Testing very high resolution Earth Observation features as predictors of habitat fragmentation at multiple scales for habitat change detection

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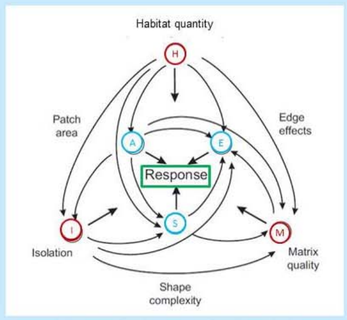
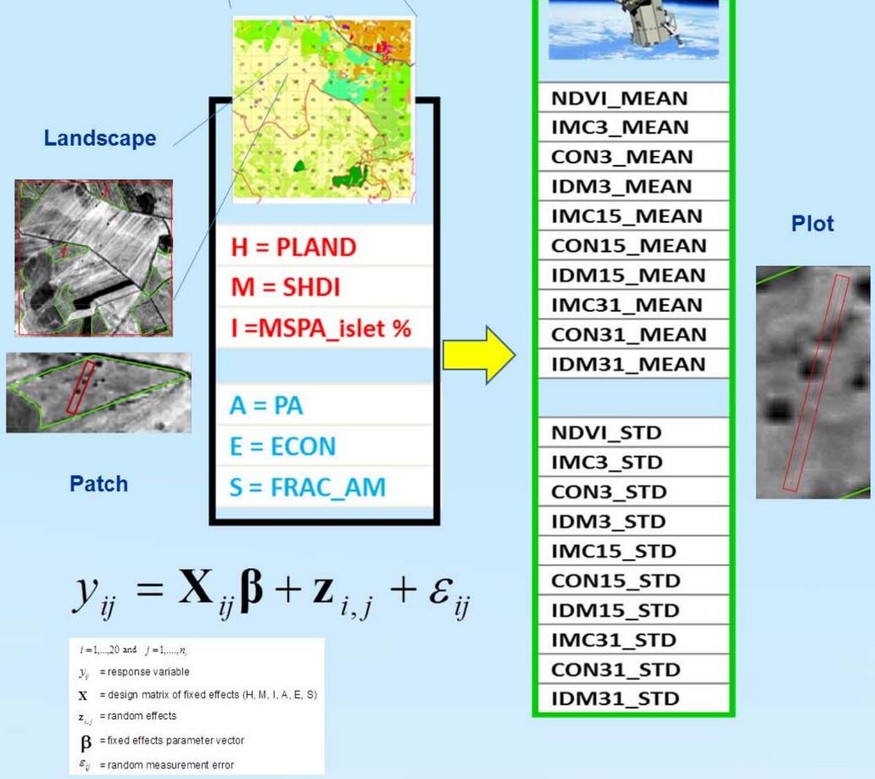
Study area location map.

Introduction

This research fits in the landscape modelling effort of the BIO_SOS - Biodiversity Multisource Monitoring System: from Space TO Species project (FP7-SPA-2010-1-263435). It is aimed at the identification of spatial explicit indicators of habitat fragmentation (i.e., landcape pattern indices computable form EO products) and of the characterization of their relations with biodiversity surrogates (e.g., species assemblages descriptors) through habitat and landscape modelling.



Theoretical conceptual model (Didham et al 2012 modified)



$$y_{ij} = \mathbf{X}_{ij}\boldsymbol{\beta} + \mathbf{z}_{i,j} + \varepsilon_{ij}$$

$i = 1,\ldots,20$ and $j = 1,\ldots,n_i$
y_{ij} = response variable
$\mathbf{X}$ = design matrix of fixed effects (H, M, I, A, E, S)
$\mathbf{z}_{i,j}$ = random effects
$\boldsymbol{\beta}$ = fixed effects parameter vector
ε_{ij} = random measurement error

Methods

The investigation was based on a hierarchical conceptual model of potential direct and indirect causal relations between landscape and patch level attributes relevant to the process of habitat fragmentation affecting a measured response variable (Didham et al. 2012).

EO image features were used as response variables as these represent some aspects of the proximate mechanisms (e.g., resource availability, vegetation structure) through which species community descriptors computed from measured field data might be explained.

A hierarchical nested sampling strategy was adopted at three observation extent levels (landscape, patch, plot) in a Natura 2000 site in southern Italy where semi-natural grasslands are the habitat of main conservation concern. Landscape pattern indices were computed at both landscape (1 km^2) and patch level, whereas EO image measures were collected at the plot level (111 5x80m transects) from a DigitalGlobe™ Worldview-2, April 2011 closest to the conditions corresponding to high biomass and species richness in the study area.

Selected EO data included both spectral and statistical features (Normalized Difference Vegetation Index (NDVI), and three Grey Level Co-occurrence Matrixes (GLCM) metrics). The setting of the values of GLCM algorithms' parameters (window size, quantization, shift and direction) likely to affect the scale even if the image spatial resolution is not altered, was guided by the perception limits of different organisms (herbaceous plants, insects and birds) and three window sizes were tested (3, 15, and 31 pixels).

A linear mixed effects model was adopted to evaluate the interrelations among LPIs and relations between LPIs and each of the EO variables (Pinheiro and Bates, 2000).

Results

The results show that **for any given EO variable**, and **for any given computation scale, the application of the model may involve a subset of the full range of potential interrelations and relations**. While confirming the potential of VHR EO for landscape modelling aimed at habitat quality change detection in connection to habitat fragmentation, we verify that **great care should be taken with regard to the scaling issues behind the assumptions related to the selection of the extent and the grain of the analysis with regard to any target taxonomic group**.

NDVI_mean ~ M + A + S + E + S:E

	Value	Std.Error	DF	t-value	p-value
(Intercept)	21008532	0.6815483	87	3.082.471	0.0027
M	-0.0624491	0.0193171	18	-4.268.187	0.0005
A	-0.0001475	0.0000610	87	-2416776	0.0177
S	-13678870	0.6234216	87	-2194160	0.0309

NDVI_std ~ M + A + S + E + S:E

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0	0.00667984	90	9.850919	0
I	0	0.00024543	17	-2.258884	0.0373
A	-7.571E-05	3.3514E-05	90	-2.25892	0.0263
I:H	0.00003441	1.9349E-05	17	1.778676	0.0932

IMC_mean_3 ~ I + A + E + I:A

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.019774159	0.029340015	88	0.6739656	0.5021
I	-0.000483636	0.000230658	18	-20.967.717	0.0504
A	-0.000115000	0.000055693	88	-20.574.899	0.0426
E	0.001329202	0.000676821	88	19.638.895	0.0527
I:A	0.000224850	0.000010341	88	21.743.359	0.0324

CON_mean_3~ H + A + S + I:A

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.30045082	0.15832368	88	1.897.597	0.0610
H	0.00100558	0.00060669	18	1.657.479	0.1147
A	-0.00024370	0.00008410	88	-2.897.789	0.0047
S	0.29521648	0.14033584	88	2.103.643	0.0383
A:I	-0.00003265	0.00001493	88	-2.200.460	0.0304

IDM_mean_3 ~ I:A

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.7533994	0.012356471	90	6.096.218	0.0000
I:A	-0.0000327	0.000013968	90	-234.332	0.0213

log(IMC_mean_15) ~ I + A + S + H:I + H:A

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-28.451.141	0.8365449	88	-3.401.030	0.0010
I	-0.0101040	0.0034924	17	-2.893.129	0.0101
A	-0.0040511	0.0015305	88	-2.646.902	0.0096
S	25.030.272	0.7629678	88	3.280.646	0.0015
I:H	0.0006685	0.0002804	17	2.384.579	0.0290
A:H	0.0000519	0.0000242	88	2.142.240	0.0349

log(CON_mean_15) ~ H + I + A + H:I

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.4196284	0.24317316	90	1.725.636	0.0878
H	-0.0059565	0.00540735	16	-1.101.564	0.2869
I	-0.0103085	0.00553171	16	-1.863.528	0.0808
A	-0.0013332	0.00063643	90	-2.088.302	0.0396
H:I	0.0009300	0.00037487	16	2.480.881	0.0246

log(IDM_mean_15) ~ H + M1_SHDI + I + A + H:I + H:A + S:E

	Value	Std.Error	DF	t-value	p-value
(Intercept)	-0.8915961	0.3639075	88	-2.450.062	0.0163
H	-0.0077489	0.0047266	15	-1.639.422	0.1219
M	0.4154367	0.1686573	15	2.463.200	0.0263
I	-0.0069376	0.0050536	15	-1.372.737	0.1900
A	-0.0041290	0.0017405	88	-2.379.036	0.0196
H:I	0.0006235	0.0003599	15	1.735.355	0.1032
H:A	0.0000506	0.0000285	88	1.756.369	0.0825
S:E	0.0248956	0.0047362	88	5.256.491	0.0000

IMC_mean_31 ~ I + A + H:I + I:A + S:E

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.7943144	0.03220865	88	24.661.526	0.0000
I	0.0012674	0.00039223	17	3.231.172	0.0049
A	0.0000201	0.00006650	88	0.302560	0.7629
I:H	-0.0001182	0.00002987	17	-3.957.309	0.0010
I:A	0.0000236	0.00001257	88	1.874.023	0.0642
S:E	-0.0017428	0.00066406	88	-2.624.482	0.0102

CON_mean_31 ~ M1_SHDI + A

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.7326071	0.021975963	90	3.333.675	0.0000
M	-0.0439572	0.019150040	18	-229.541	0.0339
A	0.0001349	0.000069796	90	193.268	0.0564

IDM_mean_31 ~ M1_SHDI + H:I + I:A

	Value	Std.Error	DF	t-value	p-value
(Intercept)	0.7425752	0.017166124	90	4.325.817	0.0000
M	-0.0399749	0.016447230	17	-243.049	0.0264
H:I	-0.0000867	0.000021649	17	-400.677	0.0009
I:A	0.0000268	0.000011813	90	226.846	0.0257

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