ACTIONS FOR THE CONSERVATION OF COASTAL DUNES WITH *JUNIPERUS* spp. IN CRETE AND THE SOUTH AEGEAN (GREECE)

LIFE07NAT/GR/000296

Action A.4
Deliverable A.4.1

MAPPING HISTORICAL LAND COVER CHANGES OF HABITAT 2250* IN CRETE

Prepared by MAICh:

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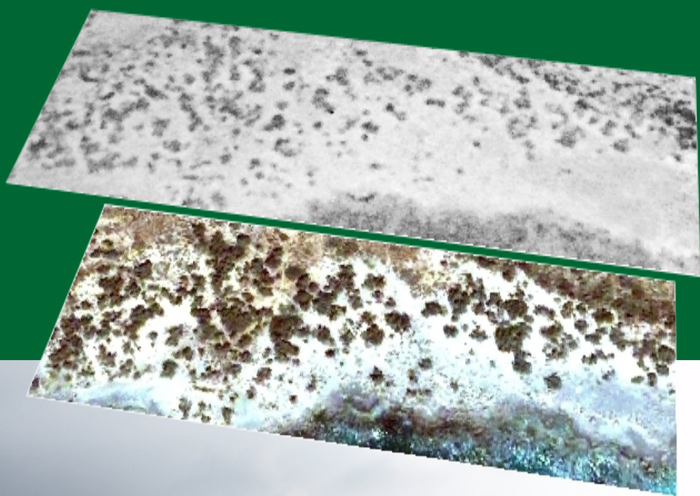

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"Actions for the conservation of coastal dunes with *Juniperus* spp. in Crete and the South Aegean (Greece)"

- JUNICOAST -

Action A.4: Habitat mapping

Deliverable A.4.1: Mapping historical land cover changes of habitat 2250* in Crete

Responsible beneficiary: Mediterranean Agronomic Institute of Chania (MAICh)

Prepared by: Panagiotis Nyktas

Chania August 2013

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1. Περίληψη

Σκοπός της παρούσας μελέτης είναι η διερεύνηση των ιστορικών αλλαγών στην κάλυψη της γης από βλάστηση στις περιοχές του οικότοπου προτεραιότητας των παράκτιων αμοθινών με είδη αρκεύθων (*2250). Η εκτίμηση των αλλαγών αυτών στο χρόνο με χρήση γεωχωρικών δεδομένων προσφέρει πολύτιμες πληροφορίες για την αξιολόγηση της κατάστασης των έξι περιοχών υπό μελέτη (τέσσερις περιοχές του δικτύου Φύση 2000). Επιπλέον, η μελέτη αυτή καταδεικνύει και καταγράφει πιθανές ανθρωπογενείς πιέσεις ή φυσικές διεργασίες όπως η φυσική διαδοχή και εξέλιξη των οικοσυστημάτων. Πέρα από την οικολογική του σημασία, η ύπαρξη πυκνής βλάστησης στου παράκτιους οικοτόπους αποτελεί πολύ σημαντικό παράγοντα προστασίας και ανθεκτικότητας των παράκτιων αμμοθινών από τη διάβρωση και την υποβάθμιση τους. Τα αποτέλεσμα της παρούσας μελέτης συνεισφέρουν στην σύνταξη των προδιαγραφών για την αποκατάσταση του οικοτόπου (Δράση A.8) και την εφαρμογή των προτεινόμενων δράσεων διατήρησης όπως την ενδυνάμωση του πληθυσμού και την αποκατάσταση της χλωριδικής σύνθεσης του οικοτόπου (Δράσεις C.3 και C.4).

Στο πλαίσιο αυτό αναπτύχθηκε μια μεθοδολογία για την εκτίμηση των αλλαγών στην κάλυψη της βλάστησης στις περιοχές μελέτης του προγράμματος Junicoast. Τα στάδια της χαρτογραφικής μελέτης υπήρξαν πανομοιότυπα για όλες τις περιοχές και ήταν τα εξής: (α) συλλογή και εκτίμηση των δεδομένων που ήταν διαθέσιμα, (β) επεξεργασία και μετατροπές της μορφής των δεδομένων, (γ) ανάλυση των εικόνων, ταξινόμηση της κάλυψης γης και των αλλαγών και (δ) εκτίμηση των αλλαγών και παρουσίαση των αποτελεσμάτων σε χάρτες. Ως δεδομένα χρησιμοποιήθηκαν αεροφωτογραφίες των ετών 1945 και 1965 και δορυφορικές εικόνες υψηλής ευκρίνειας του έτους 2007. Η ανάλυση και παρουσίαση των αποτελεσμάτων σε χάρτες έγινε με τη χρήση πλατφόρμας αντικειμενοστραφούς ανάλυσης εικόνων (Object Based Image Analysis) και Συστημάτων Γεωγραφικών Πληροφοριών (GIS).

Τα αποτελέσματα της σύγκρισης της κάλυψης γης στις έξι περιοχές μελέτης δείχνουν ότι το 80% του συνόλου της έκτασης τους δεν έχει αλλάξει. Η έκταση που καλύπτεται από βλάστηση παρουσιάζει αύξηση από 957 (42%) σε 1177 (52%)

στρέμματα. Όλες οι περιοχές που μελετήθηκαν παρουσιάζουν έστω και οριακή αύξηση της βλάστησης. Η αύξηση αυτή συνίσταται στην αύξηση της κόμης των δέντρων και των θάμνων ενώ από τους χάρτες που παράχθηκαν, πλην μιας εξαίρεσης, δεν φαίνεται να έχουν καταστραφεί συστάδες δέντρων ή θάμνων. Οι σημαντικότερες αλλαγές παρουσιάζονται στην περιοχή του Λαβρακά της Γαύδου. Ο Λαβρακάς παρουσιάζει την πιο πυκνή βλάστηση (65%) το 2007 και έχει την μεγαλύτερη αύξηση από το 1945. Η αύξηση αυτή εκτιμάται στα 150 στρέμματα (~15%) η οποία αποτελεί τα 2/3 της αύξησης που μετρήθηκε για το σύνολο των περιοχών μελέτης (220 στρέμματα). Η αύξηση αυτή παρατηρείται στο εσωτερικό τμήμα του οικοτόπου στις περιοχές που παλαιότερα καλλιεργούνταν. Αν και ο Λαβρακάς παρουσιάζει τυπική φυσική αναγέννηση της βλάστηση λόγω εγκατάλειψης των καλλιεργειών, παρατηρήσεις στο πεδίο έδειξαν ότι η αύξηση αυτή αφορά κυρίως την αύξηση των πεύκων και λιγότερο των αρκεύθων (κέδρων).

2. Introduction

Vegetation plays a major role in coastal dune formation and development (Carter, 1995). Coastal sand dunes are typically formed through the trapping of sand by dune vegetation. The type of vegetation that grows on coastal dunes has special adaptation characteristics that allow the vegetation to establish, grow and trap sand in the harsh conditions of coastal areas. The coastal environment is typically harsh for plant growth; for plants to be successfully established, they must have special adaptation characteristics that allow them to survive such a harsh environment.

Interaction between wind and vegetation is a key process for dune development (Ranwell, 1972) and differences in plant cover induce different morphological patterns in coastal dunes (Short and Hesp, 1982). Coastal dunes have been extensively altered over time by human processes, causing extensive ecological and geomorphological changes. Traditional dune-based activities include agriculture, afforestation, grazing of sheep and goats, sand extraction and recreation. At the present time, other factors have caused even more severe impacts on coastal dunes such as the development of touristic resorts, urbanisation, the spread of industrial zones and urban areas, sea ports and marinas (Mayer, 1995).

Assessment of temporal changes of vegetation cover in a spatial explicit manner offers crucial information for the assessment of the state of the seven Cretan study areas (four Natura 2000 network sites). Furthermore, it gives a good indication of anthropogenic pressures and/or natural processes such as natural succession and advancement taking place in habitat 2250*. In addition to its ecological importance, dense vegetation cover in coastal habitats is the most important indicator of resilience and protection of sand dunes from erosion and land degradation. Moreover, in the course of the project, it has been suggested by the scientific committee[1] that knowledge of the changes in the vegetation cover over the past decades is a very important element for habitat conservation and management and that land cover changes of the habitat over time should be determined when setting restoration and management priorities. Therefore, it was suggested that an

[1] 1st and 2nd scientific committee meetings held in Chania on 26-27/2/09 and 21/10/10.

investigation of the historical land cover changes should be included within action A4 "habitat mapping" as a preparatory action. Additionally, during personal contacts with local people, it was often mentioned that some decades ago, study sites in Crete "used to be closed forest".

The aim of this study was to investigate the historical changes in the vegetation cover of the Cretan sites of coastal dunes with *Juniperus* spp. (2250*) priority habitat. The study was a part of the Junicoast project commissioned by the EC under the LIFE+ programme.

3. Materials and methods

For the purpose of the present study, a methodology was developed to assess vegetation cover changes in all Junicoast Cretan study sites. The work carried out is identical for all sites and consists of (a) data review and assessment, (b) image pre-processing, (c) image analysis and vegetation cover change detection, (d) assessment of changes and presentation of results in maps. The work-flow diagram is presented in Figure 1.

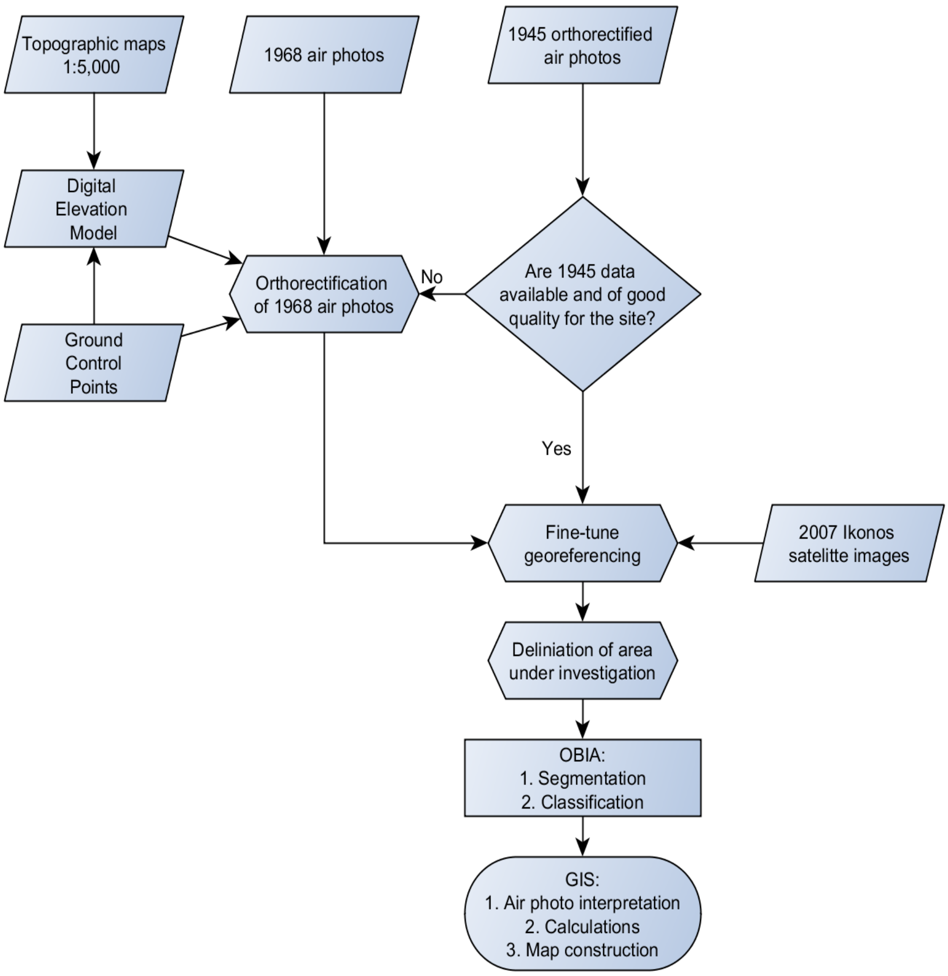


Figure 1. Work flow diagram used for mapping vegetation cover changes in each study site (OBIA: Object-Based Image Analysis, GIS: Geographic Information System)

3.1 Data acquisition and pre-processing

Due to the nature of the study, the first step that would also determine its feasibility was the review of available data. Since historical maps of such kind do not exist, the only potentially valuable data were air photographs. The Hellenic Military Geographic Service (HMGS) provides sets of orthorectified air photos dated back as early as 1945 at a scale of approximately 1:45,000. Larger scale air photographs were also acquired and are available from the campaign of years 1967-8 (1:15,000).

Although the oldest possible dataset is desirable, its quality is not good for some of the areas under study. Coastal sand dunes have higher reflectance than other terrestrial surfaces due to the bright sandy substrate, leading to overexposure of the camera's film on bright day acquisitions. Another difference between the datasets is that the 1967-8 air photographs are not orthorectified i.e not geometrically corrected to account for the effects of the camera, flight and topography. Consequently, as seen in the upper part of the work flow diagram of Figure 1, the quality of 1945 dataset was firstly evaluated and when found not to be suitable; the later air photographs were used.

The software that was used for orthorectification was Leica Photogrammetry Suite (LPS) embedded in ERDAS Imagine 11. Pre-processing of 1967-8 dataset required some information about the camera (focal length) and a Digital Elevation Model of the earth's surface. Flight information during acquisition (e.g. flight height and coordinates) is another input, but in this case, all these information had been removed from the air photo prints after acquisition by the HMGS for national security reasons.

Several Ground Control Points (GCPs) were collected on the ground using Differential Global Navigation Satellite System (GNSS) receivers providing sub-centimetre accuracy. When possible, additional GCPs were identified from topographic maps and contemporary satellite images. The digital Elevation Model used was created by on-screen digitising of all 4m and in some areas 2m contour lines, from scanned topographic maps of scale 1:5,000 purchased by the HMGS. Interpolation of contour lines was performed using the Topo to Raster tool that is embedded in ArcGIS 10 platform. The Topo to Raster and Topo to Raster by File tools use an interpolation technique specifically designed to create a surface that more closely represents a natural drainage surface and better preserve both ridgelines and stream networks from input contour data. The algorithm used is based on that of ANUDEM, developed by Hutchinson *et al.* (1988, 1989, 1996, 2000, 2011) at the Australian National University.

The contemporary vegetation cover was mapped using IKONOS satellite images from the year 2007. Images consisted of 4 multispectral bands, three in the optical spectral region and one Near Infra Red (NIR) band. All four bands were pan-sharpened to 1m resolution using the 1m panchromatic band. Ikonos images were also used as a base for a more accurate georeferencing of the orthorectified air photographs, using features that have not changed over decades (e.g. boulders). In this way, changes in tree stands or shrubs were not misidentified due to small displacements between images. All IKONOS images acquired were of good quality with the exception of the north-east part of Gavdos Island that was shadowed by clouds at the time of image acquisition. As a consequence the vegetation cover of Sarakiniko could not be mapped with acceptable accuracy and was omitted from analysis.

A final preparatory step before image analysis was to re-assess and refine the borders of the study areas. Although the extent of the habitat in each of the sites had been delineated earlier in action A4 of the Junicoast project, the present study took into account the possibility that the habitat might have had a different (larger) extent in historical times.

3.2 Geographic Information and Object-Based Image Analysis

Object-Based Image Analysis (OBIA) is a sub-discipline of Geographic Information Science that has gained popularity over the last decade. It is devoted to partitioning remote sensing (RS) imagery or other Geographic Information (GI) into meaningful image-objects, and assessing their characteristics through spatial, spectral and temporal analysis (Blaschke et al., 2008). The use and applications of OBIA has increased exponentially over the last decades as an alternative to traditional pixel-based image classification. At its most fundamental level, OBIA requires image segmentation, attribution, classification and the ability to query and link individual objects (e.g. segments) in space and time (Figure 2). The software that was used to implement OBIA was Definiens eCognition 8.7.

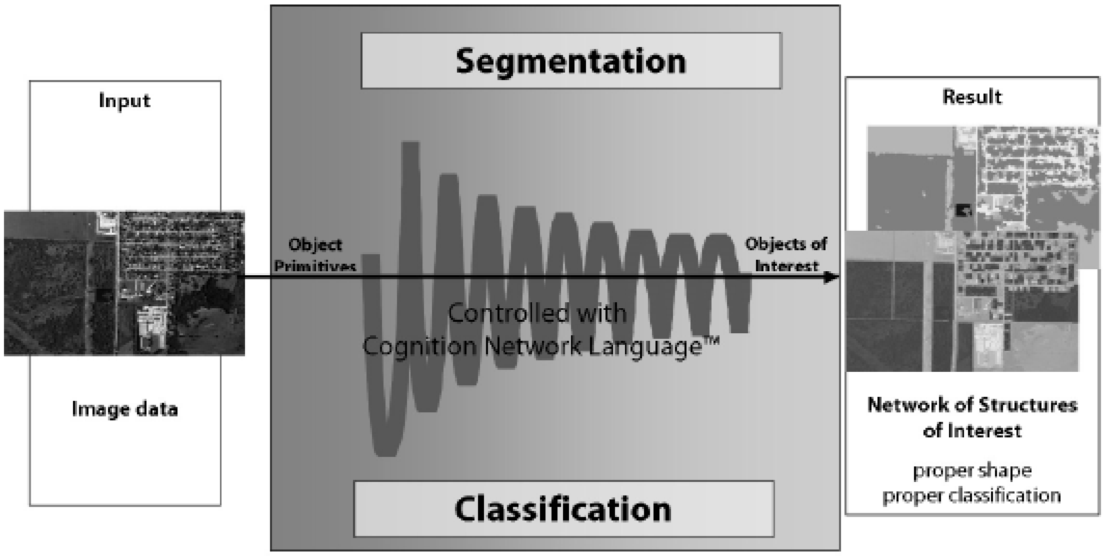


Figure 2. Object-oriented image analysis: the generic procedure (source: eCognition users manual).

What essentially makes OBIA and eCognition object-oriented classification a favourable method is that image analysis and classification is done in successive reversible steps. In each step, new classes are created from yet unclassified objects or nested within previously created classes using spatial characteristics of the objects in addition to their reflectance values (e.g. shape, size, "relation to neighbouring" objects).

For the coastal dune sites under investigation, eCognition was used to create segments from high spatial resolution IKONOS images, together with the historical air photographs. Weighting was set to be equal between all Ikonos bands and air photographs. After several trial and error tests the images were segmented using a scale factor ranging between 10 and 50 depending on the extent of the site, shape importance factor of 0.2 and compactness of 0.8 (Figure 3).

In the classification process the nearest neighbour method was chosen, based on manually chosen samples. Although image segments were common, classification was done separately for historical air photographs and Ikonos images. Due to the nature of black and white air photographs, different vegetation types could not be distinguished in a semi-automated procedure with acceptable accuracy. Therefore, it was decided to differentiate only two classes namely vegetated and non-vegetated land cover.

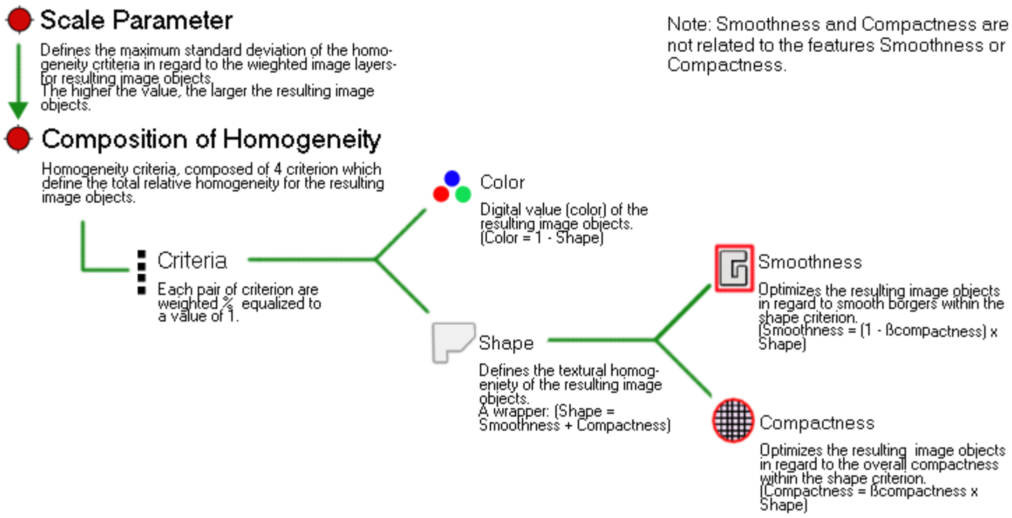
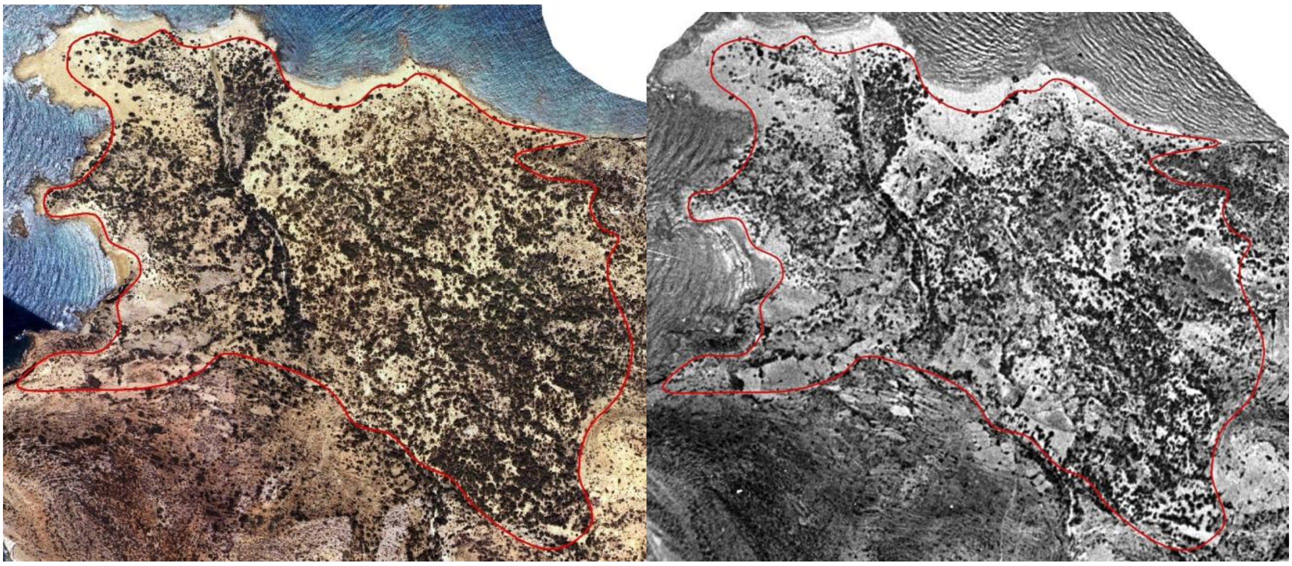


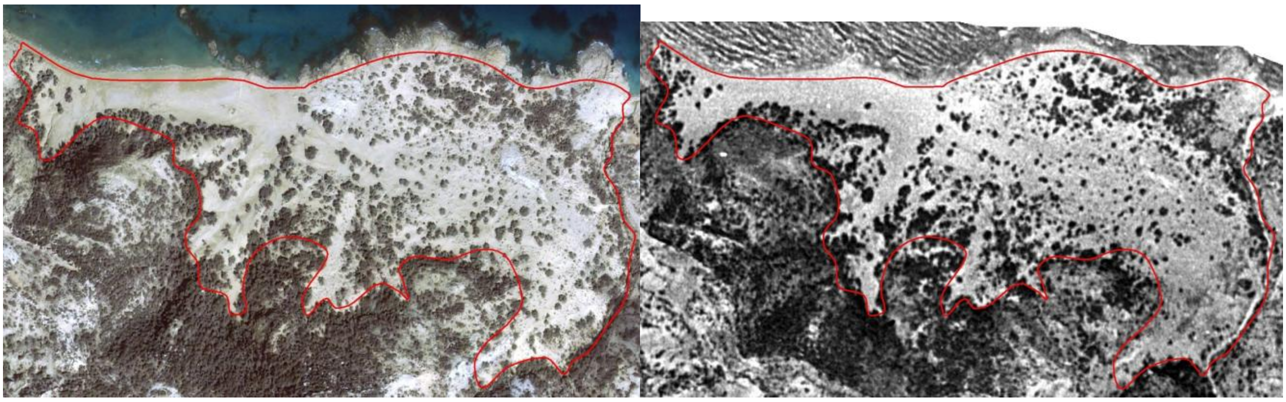
Figure 3. Schematic diagram of Composition of Homogeneity Criterion for segmentation and delineation of homogeneous landscape units in Definiens eCognition software.

Classification results were subsequently imported into GIS (ArcGIS 10) in the form of vector polygons. Further corrections were made in the attribute table using visual image interpretation from field observations and air photo interpretation. The historical and contemporary classification results were merged in ArcGIS to detect changes. Final estimates of these changes were calculated and changes were presented in maps. The legend of changes detected had four classes: (a) unvegetated areas that continued to be open, (b) unvegetated areas that appear vegetated in contemporary images, (c) vegetated areas that maintained their cover and (d) vegetated areas that lost their vegetation cover. For all maps produced the Hellenic Geodetic Reference Projection System (EGSA'87) was used.

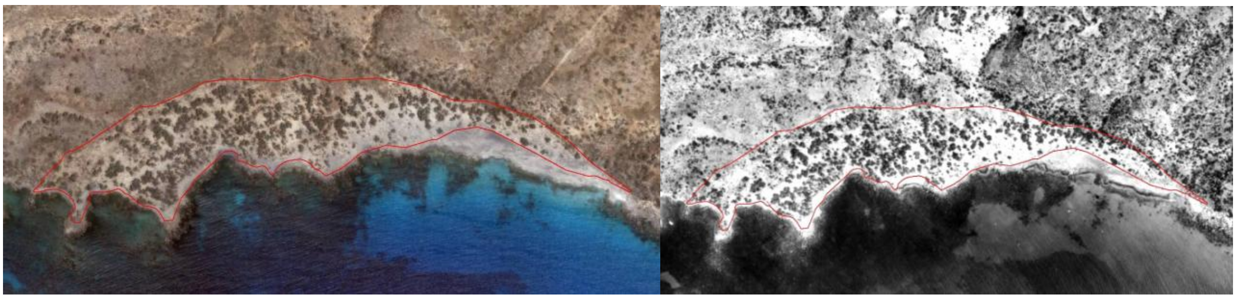
3.3 Snapshots of satellite images and air-photographs



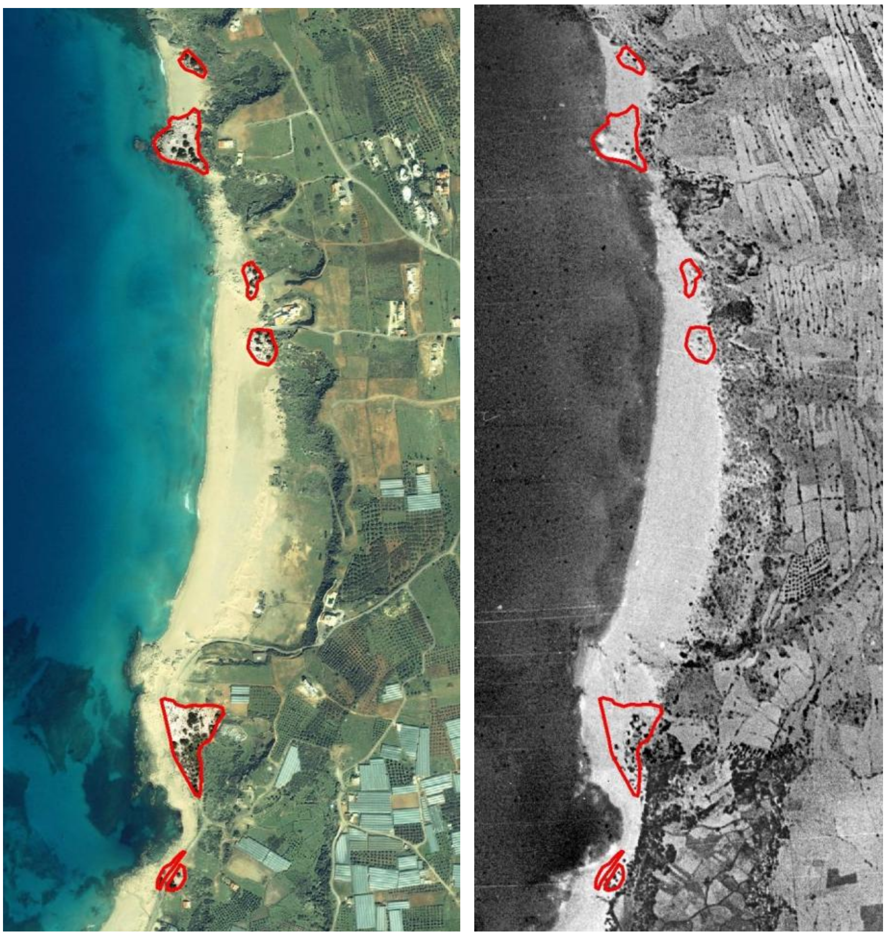
Lavrakas (Gavdos): Ikonos image (left) and 1945 air photograph (right).



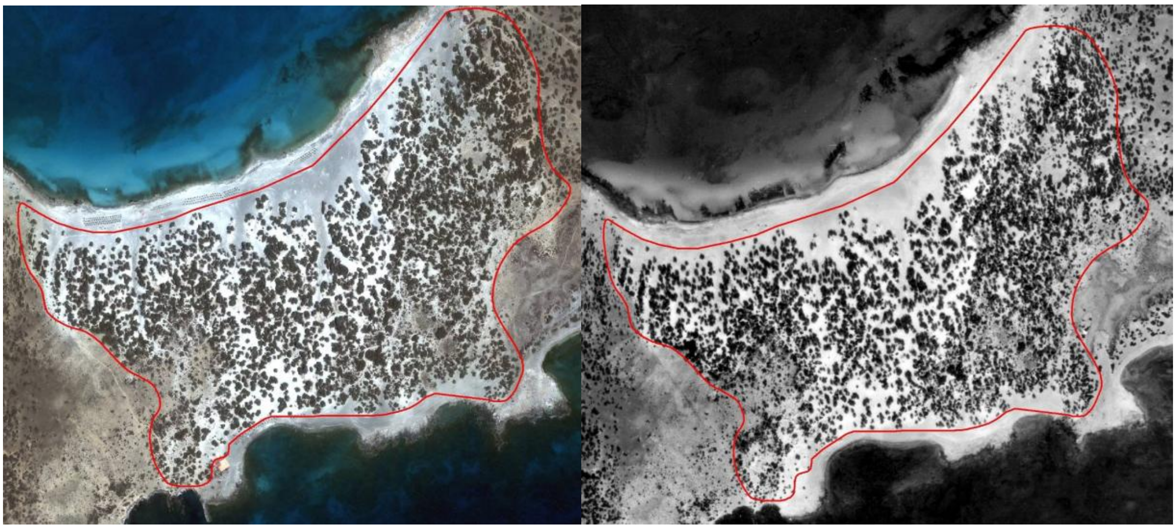
Agios Ioannis (Gavdos): Ikonos image (left) and 1945 air photograph (right).



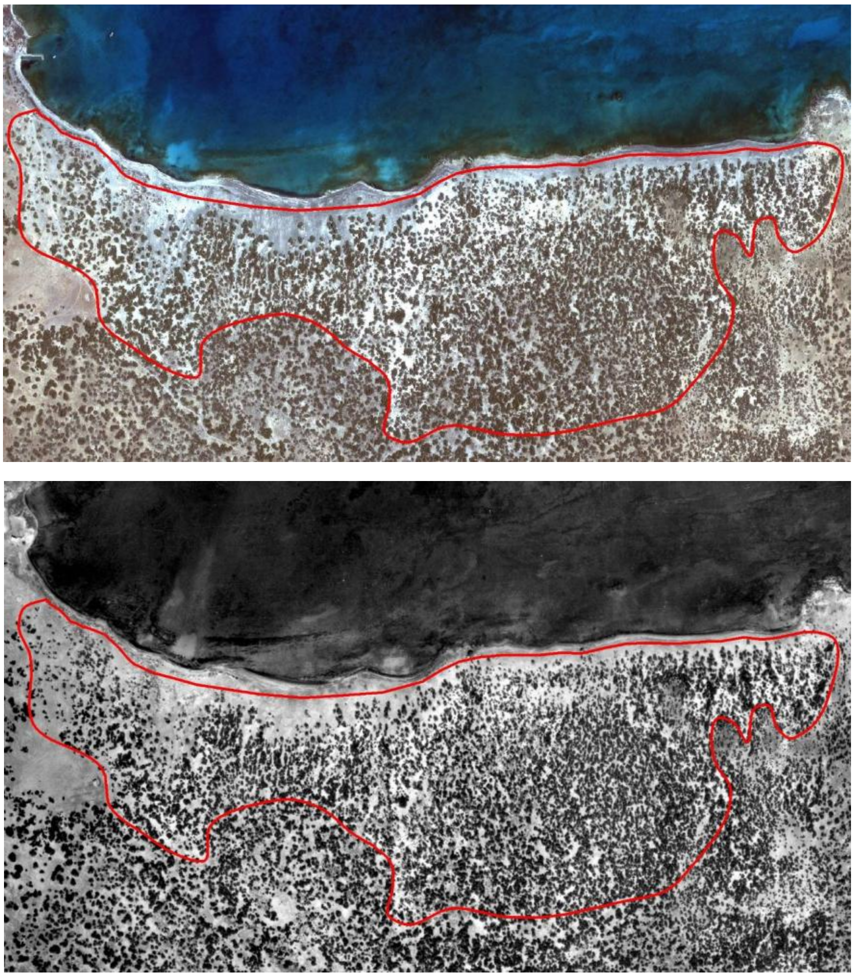
Kedrodasos (Elafonisi): Ikonos image (left) and 1968 air photograph (right).



Falasarna Ikonos image (left) and 1945 air photograph (right).



East Chrysi site: Ikonos image (left) and 1968 air photograph (right).



West Chrysi site: Ikonos image (top) and 1968 air photograph (bottom).

4. Results

Estimates of vegetation cover changes in the coastal sand dunes with *Juniperus* spp. priority habitat (2250*) in Crete showed that overall 80% of land cover did not change. Vegetated land shows an overall increase in all habitats from 95.7 ha (42%) to 117.7 ha (52%). Out of all sites under investigation, open areas that remained open account for the 43% of the total 227 hectares. Vegetation cover was maintained in 37%, it declined in 5% and increased in 15% of the total area.

Changes per site (Table 1) show in all areas that, the increase of vegetation cover, was at least marginally greater than areas of decline. The most significant changes can be seen in Lavrakas. It is the most densely vegetated site with 65% cover in 2007. Vegetation cover has increased overall by 15 ha (~15%). This accounts for more than 2/3 of vegetation increase in all sites (22 ha in total). Chrysi island sites are 2nd and 3rd in vegetation increase with 2.43 and 2.13 ha (West and East sites respectively).

Table 1. Changes in vegetation cover in 2250* priority habitat sites.

Vegetation Cover Change	Area (ha)					
	Lavrakas	Ag. Ioannis	Falassarna	Kedrodasos	Chrysi East	Chrysi West
	1945-2007	1945-2007	1968-2007	1968-2007	1968-2007	1968-2007
Maintained open areas	30.11 (31%)	14.57 (63%)	2.122 (77%)	5.267 (51%)	18.8 (49%)	26.97 (49%)
Vegetation decline	4.05 (4%)	1.15 (5%)	0.145 (5%)	1.044 (10%)	2.74 (7%)	2.5 (4%)
Vegetation increase	19.10 (20%)	2.97 (13%)	0.333 (12%)	1.365 (13%)	4.87 (13%)	4.936 (9%)
Maintained veg. cover	43.99 (45%)	4.48 (19%)	0.158 (6%)	2.606 (26%)	12.14 (31%)	20.7 (38%)
Total	97.25	23.17	2.758	10.282	38.55	55.106

Visual interpretation of resulting maps of each site (Maps 1-6) shows that the observed increase in vegetation cover in all sites, except Lavrakas, is mainly due to canopy increase. Decrease of vegetation cover is mapped mainly because of changes in shape or displacement of canopy in the contemporary images e.g. changes in shrub and tree architecture. Increase of diameter of canopy is most prominent in Agios Ioannis and East Chrysi sites. Nevertheless, with the exception of one stand in

Agios Ioannis (south-central part), no big trees or stands have entirely disappeared over the last decades.

In Lavrakas, the significant increase in natural vegetation is found in the inland side of the habitat in areas that used to be arable land and around the two main streams crossing the habitat. Although Lavrakas shows typical signs of natural regeneration due to land abandonment, natural vegetation increase (by the riverside in particular), to some extent, is attributed to pine trees rather than Junipers.

5. References

Blaschke, T., Lang, S., Hay, G.J. (Eds.), 2008. Object Based Image Analysis. Springer, Heidelberg, Berlin, New York, 817 p.

Carter, R.W.G., 1995. Coastal environments: an introduction to the physical, ecological and cultural systems of coastlines. 5th edn. London: Academic press, 617pp.

Hutchinson, M. F. 1988. Calculation of hydrologically sound digital elevation models. Paper presented at Third International Symposium on Spatial Data Handling at Sydney, Australia.

Hutchinson, M. F. 1989. A new procedure for gridding elevation and stream line data with automatic removal of spurious pits. Journal of Hydrology, 106: 211–232.

Hutchinson, M. F. 1996. A locally adaptive approach to the interpolation of digital elevation models. In Proceedings, Third International Conference/Workshop on Integrating GIS and Environmental Modeling. Santa Barbara, CA: National Center for Geographic Information and Analysis.

Hutchinson, M.F. and Gallant, J.C. 2000. Digital elevation models and representation of terrain shape. In: J.P. Wilson and J.C. Gallant (eds) Terrain Analysis. Wiley, New York, pp. 29–50.

Hutchinson, M.F., Xu, T. and Stein, J.A. 2011. Recent Progress in the ANUDEM Elevation Gridding Procedure. In: Geomorphometry 2011, edited by T. Hengel, I.S. Evans, J.P. Wilson and M. Gould, pp. 19–22. Redlands, California, USA.

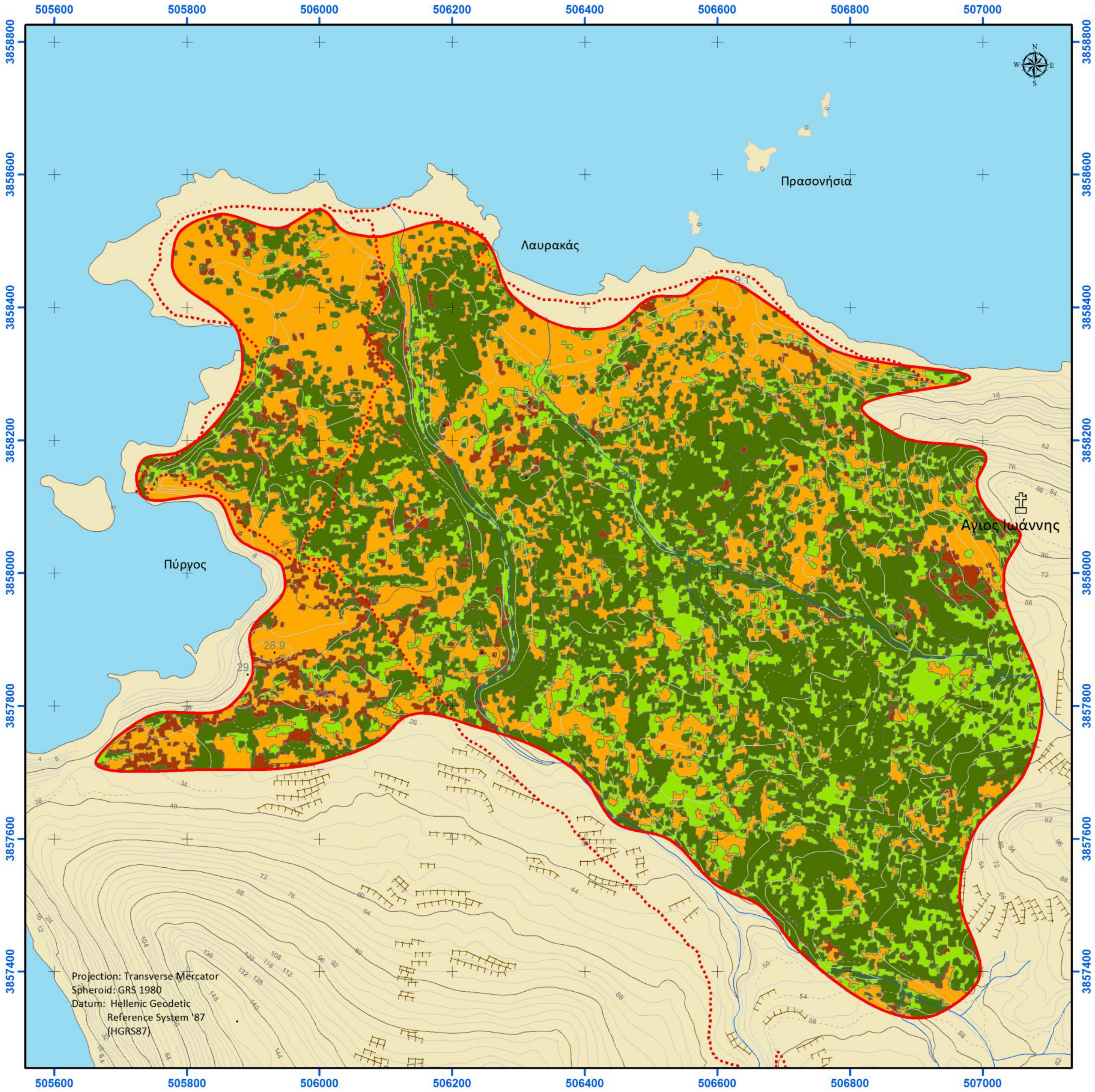
Mayer, A., 1995. Comparative study of the coastal vegetation of Sardinia (Italy) and Crete (Greece) with respect to the effects of human influence. IHW-Verlag, Libri Botanici, 15.

Ranwell, D.S., 1972. Ecology of salt marshes and sand dunes. Chapman and Hall, London.

Short, A.D., Hesp, P., 1982. Wave, beach and dune interaction in southeastern Australia. Marine Geology, 48:259-284.

6. MAPS

Land cover changes map of Lavrakas-Gavdos 2250* habitat (1945 - 2007)



Land cover change estimates between reference years 1945-2007.

	Area (hectars)
Vegetated with no changes	43.9
Open areas with no changes	30.1
Vegetation loss	4.05
Vegetation gain	19.1

Junicoast

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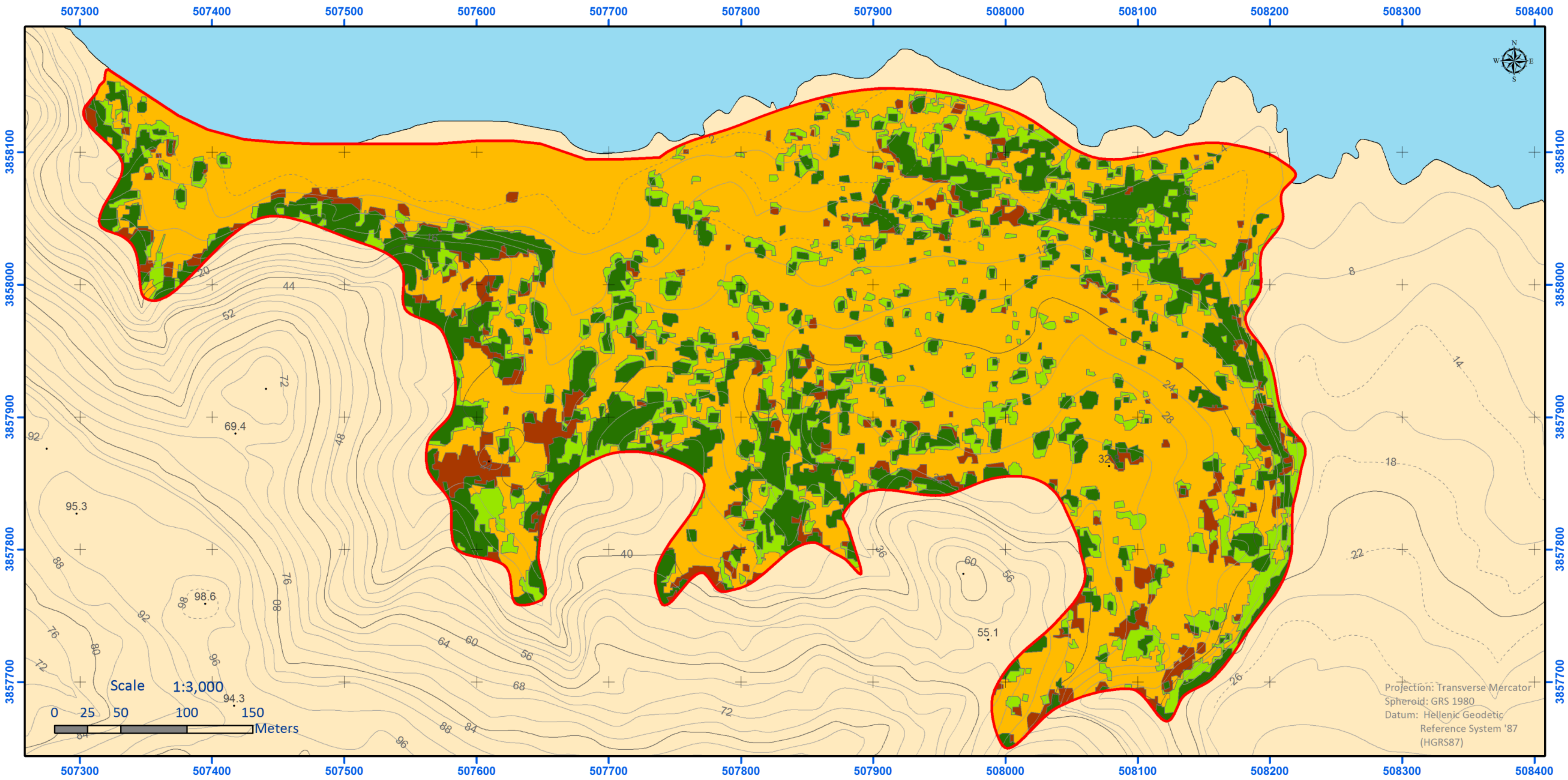
Map 1. Vegetation cover changes map of Lavrakas

Land cover changes map of Agios Ioannis-Gavdos 2250* habitat (1945-2007)



LEGEND

Study area (2250* habitat)

Contour lines

- 20 m
- 4 m
- 2 m

Land cover changes

- Bare land with no changes
- Vegetated with no changes
- Vegetation loss
- Vegetation gain

Land cover change estimates between reference years 1945-2007.

	Area (hectars)
Vegetated with no changes	4.48
Open areas with no changes	14.57
Vegetation loss	1.15
Vegetation gain	2.97

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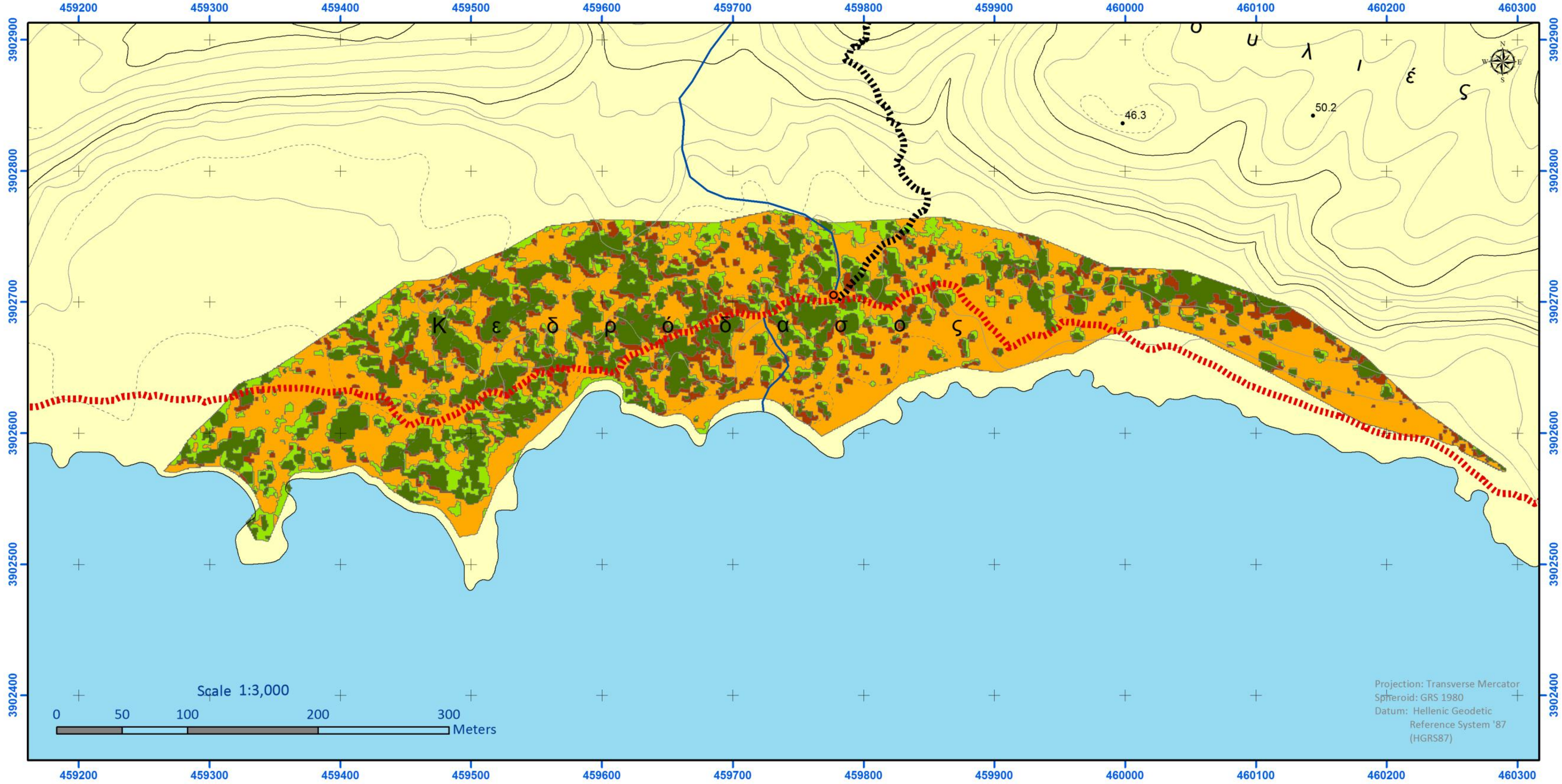
Map 2. Vegetation cover changes map of Agios Ioannis.

Land cover changes map of Kedrodasos-Elafonisi 2250* habitat (1968-2007)



LEGEND

- Well
- Elevations
- Surface run-off
- Trails
- E4 trail

Contour lines

- 20 m
- 4 m
- 2 m

Land cover changes

- Vegetated with no changes
- Bare land with no changes
- Vegetation loss
- Vegetation gain

Land cover change estimates between reference years 1968-2007.

	Area (hectars)
Vegetated with no changes	2.6
Open areas with no changes	5.27
Vegetation loss	1.04
Vegetation gain	1.37

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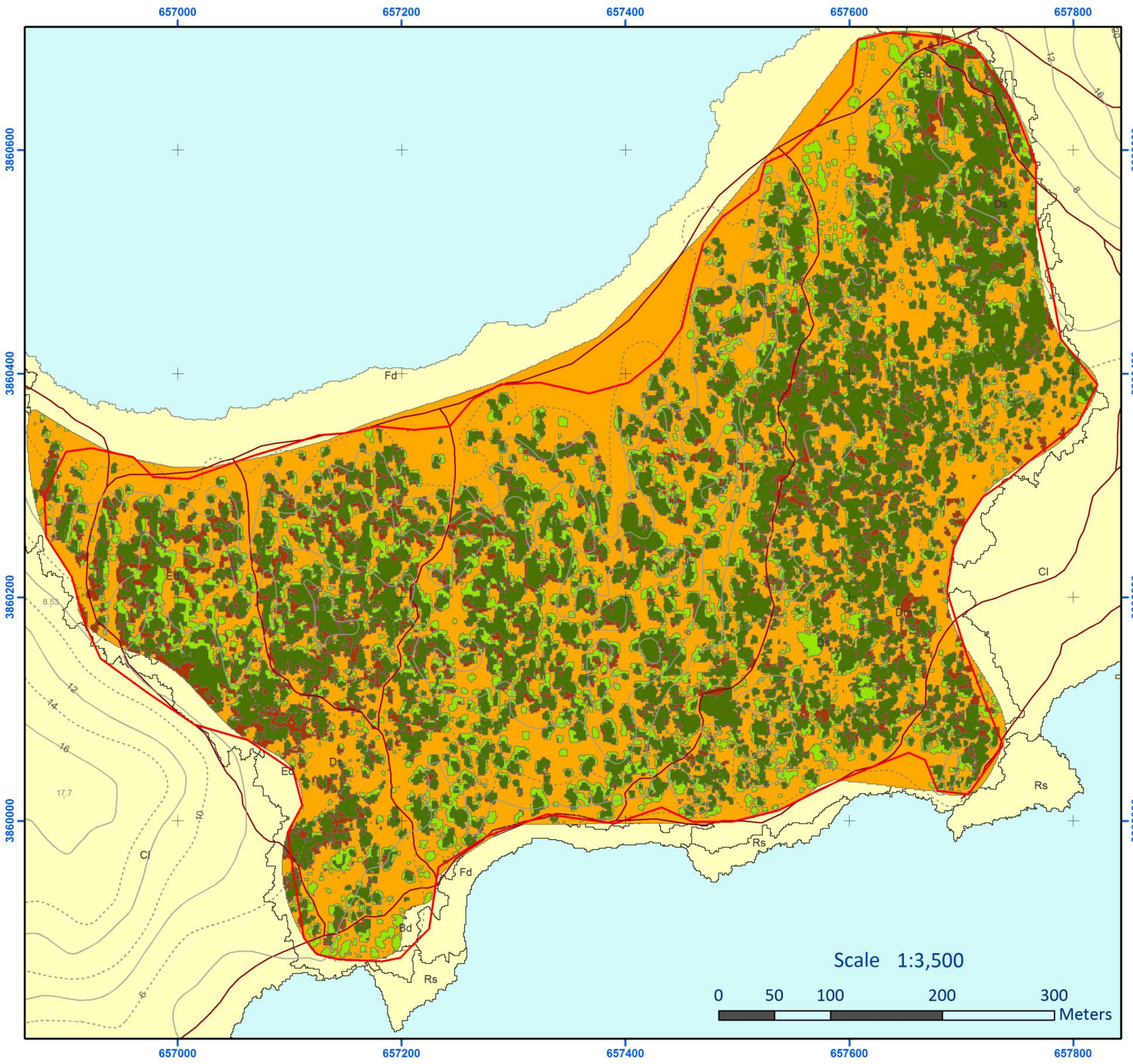
"Actions for the conservation of coastal dunes with Juniperus spp. in Crete and the South Aegean (Greece)"
Action A.4: Habitat Mapping

Map 3. Vegetation cover changes map of Kedrodasos (Elafonisi).

Land cover changes map of east Chrysi island 2250* habitat (1968-2007)



Land cover change estimates between reference years 1968-2007.

	Area (hectars)
Vegetated with no changes	12.14
Open areas with no changes	18.8
Vegetation loss	2.74
Vegetation gain	4.87

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"Actions for the conservation of coastal dunes with Juniperus spp. in Crete and the South Aegean (Greece)"
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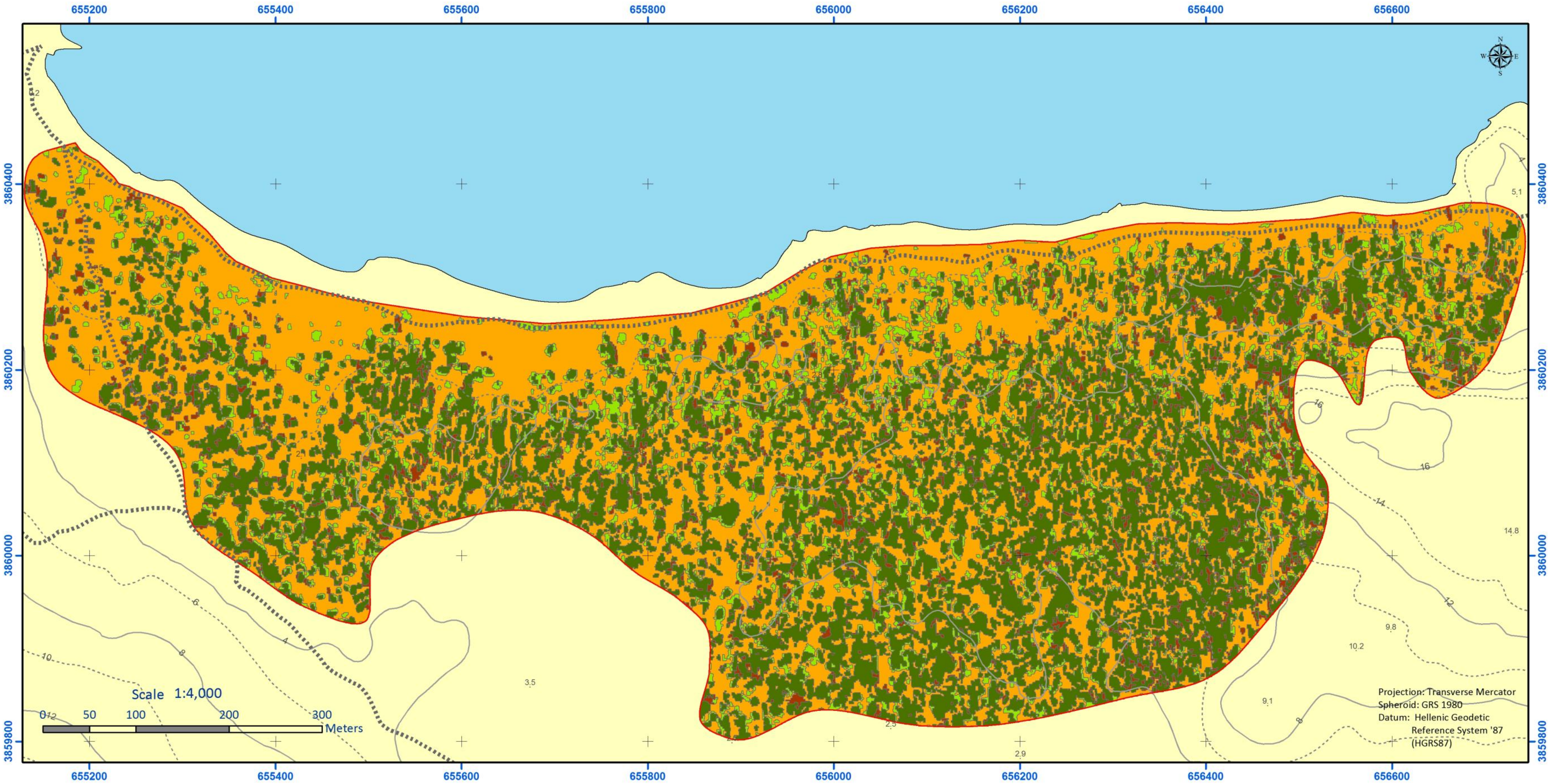
Map 4. Vegetation cover changes map of East Chrysi.

Land cover changes map of west Chrysi island 2250* habitat (1968-2007)



LEGEND

Study area (2250* habitat)
Trails or dirt roads

Contour lines
- 20 m
- 4 m
- 2 m

Land cover changes
- Vegetated with no changes
- Bare land with no changes
- Vegetation loss
- Vegetation gain

Land cover change estimates between reference years 1968-2007.

	Area (hectars)
Vegetated with no changes	20.7
Open areas with no changes	27
Vegetation loss	2.5
Vegetation gain	5

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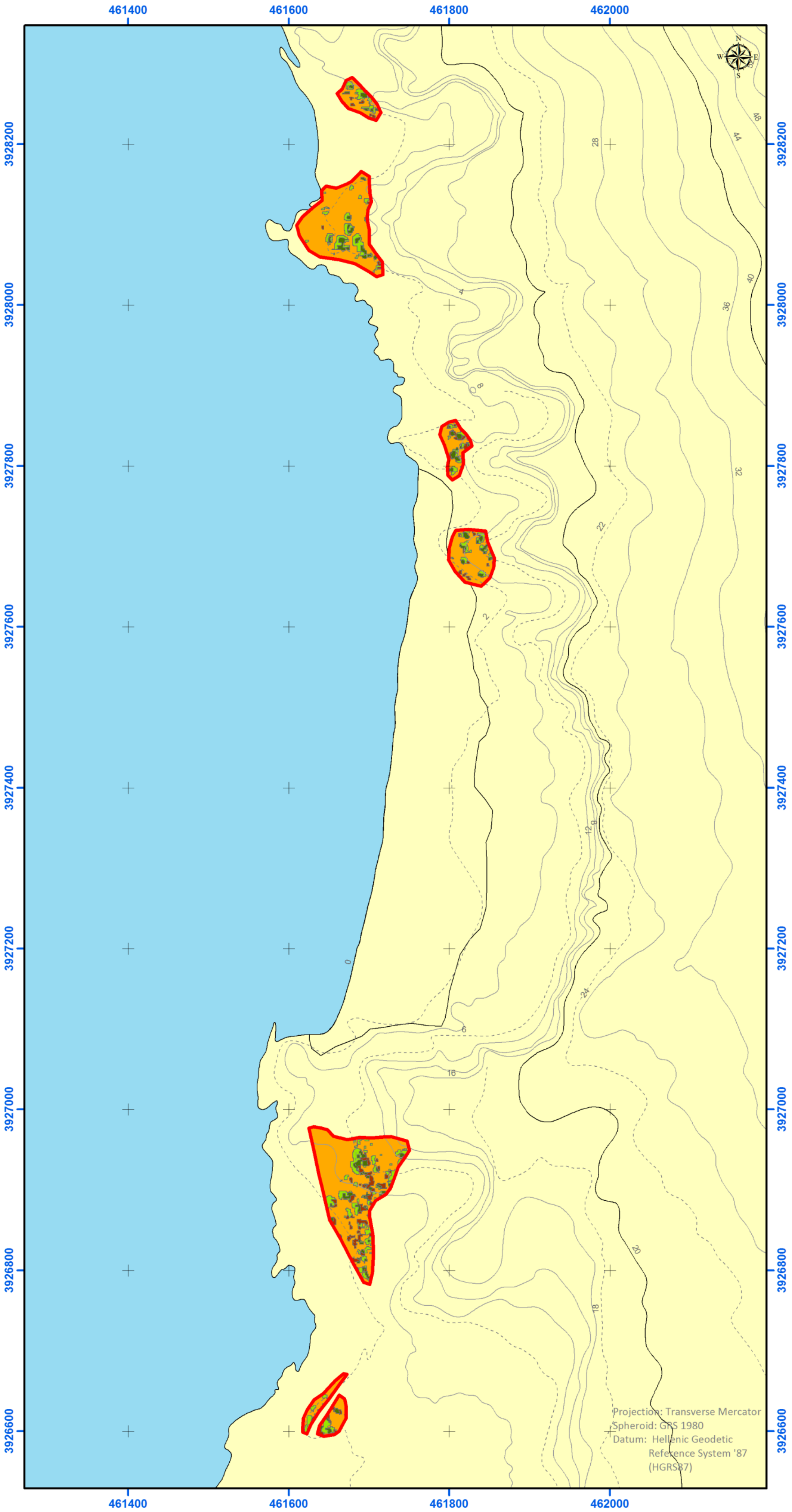
Action A.4: Habitat Mapping

NATURA 2000

Map 5. Vegetation cover changes map of West chrysi

Land cover changes map of east Falasarna 2250* habitat (1968-2007)



ΥΠΟΜΝΗΜΑ

Study area (2250* habitat)

Contour lines

20 m

4 m

2 m

Land cover changes

Vegetated with no changes

Bare land with no changes

Vegetation loss

Vegetation gain

Land cover change estimates between reference years 1968-2007.

	Area (hectars)
Vegetated with no changes	0.16
Open areas with no changes	2.12
Vegetation loss	0.15
Vegetation gain	0.33

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Life

NATURA 2000

Scale 1:5,000

0 50 100 200 300 Meters

Map 6. Vegetation cover changes map of Falasarna.