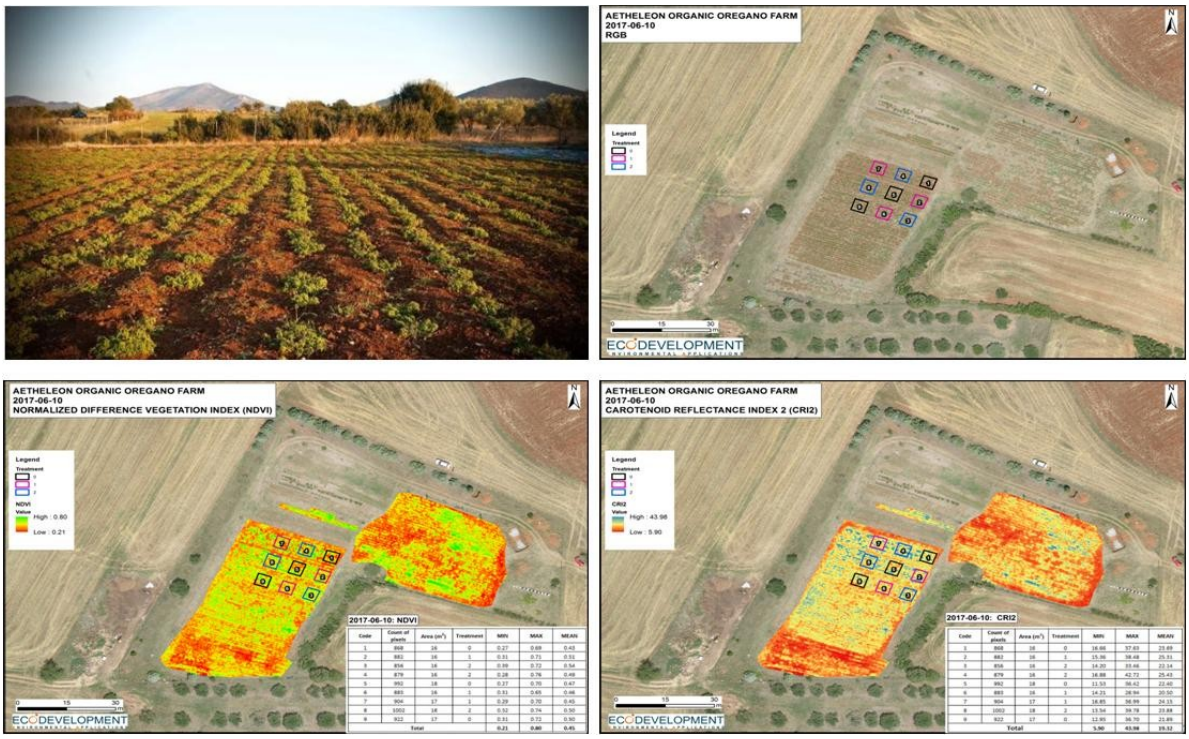
ECODEVELOPMENT
ENVIRONMENTAL APPLICATIONS

REMOTE SENSING FOR QUALITY MANAGEMENT OF THE ATHELEON ORGANIC OREGANO FIELD



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Scope

The purpose of this work is to depict the spatial variability of specific spectral vegetation indices (NDVI, Green Model and CRI2) which are representative for the vigorousness and the stage of maturation and or leaf carotenoid content of the organic oregano cultivation of Aetheleon plantation at Peristera, Greece. The latter may be related to the carvacrol content of oregano plants. The vegetation indices were obtained by means of contract remote sensing and an evaluation of this method for its possible impact on the quality management of the oregano plantation is presented.

The study is structured in three parts:

- Acquisition of a time series of 4 UAV (Unmanned Aerial Vehicle) imageries at specific dates during May and June 2017, corresponding empirically to the development stage of the oregano plantation.
- The calculation of specific vegetation indices for an experimental setting with different cultivation treatments within the plantation and for the whole field.
- A statistical analysis of the correlation between the calculated indices and the final content of carvacrol in the oregano plants within the experimental setting after distillation.

Study site

The organic oregano plantation of Aetheleon is located at Peristera, Nothern Greece, about 30 km southeast of Thessaloniki at an altitude between 140 and 170 m above sea level and comprises a total area of 7.200 m^2 with approximately 4500 oregano plants at a plantation grid of 30cm x 50cm. The mean age of the oregano plants (Origanum vulgare *ssp.* hirtum) is three years.

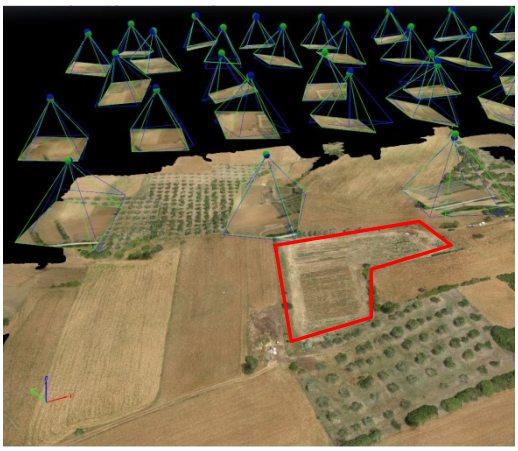
Map 1. Location of the study site in Peristera, Northern Greece

Remote sensing imagery

Remote sensing imagery was acquired at four different dates, actually

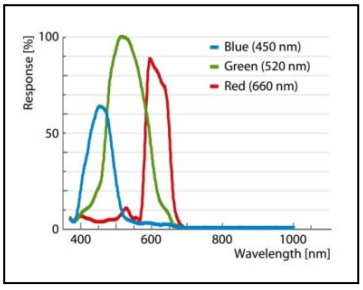
1. on the 19th of May 2017
2. on the 10th of June 2017
3. on the 23th of June 2017 and
4. on the 29th of June 2017

The UAV used was the professional mapping drone eBee from the company SenseFly which captures high-resolution aerial photos that can be transformed into accurate orthomosaics & 3D models.

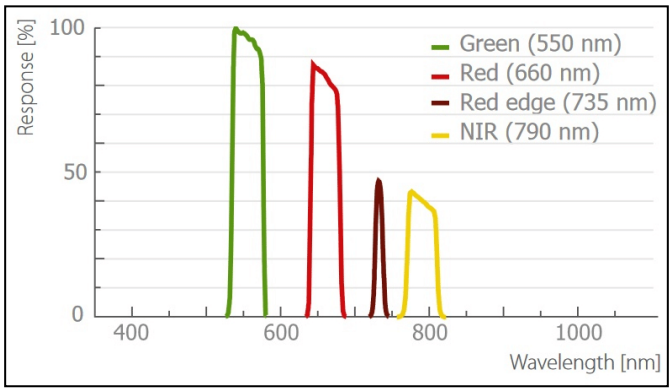


At every date two imagery series were taken, one RGB (red-green-blue, the optical imagery) and one multispectral with channels in specific wavelengths.

At the first two dates RGB imagery was captured with the Canon S110 RGB camera and an analysis of 6cm/pixel.



For the multispectral imagery a customized MultiSpec 4C camera was used with specific bands for the calculation of the carotenoid Index CRI 2 Gitelson.



Photogrammetry was performed with the Pix4D software and the final output of the RGB orthomosaic had a spatial analysis of 7cm/pixel whereas the multispectral orthomosaic had a final spatial analysis of 13,1 cm/pixel.
The mean reflectance calculated from the 4 bands was used to calculate the Normalized Difference Vegetation Index (NDVI) [Rouse et al., 1974) and the Carotenoid Reflectance Index 2 (CRI2) [Gitelson et al., 2002].

- NDVI = (R790 - R660)/(R790 + R660)
- CRI2 = ((1/R510) - (1/R710)) × R790

On the other two dates (23th and 29th of June 2017), the UAV was equipped with the Parrot Sequoia camera which captures images across four defined, visible and non-visible spectral bands, plus RGB imagery, in the same flight.
The mean reflectance calculated from the 4 bands was used to calculate the NDVI (see above) and the Green Model [Gitelson et al., 2005]

G-M = (R750/R550)-1 (Green Model)

Experimental setting

In the southern part of the oregano plantation an experiment with two different treatments and a control was set up. Concretely, three blocks, each of which comprised three plots with different treatments (0 = control, 1 = organic fertilizers, 2 = Bioshell products, plant growth enhancers) were implemented (Fig.2). The materials used in both treatments were certified organic.
Bioshell is a formulation based on micronized zeolite (clinoptilolite) which contains non-crystalline silica of organic origin and organic acids in the form of humic and fulvic acids. This formulation acts as plant growth enchancer.
The different treatments concerned nutrition and aimed in the increase of carvacrol content in the final distillation.

Map 2. RGB map with the experimental design

Results

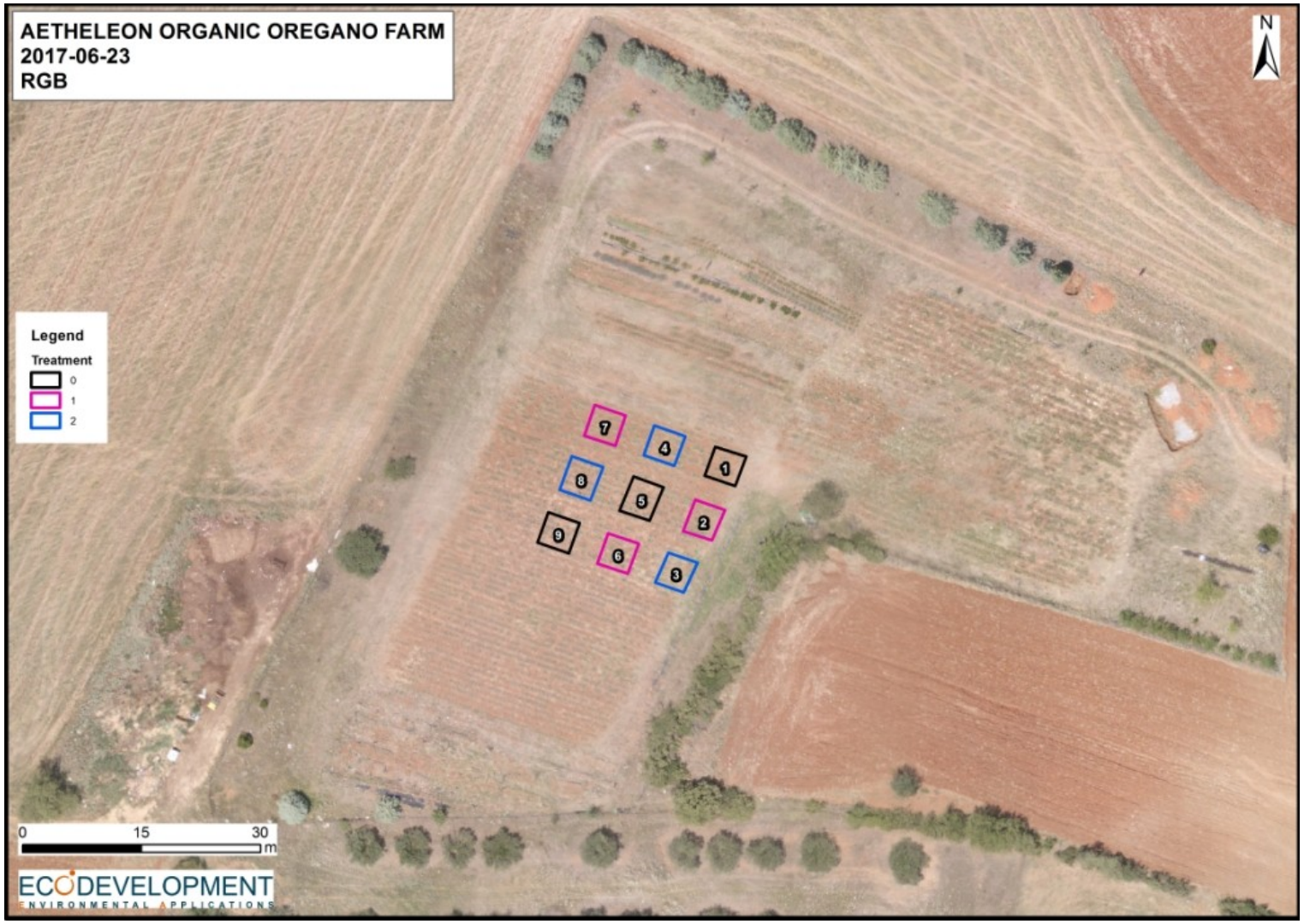
1. RGB Aerial Imagery

Maps 3-6 show the oregano field as it appeared in the RGB Aerial imagery

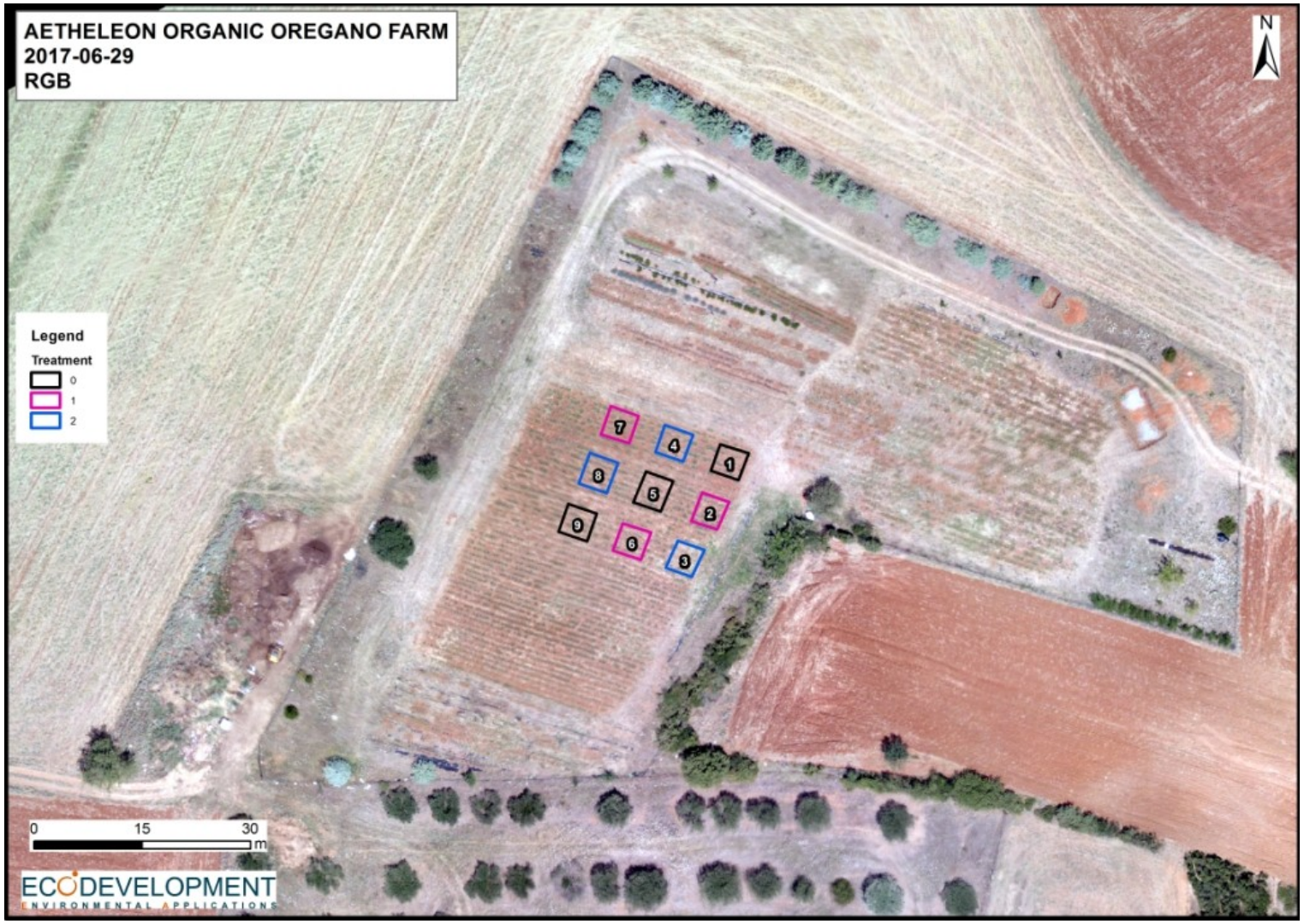
1. on the 19th of May 2017
2. on the 10th of June 2017
3. on the 23th of June 2017 and
4. on the 29th of June 2017

Map 3. RGB imagery on 19th of May 2017

Map 4. RGB imagery on 10th of June 2017



Map 5. RGB imagery on 23rd of June 2017

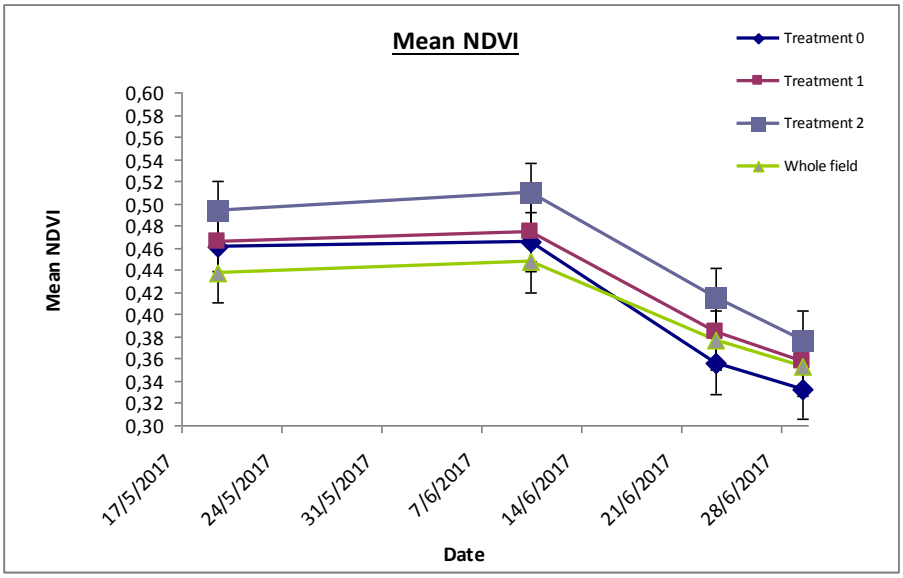


Map 6. RGB imagery on 29th of June 2017

2. NDVI (Normalized Difference Vegetation Index)

In the table below, the calculated mean NDVI values per treatment and for the whole field as derived from the multispectral imagery are presented.
Values between 0.20 and 0.35 (In red and orange color) represent bare soil and values between 0.35 and 0.80 (different green tones) represent the oregano plants. Darker green color is associated with high chlorophyll content while light green with lower chlorophyll content.

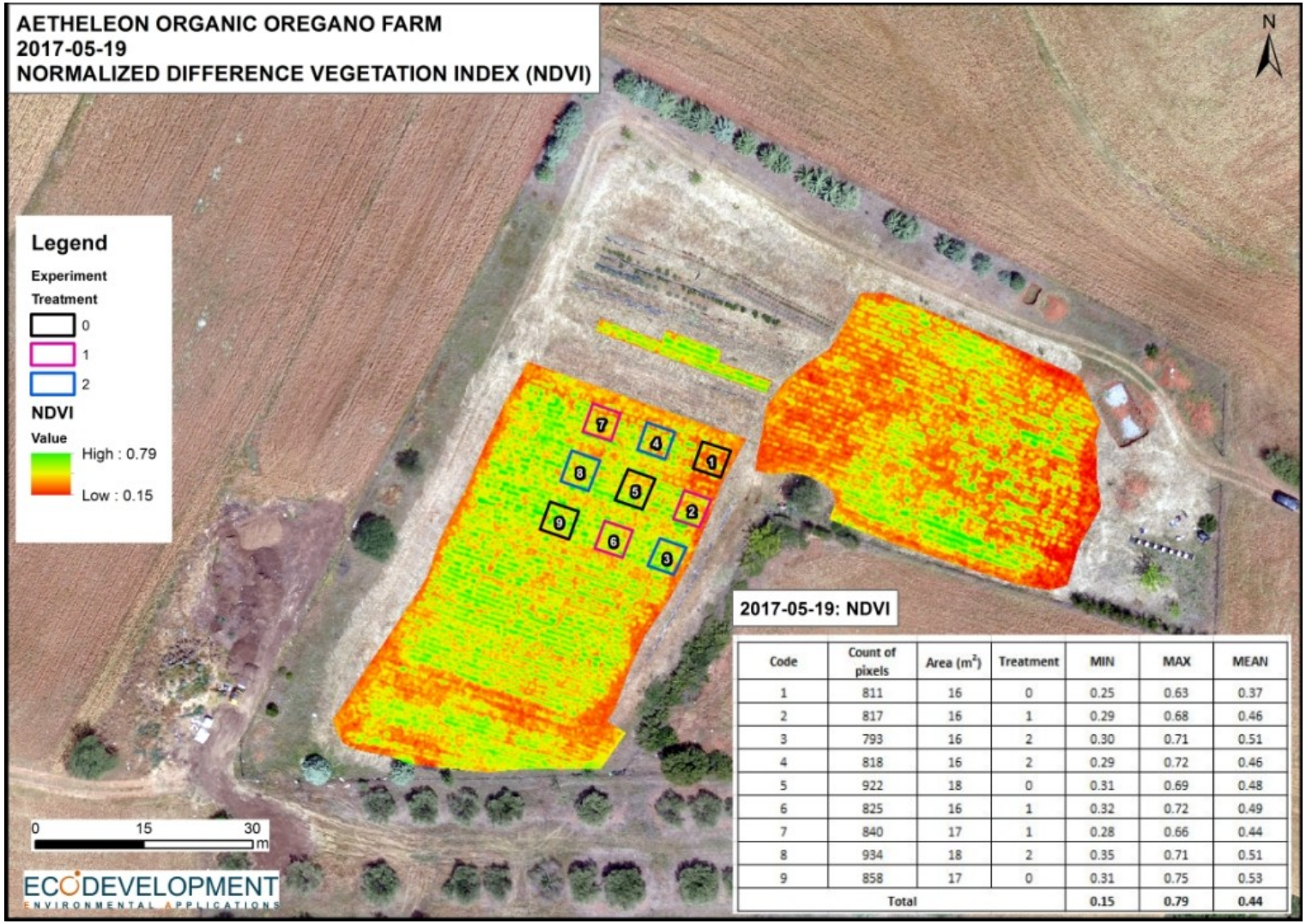
Code	Treatment	mean NDVI 19/05/2017	mean NDVI 10/06/2017	mean NDVI 23/06/2017	mean NDVI 29/06/2017
1	0	0,37	0,43	0,36	0,34
2	1	0,46	0,51	0,45	0,41
3	2	0,51	0,54	0,48	0,43
4	2	0,46	0,49	0,39	0,36
5	0	0,48	0,47	0,36	0,33
6	1	0,49	0,46	0,33	0,30
7	1	0,44	0,45	0,37	0,36
8	2	0,51	0,50	0,37	0,34
9	0	0,53	0,50	0,35	0,33
Whole field		0,44	0,45	0,38	0,35



Graph 1. Mean NDVI values per treatment per date

The highest NDVI values are observed in plots with treatment 2 throughout the implementation period of the study (p=0,034). Relatively lower values at 23th of June may be due to the use of a different camera in combination with the degradation of chlorophyll content in plants because of plant aging. Plots with

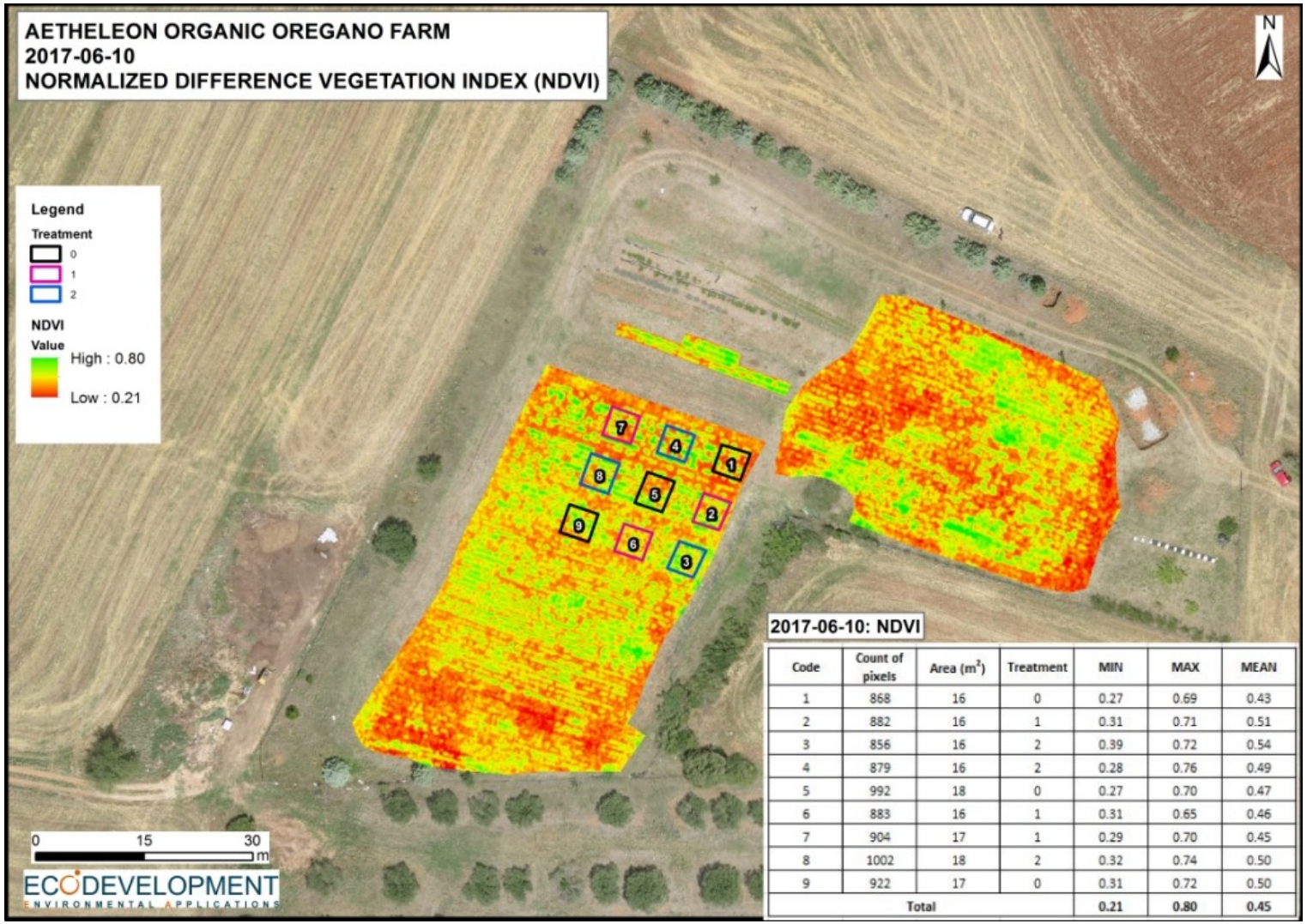
treatment 1 in relation to the control plots also had higher NDVI values despite that there was not a statistical significant difference.
In maps 7-10 the NDVI measures on the four dates are presented:



2017-05-19: NDVI

Code	Count of pixels	Area (m^2)	Treatment	MIN	MAX	MEAN
1	811	16	0	0.25	0.63	0.37
2	817	16	1	0.29	0.68	0.46
3	793	16	2	0.30	0.71	0.51
4	818	16	2	0.29	0.72	0.46
5	922	18	0	0.31	0.69	0.48
6	825	16	1	0.32	0.72	0.49
7	840	17	1	0.28	0.66	0.44
8	934	18	2	0.35	0.71	0.51
9	858	17	0	0.31	0.75	0.53
Total				**0.15**	**0.79**	**0.44**

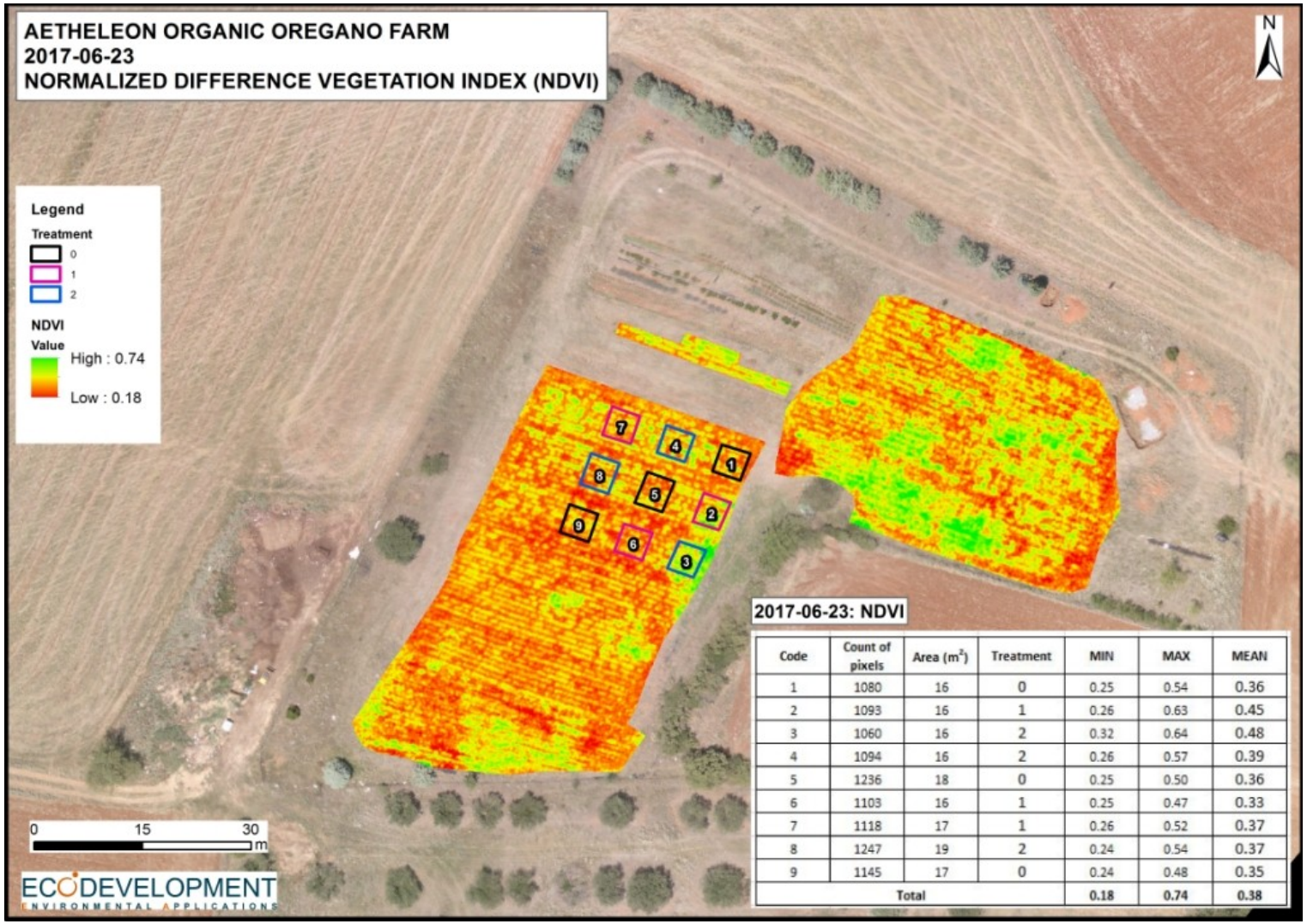
Map 7. NDVI measurement on 19th of May 2017



2017-06-10: NDVI

Code	Count of pixels	Area (m^2)	Treatment	MIN	MAX	MEAN
1	868	16	0	0.27	0.69	0.43
2	882	16	1	0.31	0.71	0.51
3	856	16	2	0.39	0.72	0.54
4	879	16	2	0.28	0.76	0.49
5	992	18	0	0.27	0.70	0.47
6	883	16	1	0.31	0.65	0.46
7	904	17	1	0.29	0.70	0.45
8	1002	18	2	0.32	0.74	0.50
9	922	17	0	0.31	0.72	0.50
Total				**0.21**	**0.80**	**0.45**

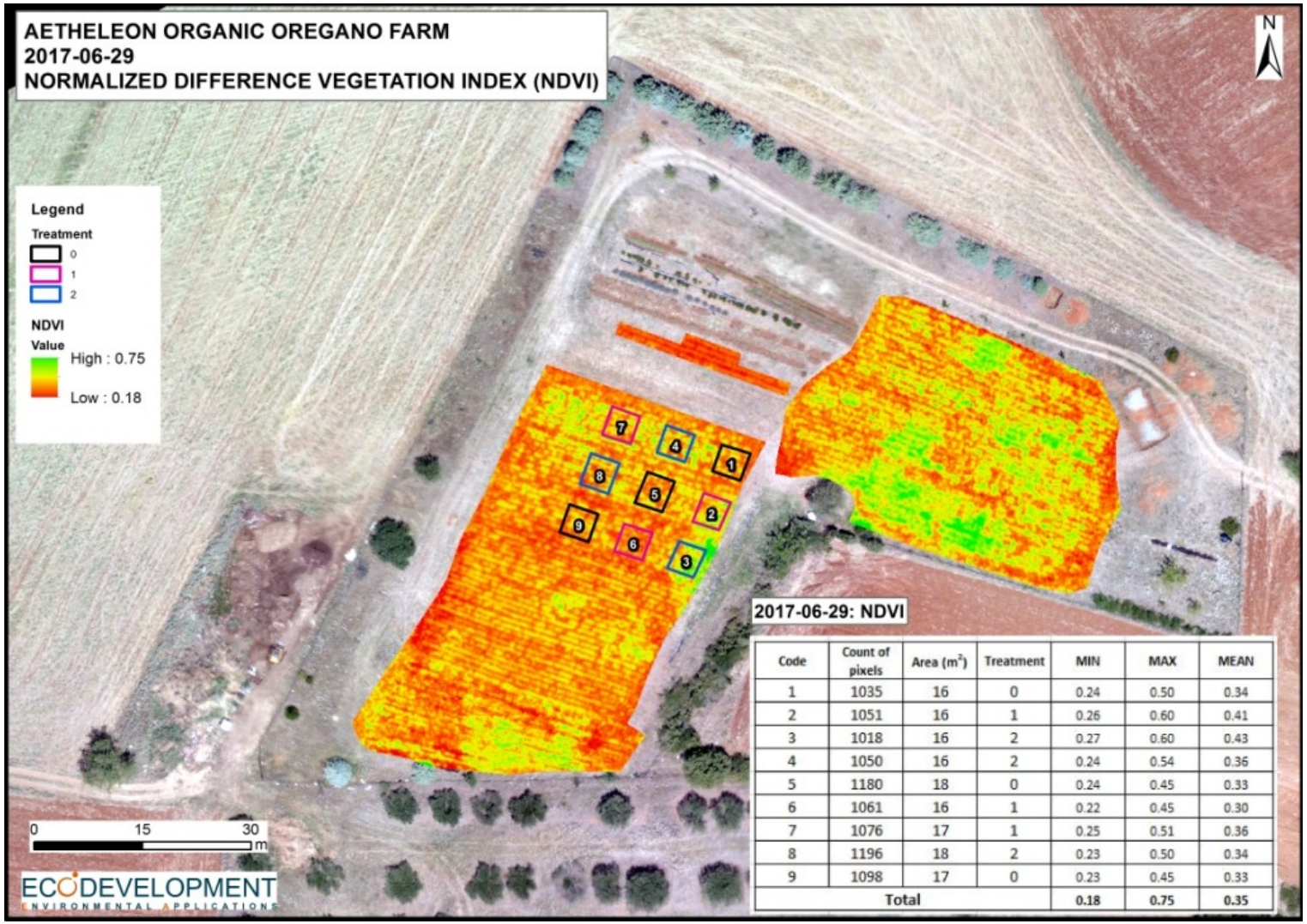
Map 8. NDVI measurement on 10th of June 2017



2017-06-23: NDVI

Code	Count of pixels	Area (m^2)	Treatment	MIN	MAX	MEAN
1	1080	16	0	0.25	0.54	0.36
2	1093	16	1	0.26	0.63	0.45
3	1060	16	2	0.32	0.64	0.48
4	1094	16	2	0.26	0.57	0.39
5	1236	18	0	0.25	0.50	0.36
6	1103	16	1	0.25	0.47	0.33
7	1118	17	1	0.26	0.52	0.37
8	1247	19	2	0.24	0.54	0.37
9	1145	17	0	0.24	0.48	0.35
Total				0.18	0.74	0.38

Map 9. NDVI measurement on 23th of June 2017



2017-06-29: NDVI

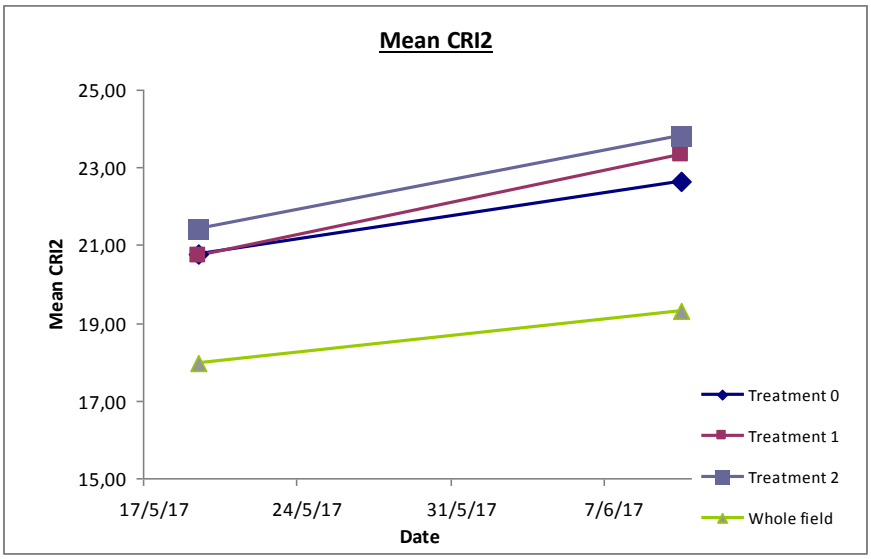
Code	Count of pixels	Area (m^2)	Treatment	MIN	MAX	MEAN
1	1035	16	0	0.24	0.50	0.34
2	1051	16	1	0.26	0.60	0.41
3	1018	16	2	0.27	0.60	0.43
4	1050	16	2	0.24	0.54	0.36
5	1180	18	0	0.24	0.45	0.33
6	1061	16	1	0.22	0.45	0.30
7	1076	17	1	0.25	0.51	0.36
8	1196	18	2	0.23	0.50	0.34
9	1098	17	0	0.23	0.45	0.33
Total				0.18	0.75	0.35

Map 10. NDVI measurement on 29th of June 2017

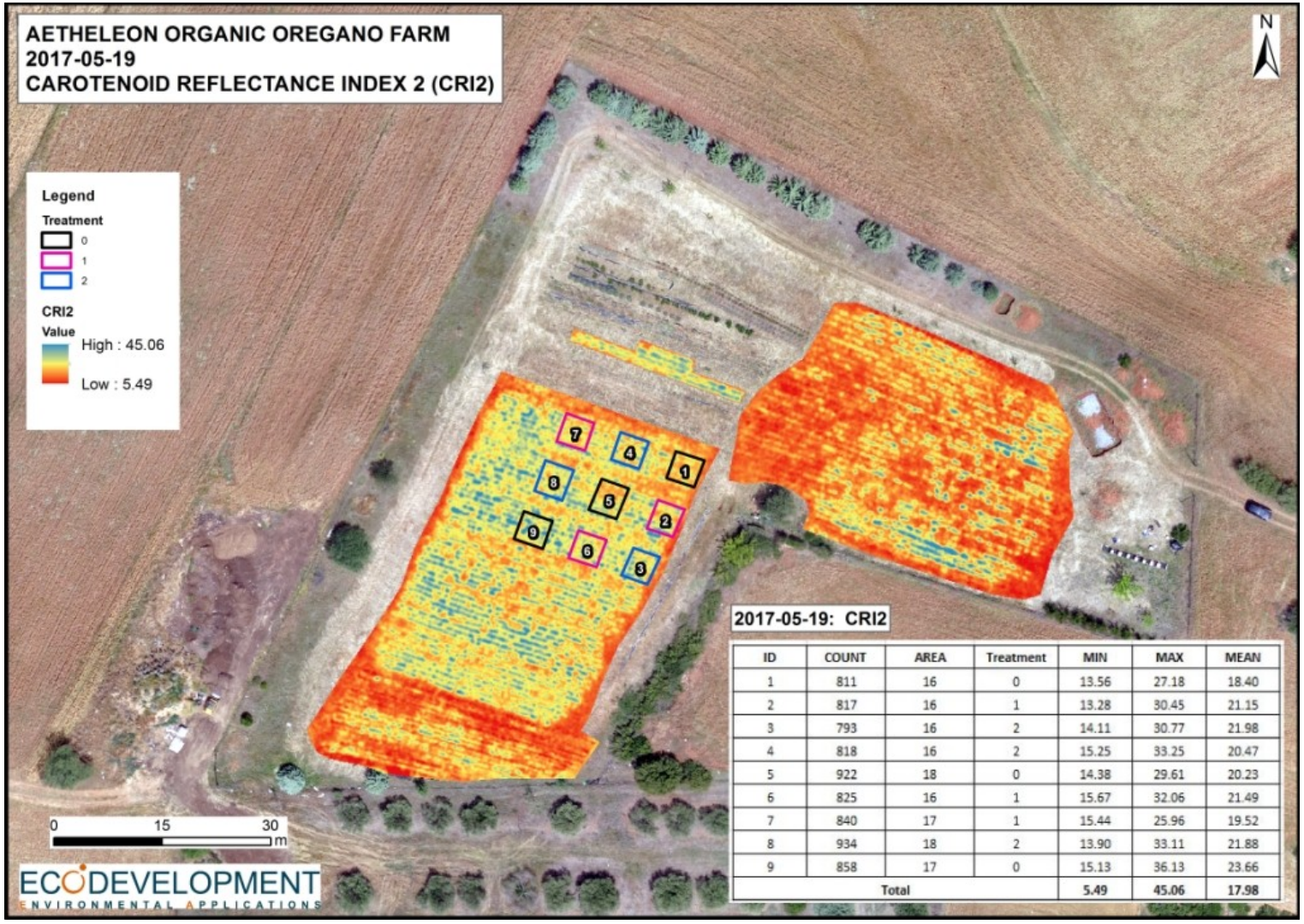
3. CRI 2 (Carotenoid Reflectance Index 2)

In the table below, the calculated mean CRI2 values per treatment and for the whole field as derived from the multispectral imagery are presented.
The higher the CRI2 value (blue color) the higher is the biomass for oregano plants of the individual plots.

Code	Treatment	mean CRI2 19/05/2017	mean CRI2 10/06/2017
1	0	18,40	23,69
2	1	21,15	25,31
3	2	21,98	22,14
4	2	20,47	25,43
5	0	20,23	22,40
6	1	21,49	20,50
7	1	19,52	24,15
8	2	21,88	23,88
9	0	23,66	21,89
Whole field		17,98	19,32



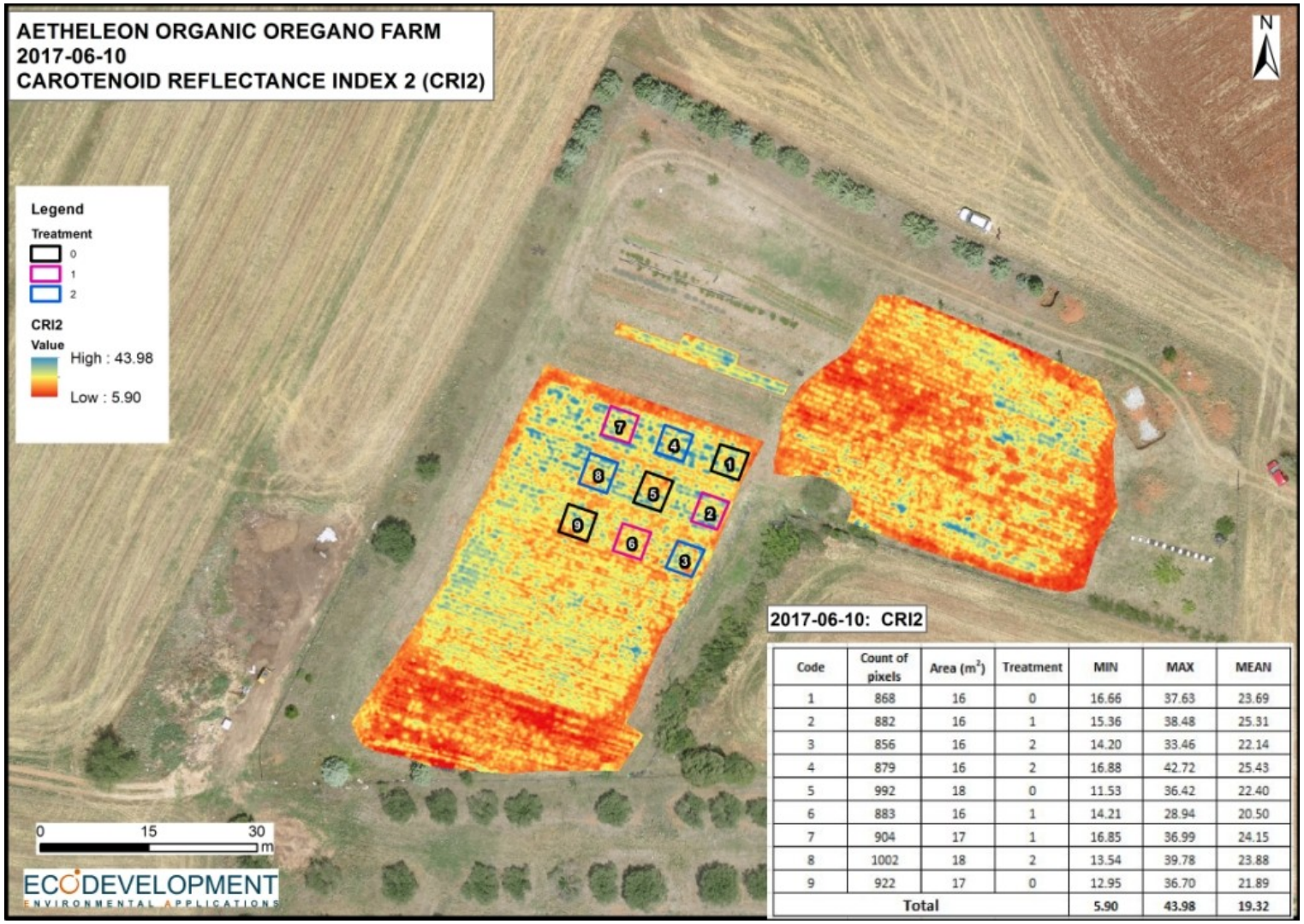
No statistical significant difference between the plots of the different treatments have been observed using the CRI2 index.



2017-05-19: CRI2

ID	COUNT	AREA	Treatment	MIN	MAX	MEAN
1	811	16	0	13.56	27.18	18.40
2	817	16	1	13.28	30.45	21.15
3	793	16	2	14.11	30.77	21.98
4	818	16	2	15.25	33.25	20.47
5	922	18	0	14.38	29.61	20.23
6	825	16	1	15.67	32.06	21.49
7	840	17	1	15.44	25.96	19.52
8	934	18	2	13.90	33.11	21.88
9	858	17	0	15.13	36.13	23.66
Total				5.49	45.06	17.98

Map 11. CRI2 measurement on 19th of May 2017



2017-06-10: CRI2

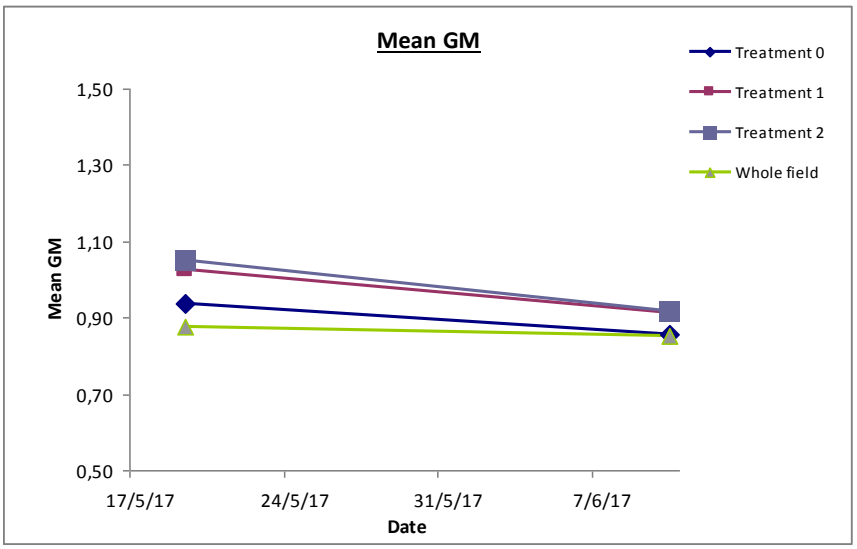
Code	Count of pixels	Area (m^2)	Treatment	MIN	MAX	MEAN
1	868	16	0	16.66	37.63	23.69
2	882	16	1	15.36	38.48	25.31
3	856	16	2	14.20	33.46	22.14
4	879	16	2	16.88	42.72	25.43
5	992	18	0	11.53	36.42	22.40
6	883	16	1	14.21	28.94	20.50
7	904	17	1	16.85	36.99	24.15
8	1002	18	2	13.54	39.78	23.88
9	922	17	0	12.95	36.70	21.89
Total				5.90	43.98	19.32

Map 12. CRI2 measurement on 10th of June 2017

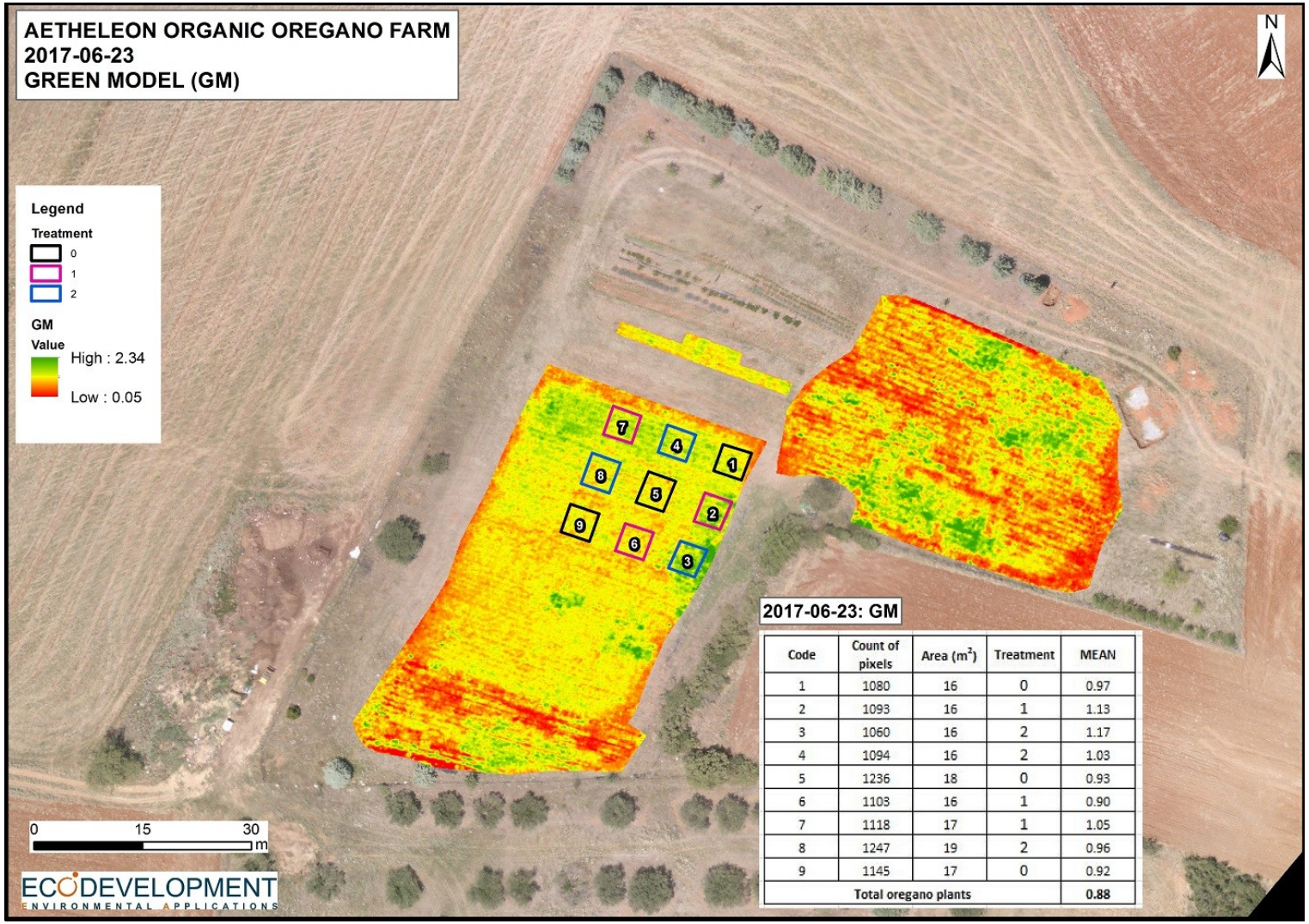
4. GM (Green Model)

In the table below, the calculated mean GM values per treatment and for the whole field as derived from the multispectral imagery are presented.
The higher the GM value (blue color) the higher is the biomass for oregano plants of the individual plots.

Code	Treatment	Mean GM 19/05/2017	Mean GM 10/06/2017
1	0	0,97	0,92
2	1	1,13	0,97
3	2	1,17	0,95
4	2	1,03	0,95
5	0	0,93	0,83
6	1	0,90	0,79
7	1	1,05	0,98
8	2	0,96	0,86
9	0	0,92	0,82
Total		0,88	0,85



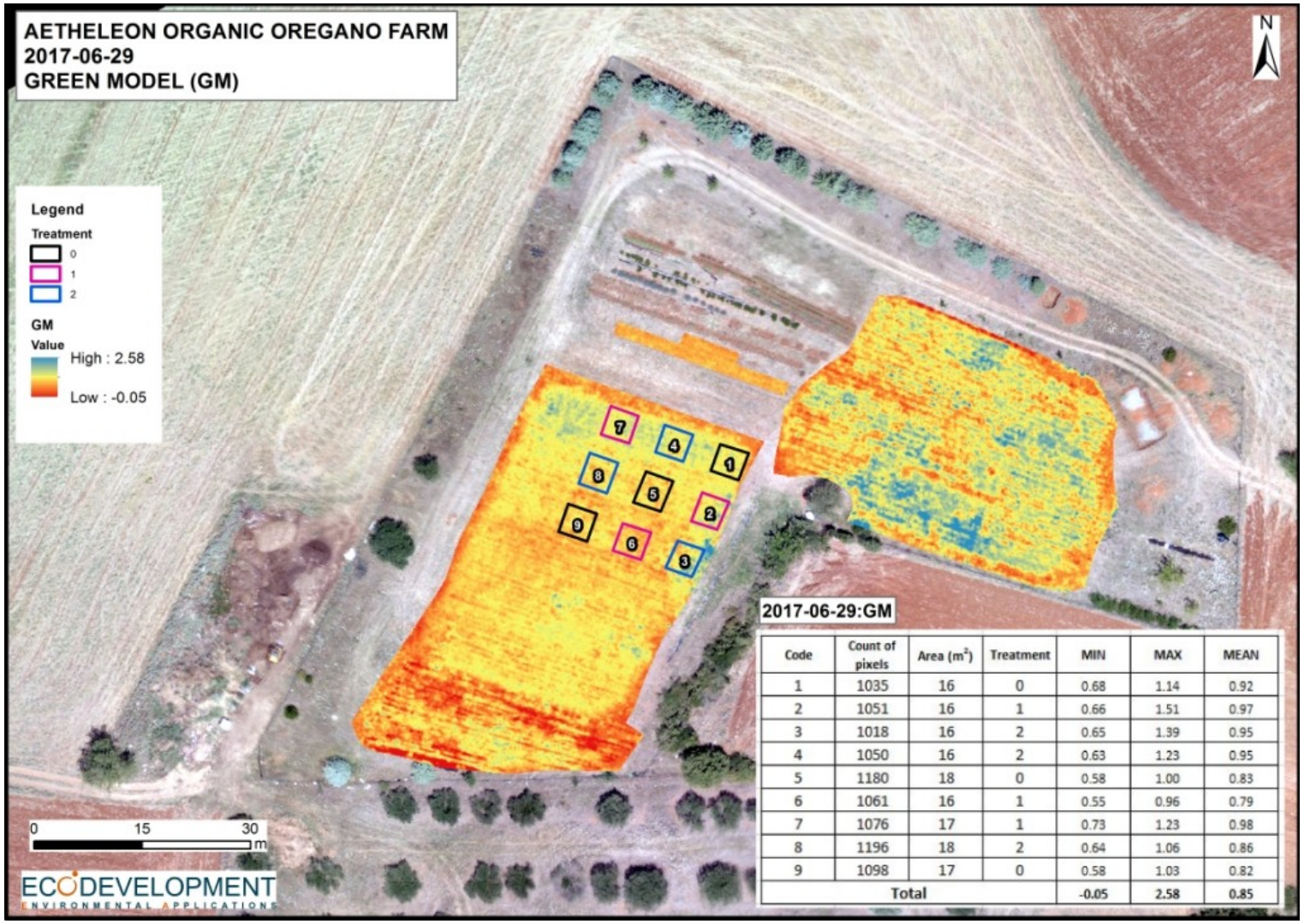
No statistically significant difference between the plots of the different treatments was observed using the GM.



2017-06-23: GM

Code	Count of pixels	Area (m^2)	Treatment	MEAN
1	1080	16	0	0.97
2	1093	16	1	1.13
3	1060	16	2	1.17
4	1094	16	2	1.03
5	1236	18	0	0.93
6	1103	16	1	0.90
7	1118	17	1	1.05
8	1247	19	2	0.96
9	1145	17	0	0.92
Total oregano plants				0.88

Map 13. GM measurement on 23th of June 2017



2017-06-29:GM

Code	Count of pixels	Area (m^2)	Treatment	MIN	MAX	MEAN
1	1035	16	0	0.68	1.14	0.92
2	1051	16	1	0.66	1.51	0.97
3	1018	16	2	0.65	1.39	0.95
4	1050	16	2	0.63	1.23	0.95
5	1180	18	0	0.58	1.00	0.83
6	1061	16	1	0.55	0.96	0.79
7	1076	17	1	0.73	1.23	0.98
8	1196	18	2	0.64	1.06	0.86
9	1098	17	0	0.58	1.03	0.82
Total				-0.05	2.58	0.85

Map 14. GM measurement on 29th of June 2017

After harvesting, the carvacrol content of the plots with the three different treatments has been analyzed in one sample per treatment and the results are as follows:

Control (no treatment at all):	2.5% essential oil
Treatment 1 (organic fertilizers):	3.09% essential oil
Treatment 2 (BIOSHELL products)	3.4% essential oil

Extra 270 samples (thus 30 samples / plot) have been sent to the lab for analysis of carvacrol content with which a concrete correlation between the vegetation indices used in this study and the carvacrol content of oregano plants treated with different fertilizers and/or organic growth enhancers will be able to be established.

Conclusions

In order to compare the effect on oregano plant growth of two different application methodologies concerning conventional fertilizers and organic growth enhances of the Bioshell series, spectral reflectance measurements were taken at different growth stages in an oregano field experiment. The indices calculated from the spectral reflectance measurements were the Normalized Difference Vegetation Index (NDVI), the Carotenoid Reflectance Index 2 (CRI2) and the Green Model (G-M). Results of the present study show that Bioshell application on oregano plants resulted in increased NDVI, CRI2 and G-M values of the crop for all the different growth stages for which multispectral imagery was acquired by means of contract remote sensing. Preliminary data show that the NDVI index performed better than the other two indices. This is in agreement with Gitelson et al. (2002) who supported the idea that the Carotenoid Reflectance Index measuring carotenoids in plant canopies is more suitable for assessing the physiological status of higher plants (trees). NDVI has proven to be superior compared to the other two indices, because oregano is a small shrub. The results of the present study will be published later when all the data become available, as they are still in the process of the analysis in the lab.