Measuring alpha and beta diversity by field and remote sensing data: A challenge for coastal dunes biodiversity monitoring

Flavio Marzialetti [1,*], Silvia Cascone [2], Ludovico Frate [1], Mirko Di Febbraro [1], Alicia Teresa Rosario Acosta [2] and Maria Laura Carranza [1]

[1] Envix-Lab, Departement of Biosciences and Territory, Molise University, Contrada Fonte Lappone, 86090 Pesche (Is).; flavio.marzialetti@unimol.it (F. M.); frateludovico@gmail.com (L. F.); mirko.difebbraro@unimol.it (M. D. F.); carranza@unimol.it (M. L. C.)

[2] Department of Sciences, Roma Tre University, Viale G. Marconi 446, 00146 Rome, Italy; silvia.cascone@uniroma3.it (S. C.); aliciateresarosario.acosta@uniroma3.it (A. T. R. A.)

* Correspondence: flavio.marzialetti@unimol.it; Tel.: +39 3291543594

Table S1. PlanetScope images selected accounting of the geographic and temporal distribution of field collected vegetation plots. For each image we reported: the satellite, the date and the hour of acquisition, the product level, the cloud percentage, the zenith angle of acquisition, the coordinate of the center of each multispectral image, the name of cities and geographic area covered and the administrative Province in brackets (RM: Rome; LT: Latina; VT: Viterbo).

Satellite	Date	Hour	Level	Cloud (%)	Zenith angle	Coordinate of center	Cities and geographic area
0e2f	27/05/2017	09.19	3B	0	3.785	12.1936675271 41.9379571084	Passoscuro – Fiumicino, (RM)
102d	31/05/2017	09.07	3B	1	9.172	13.3541468572 41.2546364732	Terracina – Sperlonga (LT)
1001	02/05/2017	09.10	3B	1	7.728	12.4889034354 41.5776757004	Tor San Lorenzo – Ardea (RM)
1001	02/05/2017	09.10	3B	1	7.854	12.469110219 41.5104592855	Tor San Lorenzo – Ardea (RM)
1033	20/05/2018	09.25	3B	0	1.751	12.6713729304 41.5264322048	Tor San Lorenzo – Ardea (RM)
1024	26/05/2018	09.30	3B	0	1.274	11.5377771274 42.3621860846	Montalto di Castro – Tarquinia (VT)
1024	26/05/2018	09.30	3B	0	1.385	11.5180971353 42.2968474549	Montalto di Castro – Tarquinia (VT)
1035	04/05/2020	09.41	3B	0	4.390	12.431300301 41.6706456578	Castel Porziano – Torvaianica (RM)
1025	22/05/2020	09.37	3B	0	2.147	12.6736592396 41.4095091625	Astura – Nettuno (LT)
1040	31/05/2020	09.40	3B	5	5.516	13.0277337974 41.3654442532	San Felice Circeo – Sabaudia (LT)
1040	31/05/2020	09.40	3B	5	5.503	13.0085585357 41.3000635355	San Felice Circeo – Sabaudia (LT)
1040	31/05/2020	09.40	3B	0	5.504	12.9888313645 41.234645998	San Felice Circeo – Sabaudia (LT)

Table S2. Results of permutation marginal regressions, indicating the significance of estimates in all three linear regression (Species Richness – Distance to Centroid, Shannon Index – Distance to centroid, Simpson Index – Distance to Centroid) after 5000 permutations. P-value: * < 0.05; ** < 0.01; *** < 0.001.

Species Richness – Distance to centroid	**p-value after 5000 permutations**
Distance to centroid: Shifting dunes	0.0001***
Distance to centroid: Transition dunes	0.0001***
Distance to centroid: Invaded dunes	0.0001***
Shannon Index – Distance to centroid	**p-value after 5000 permutations**
Distance to centroid: Shifting dunes	0.0212*
Distance to centroid: Transition dunes	0.0006***
Distance to centroid: Invaded dunes	0.0010**
Inverse Simpson Index – Distance to centroid	**p-value after 5000 permutations**
Distance to centroid: Shifting dunes	0.0086**
Distance to centroid: Transition dunes	0.0004***
Distance to centroid: Invaded dunes	0.0004***

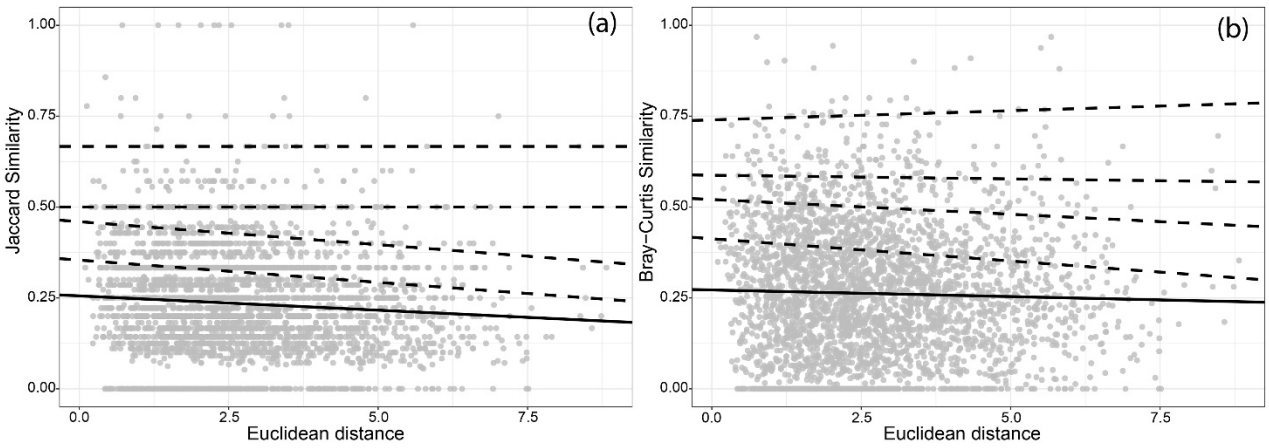

Figure S1. Distance Decay Models of species similarity, Jaccard (**a**) and Bray-Curtis (**b**), versus spectral distance (spectral pairwise Euclidean distance) considering Shifting dunes (N14 EUNIS category). The linear regression is described by solid line, the quantile regressions considering four different τ (from upper to lower lines: 0.99, 0.95, 0.90, 0.75) are reported by dashed lines. Gray dots represent the sampling plots.

Table S3. Results of Distance Decay Models calculated by linear regression model and quantile regression at four different τ values (from upper to lower lines: 0.99, 0.95, 0.9, 0.75), considering the vegetation plots and the pixels of Shifting dunes (N14 EUNIS category). P-value: * < 0.05; ** < 0.01; *** < 0.001.

Jaccard similarities – Euclidean distance

Regression type	τ	Intercept	Intercept boundaries (99%)	decay rate	decay rate boundaries (99%)
Linear regression	–	0.256***	0.238 – 0.275	-0.049***	-0.084 – -0.013
Quantile	0.75	0.353***	0.333 – 0.371	-0.073***	-0.106 – 0.000
	0.90	0.463***	0.435 – 0.505	-0.082***	-0.160 – -0.033
	0.95	0.500***	0.500 – 0.568	0.000	-0.156 – 0.000
	0.99	0.667***	0.631 – 0.854	0.000	-0.262 – 0.123

Bray-Curtis similarities – Euclidean Distance

Regression type	τ	Intercept	Intercept boundaries (99%)	decay rate (10^{-2})	decay rate (10^{-2}) boundaries (99%)
Linear regression	–	0.272***	0.250 – 0.295	-0.365	-1.081 – 0.351
Quantile	0.75	0.413***	0.386 – 0.440	-1.222***	-1.963 – -0.379
	0.90	0.521***	0.484 – 0.564	-0.810	-2.245 – 0.481
	0.95	0.587***	0.555 – 0.648	-0.201	-2.048 – 1.047
	0.99	0.740***	0.688 – 0.796	0.505	-1.202 – 4.509

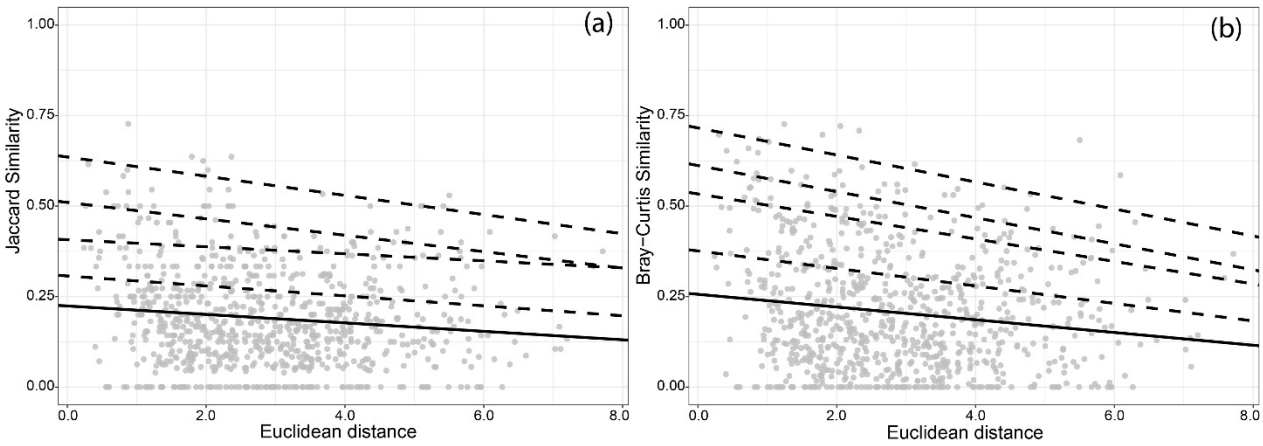

Figure S2. Distance Decay Models of species similarity, Jaccard (**a**) and Bray-Curtis (**b**), versus spectral distance (spectral pairwise Euclidean distance) considering the vegetation plots and the pixels of Transition dunes (N16 EUNIS category. The linear regression is described by solid line, the quantile regressions considering four different τ (from upper to lower lines: 0.99, 0.95, 0.90, 0.75) are reported by dashed lines. Gray dots represent the sampling plots.

Table S4. Results of Distance Decay Models calculated by linear regression model and quantile regression at four different τ values (from upper to lower lines: 0.99, 0.95, 0.9, 0.75), considering the vegetation plots and the pixels of Transition dunes (N16 EUNIS category). P-value: * < 0.05; ** < 0.01; *** < 0.001.

Jaccard similarities – Euclidean distance					
Regression type	τ	Intercept	Intercept boundaries (99%)	decay rate (10^{-2})	decay rate (10^{-2}) boundaries (99%)
Linear regression	–	0.224***	0.189 – 0.260	-1.168***	-2.268 – -0.067
Quantile	0.75	0.307***	0.267 – 0.364	-1.374	-3.022 – 0.127
	0.90	0.407***	0.357 – 0.509	-0.973	-4.031 – 0.403
	0.95	0.510***	0.430 – 0.573	-2.267***	-3.911 – -0.276
	0.99	0.635***	0.576 – 0.749	-2.649**	-4.132 – -0.374
Bray-Curtis similarities – Euclidean Distance					
Regression type	τ	Intercept	Intercept boundaries (99%)	decay rate (10^{-2})	decay rate (10^{-2}) boundaries (99%)
Linear regression	–	0.256***	0.214 – 0.299	-1.759***	-3.082 – -0.436
Quantile	0.75	0.376***	0.316 – 0.452	-2.417***	-4.427 – -0.441
	0.90	0.534***	0.491 – 0.594	-3.108***	-4.892 – -1.718
	0.95	0.612***	0.535 – 0.673	-3.602***	-5.302 – -1.646
	0.99	0.716***	0.658 – 0.804	-3.73*	-5.459 – 0.581

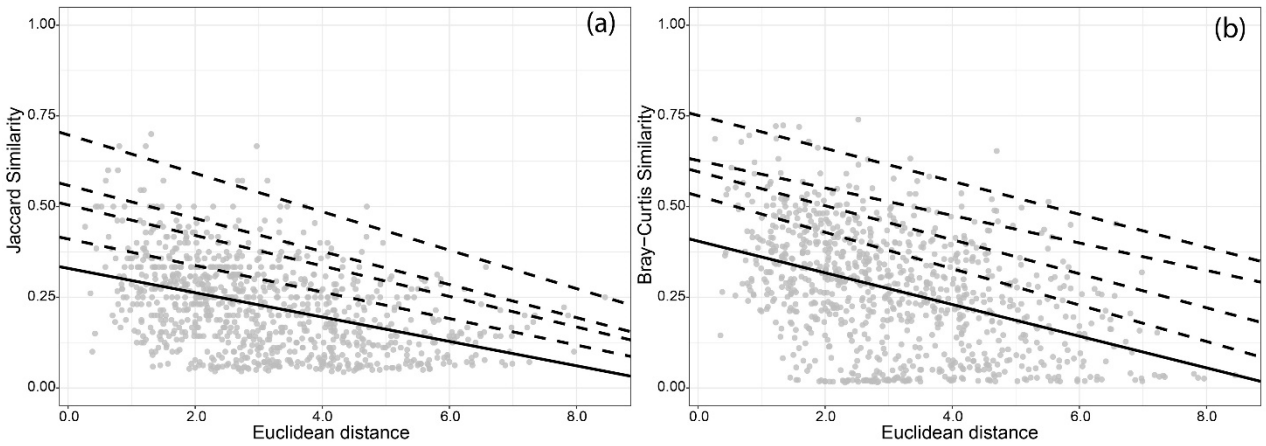

Figure S3. Distance Decay Models of species similarity, Jaccard (**a**) and Bray-Curtis (**b**), versus spectral distance (Euclidean distance) considering the vegetation plots and the pixels invaded by *Carpobrotus* spp., Invaded category. The linear regression is described by solid line, the quantile regressions considering four different τ (from upper to lower lines: 0.99, 0.95, 0.90, 0.75) are reported by dashed lines. Gray dots represent the sampling plots.

Table S5. Results of Distance Decay Models calculated by linear regression model and quantile regression at four different τ values (from upper to lower lines: 0.99, 0.95, 0.9, 0.75), considering the vegetation plots and the pixels invaded by *Carpobrotus* spp., Invaded category. P-value: * < 0.05; ** < 0.01; *** < 0.001.

Jaccard similarities – Euclidean distance					
Regression type	τ	Intercept	Intercept boundaries (99%)	decay rate (10^{-2})	decay rate (10^{-2}) boundaries (99%)
Linear regression	–	0.330***	0.301 – 0.358	-3.357***	-3.018 – -3.577
Quantile	0.75	0.411***	0.383 – 0.445	-3.657***	-4.560 – -2.815
	0.90	0.505***	0.460 – 0.525	-4.204***	-4.943 – -3.078
	0.95	0.558***	0.503 – 0.609	-4.557***	-5.571 – -3.126
	0.99	0.698***	0.626 – 0.791	-5.299***	-6.832 – -2.232
Bray-Curtis similarities – Euclidean Distance					
Regression type	τ	Intercept	Intercept boundaries (99%)	decay rate (10^{-2})	decay rate (10^{-2}) boundaries (99%)
Linear regression	–	0.405***	0.368 – 0.441	-4.367***	-5.421 – -3.313
Quantile	0.75	0.529***	0.484 – 0.564	-5.016***	-6.131 – -3.679
	0.90	0.596***	0.551 – 0.639	-4.688***	-6.027 – -2.938
	0.95	0.627***	0.562 – 0.721	-3.788***	-6.789 – -1.964
	0.99	0.751***	0.717 – 0.820	-4.544***	-6.344 – -2.105