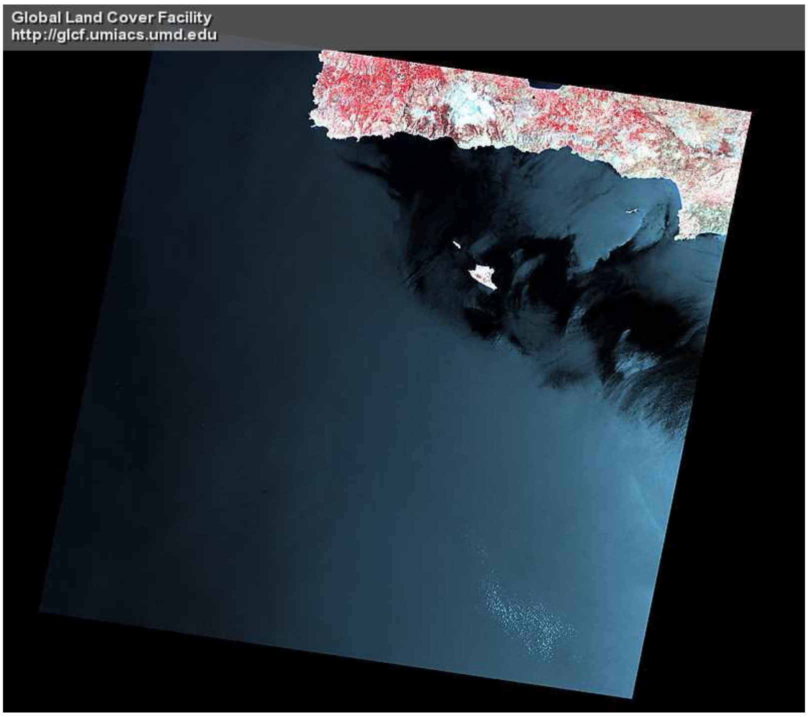

Fig.9. *031-223LandsatWRS1p196r35_2m_19750726_MSS-EarthSat-Orthorectified*

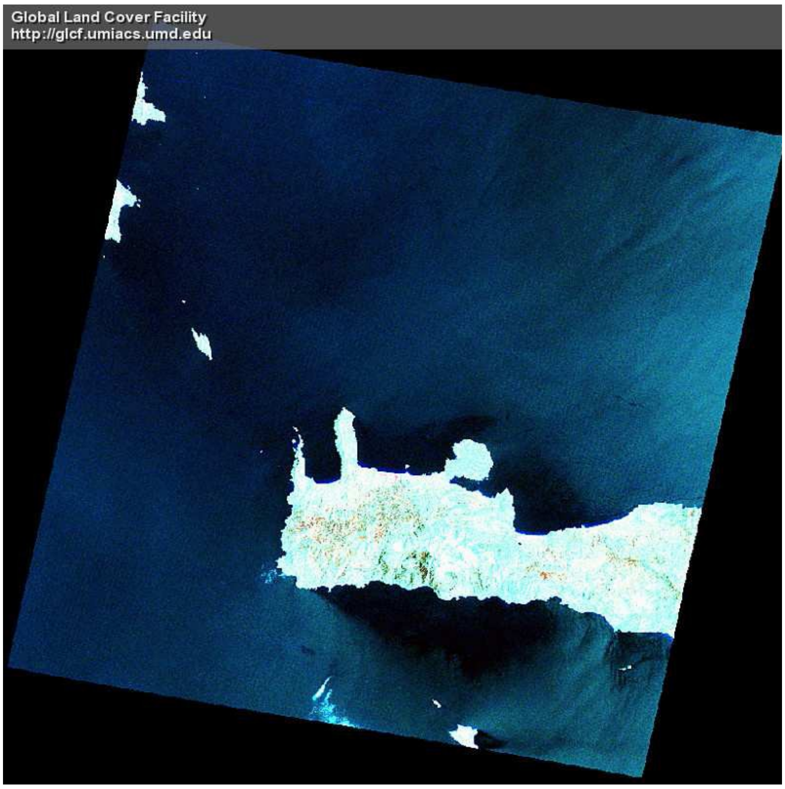

Fig. 10. *012-807LandsatWRS2p183r35_5t_19870610_TM-EarthSat-Orthorectified*

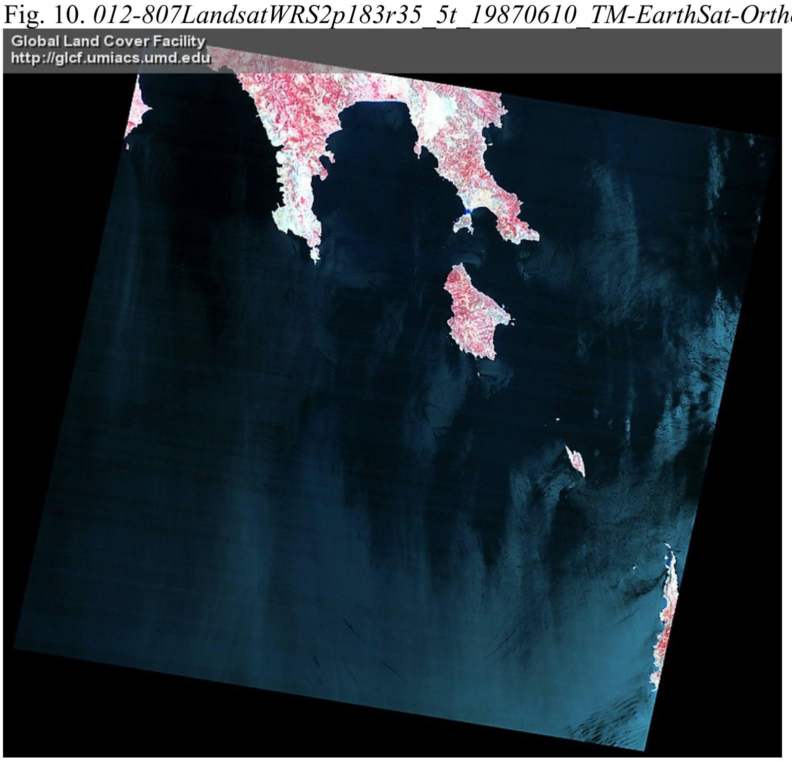

Fig.11. *213-716LandsatWRS2p182r036_7dx_20000630_ETM-GLS2000*

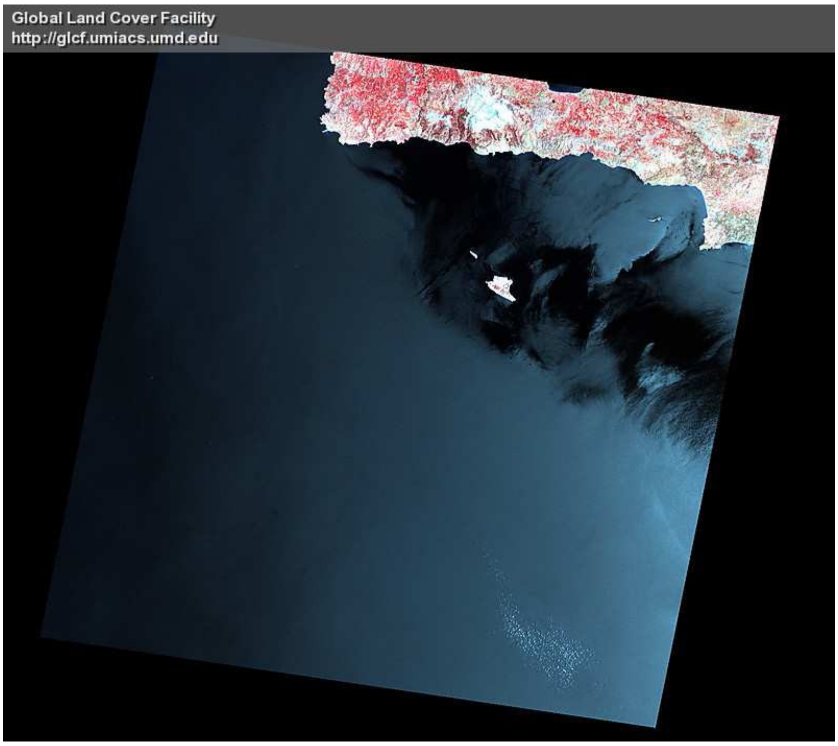

Fig.12. *220-220LandsatWRS2p182r036L71182036_036_20050409_ETM-GLS2005*