Regional Environmental Change

Bioclimatic habitat limitations for argan trees (*Argania spinosa* (L.) Skeels) in Northern Africa and Spain

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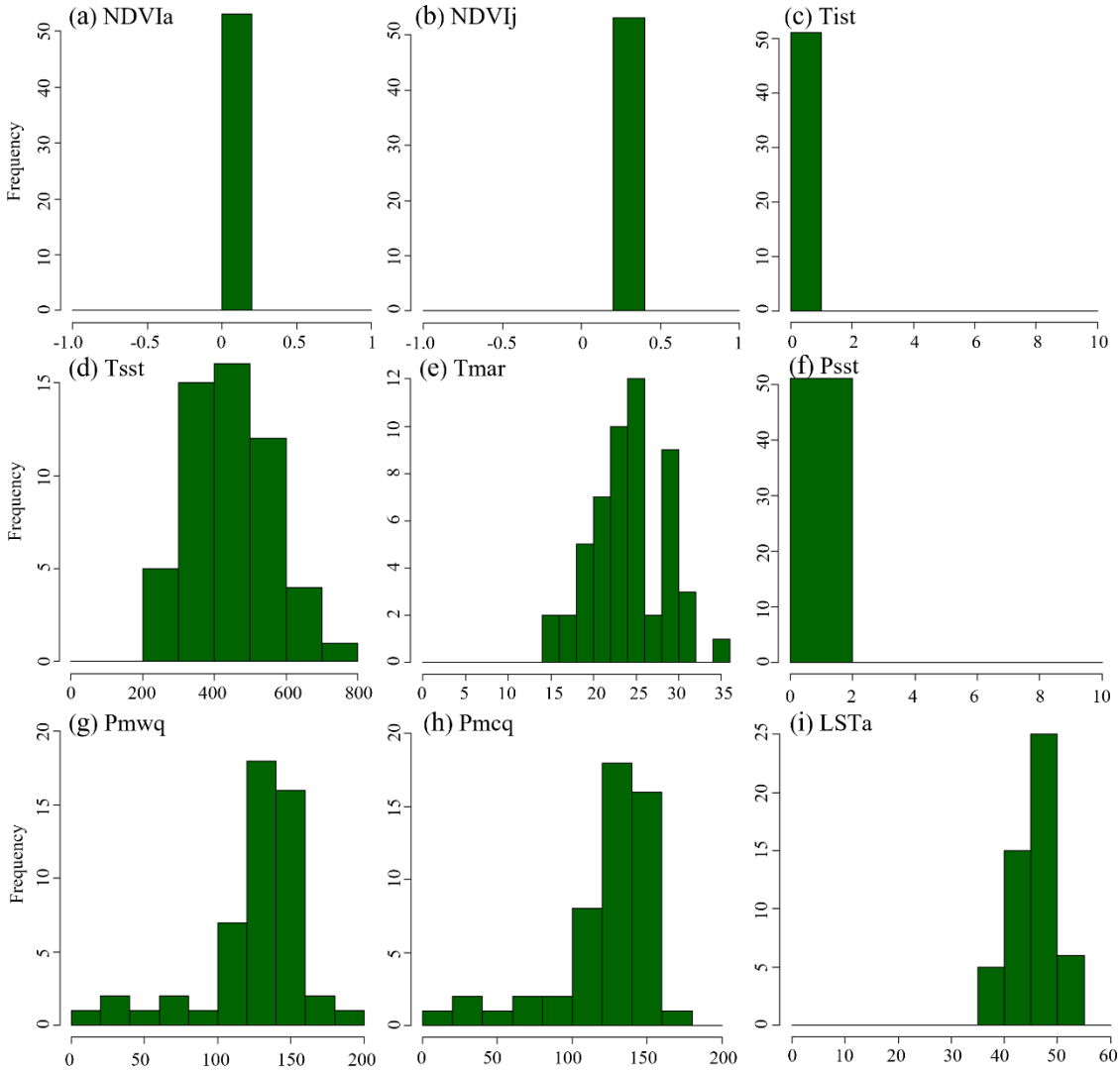
Online Resource 1 Argan occurrence points used in the analysis. WGS84 geographic system. GBIF Occurrence Download https://doi.org/10.15468/dl.gwfscj

ID	Latitude	Longitude	Elev (m)	Country	Province
1	28.46	-8.15	529	Algeria	Tindouf
2	28.43	-9.42	329	Morocco	Assa-Zag
3	27.16	-13.23	26	Morocco	Laayoune
4	32.03	-9.32	64	Morocco	Safi
5	31.94	-9.40	99	Morocco	Safi
6	31.32	-9.57	239	Morocco	Essaouira
7	30.60	-9.68	198	Morocco	Agadir-Ida ou Tanane
8	30.60	-9.65	295	Morocco	Agadir-Ida ou Tanane
9	31.51	-9.64	171	Morocco	Essaouira
10	31.61	-9.66	164	Morocco	Essaouira
11	30.40	-9.58	30	Morocco	Agadir-Ida ou Tanane
12	31.79	-9.40	313	Morocco	Essaouira
13	31.54	-9.48	266	Morocco	Essaouira
14	31.36	-9.38	523	Morocco	Essaouira
15	31.01	-9.62	534	Morocco	Essaouira
16	31.64	-9.17	372	Morocco	Essaouira
17	30.40	-9.51	59	Morocco	Agadir-Ida ou Tanane
18	31.05	-9.68	294	Morocco	Essaouira
19	35.09	-2.80	26	Morocco	Nador
20	35.04	-2.75	184	Morocco	Nador
21	34.85	-2.57	217	Morocco	Berkane Taourirt
22	31.04	-9.38	923	Morocco	Essaouira
23	30.29	-8.49	1237	Morocco	Taroudannt
24	30.81	-8.40	1195	Morocco	Taroudannt
25	30.65	-9.52	1066	Morocco	Agadir-Ida ou Tanane
26	30.73	-9.23	854	Morocco	Taroudannt
27	30.62	-8.11	789	Morocco	Taroudannt
28	30.50	-7.87	1332	Morocco	Taroudannt
29	30.53	-7.89	1029	Morocco	Taroudannt
30	30.62	-8.09	902	Morocco	Taroudannt
31	30.75	-9.13	843	Morocco	Taroudannt
32	30.78	-9.16	938	Morocco	Taroudannt
33	30.79	-8.38	996	Morocco	Taroudannt
34	31.09	-9.01	1242	Morocco	Chichaoua
35	36.17	1.33	124	Algeria	Chlef
36	30.82	-8.40	1275	Morocco	Taroudannt
37	29.40	-9.73	939	Morocco	Tiznit
38	30.29	-8.50	1196	Morocco	Taroudannt
39	33.46	-6.37	450	Morocco	Khemisset
40	29.71	-9.06	841	Morocco	Tiznit
41	29.72	-8.87	1413	Morocco	Tiznit
42	31.58	-9.03	385	Morocco	Chichaoua
43	31.59	-9.02	386	Morocco	Chichaoua
44	30.33	-9.36	88	Morocco	Inezgane-Aït Melloul
45	30.56	-9.09	253	Morocco	Taroudannt
46	30.11	-9.23	488	Morocco	Chtouka-Aït Baha
47	30.50	-9.16	151	Morocco	Taroudannt
48	30.37	-9.10	162	Morocco	Taroudannt
49	29.11	-10.11	389	Morocco	Tiznit
50	28.97	-10.08	254	Morocco	Guelmim
51	29.24	-10.08	392	Morocco	Tiznit
52	35.73	-0.26	96	Algeria	Mascara*
53	35.80	-0.07	37	Algeria	Mostaganem*
54	30.42	-9.38	98	Morocco	Agadir Ida Outanane*
55	30.45	-9.55	231	Morocco	Agadir Ida Outanane*
56	34.86	-2.59	156	Morocco	Berkane*
57	30.68	-9.25	795	Morocco	Taroudant*
58	38.35	-0.49	30	Spain	Alicante*
59	38.35	-0.51	48	Spain	Alicante*
60	37.89	-0.76	16	Spain	Alicante*
61	38.42	-0.42	48	Spain	Alicante*
62	38.49	-0.48	221	Spain	Alicante*
63	38.38	-0.45	23	Spain	Alicante*
64	38.39	-0.46	51	Spain	Alicante*
65	38.06	-1.17	184	Spain	Murcia*

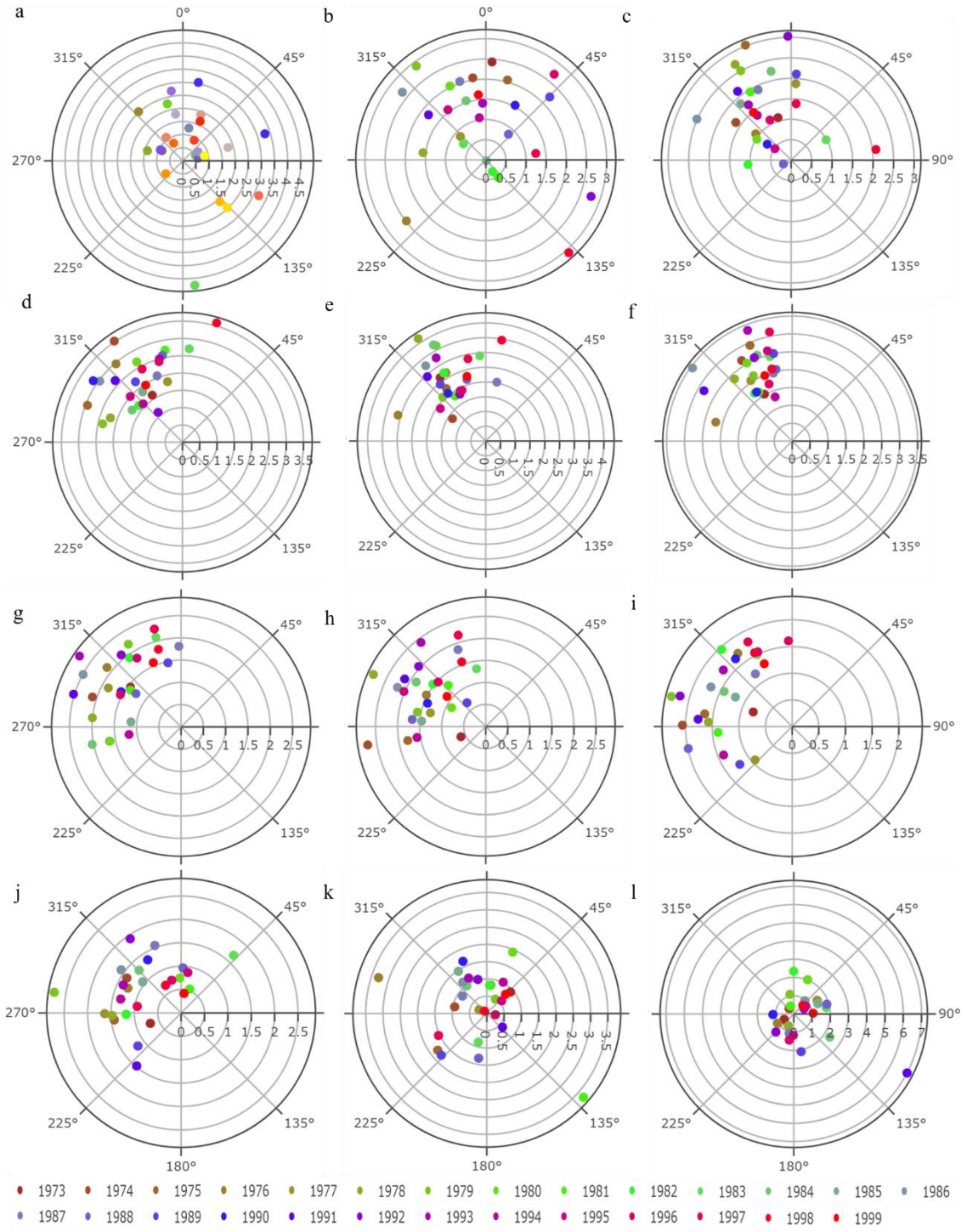
*Samples added to the suitability analysis

Online Resource 2 Descriptive statistics of the variables used in the analysis

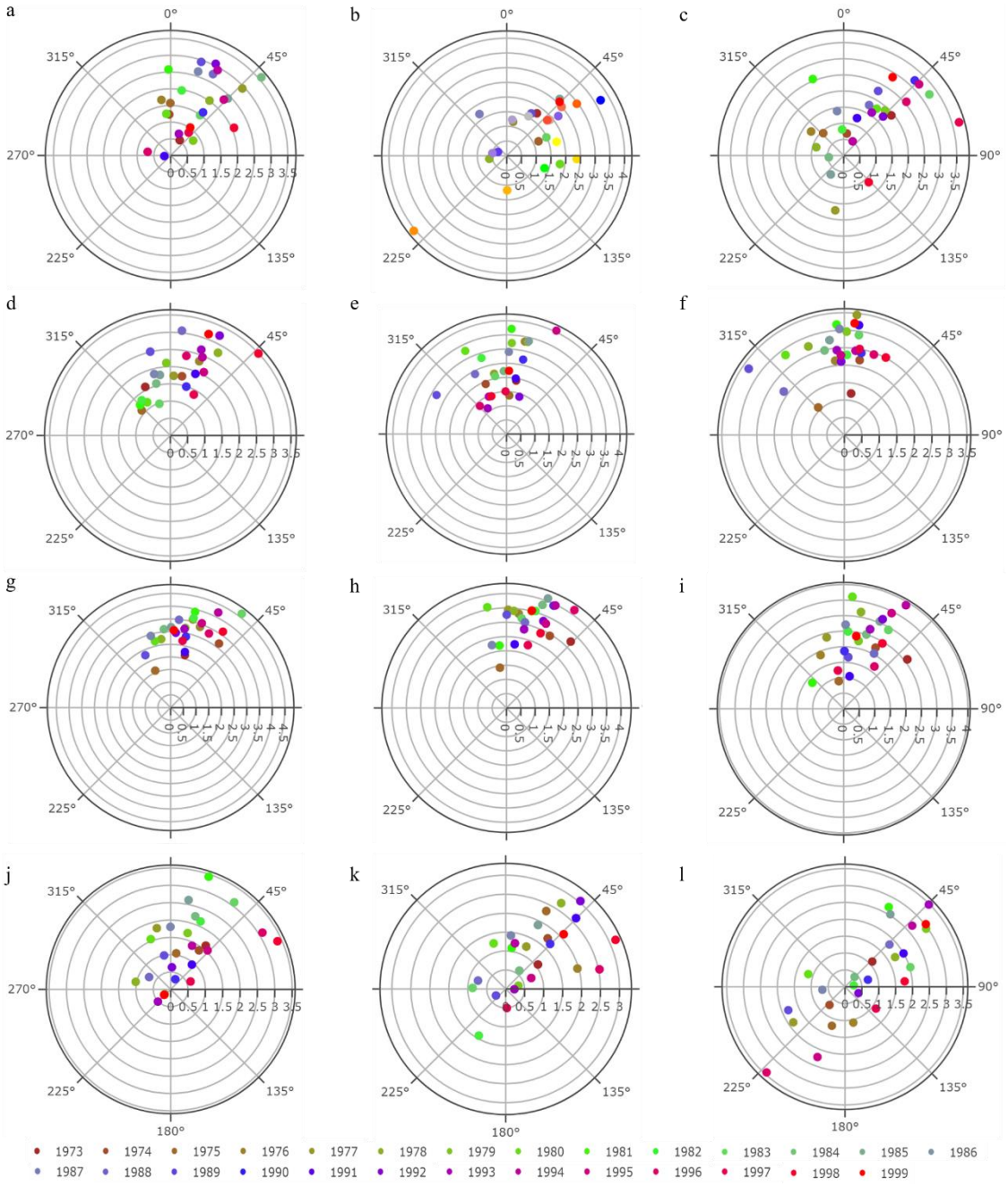
Code	Variable	Mean	Max	Min	SD
Temp	Annual Mean Temperature	17.87	22.24	14.00	1.65
Tmdr	Mean Diurnal Range temperature	10.97	13.58	7.86	1.14
Tmwm	Max Temperature of Warmest Month	30.25	39.60	25.00	2.57
Tncm	Min Temperature of Coldest Month	5.88	12.00	1.30	2.42
Tmar	Temperature Annual Range	24.38	34.30	15.90	4.00
Prec	Annual Precipitation	273.49	427.00	28.00	89.05
Pmwm	Precipitation of Wettest Month	48.53	69.00	8.00	12.76
Pmdm	Precipitation of Driest Month	0.78	2.00	0.00	0.58
Pmdq	Precipitation of Driest Quarter	7.04	16.00	1.00	3.83
Elev	Elevation	538.51	1413.00	26.00	420.62
Dai	Global Aridity Index	0.14	0.24	0.01	0.05
Devt	Evapotranpiration	1969.33	3224.00	153.00	296.83



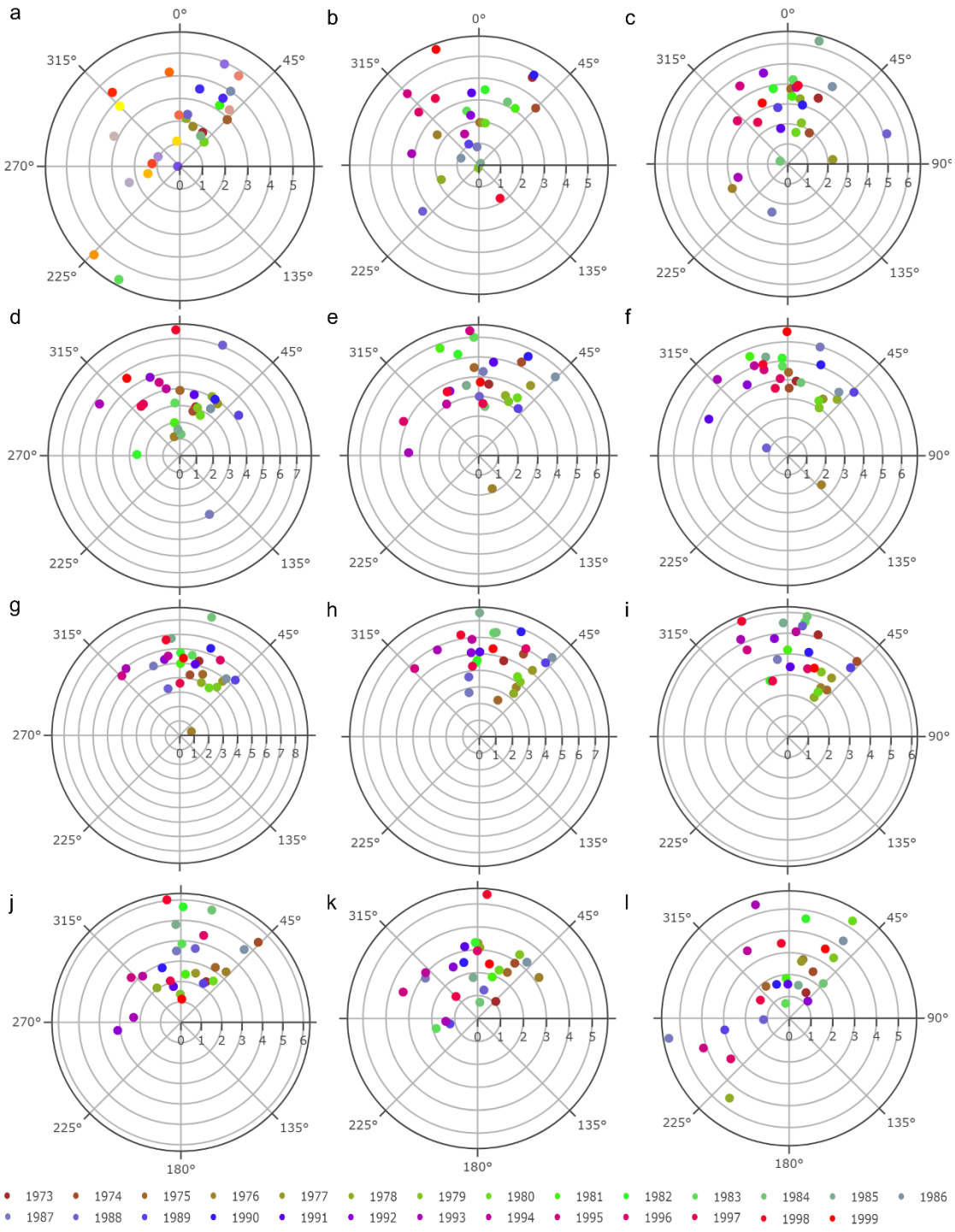
Online Resource 3 Frequency distribution of rest of bioclimatic variables in North Africa (n = 51). (a) Normalized Difference Vegetation Index April 2002 (NDVIa). (b) Normalized Difference Vegetation Index April 2002 (NDVIj). (c) Isothermality (Tmdr/Tmar) (Tist). (d) Temperature Seasonality (Tsst). (e) Temperature Annual Range (Tmar). (f) Precipitation Seasonality (Psst). (g) Precipitation of Wettest Quarter (Pmwq). (h) Precipitation of Coldest Quarter (Pmcq). (i) Land Surface Temperature April 2002 (LSTa)



Online Resource 4 Mean speed (m/s) and direction (degree) of the wind (period 1973-1999) at Sidi Ifni station. (a) January. (b) February. (c) March. (d) April. (e) May. (f) June. (g) July. (h) August. (i) September. (j) October. (k) November. (l) December



Online Resource 5 Mean speed (m/s) and direction (degree) of the wind (period 1973-1999) at Safi station. (a) January. (b) February. (c) March. (d) April. (e) May. (f) June. (g) July. (h) August. (i) September. (j) October. (k) November. (l) December



Online Resource 6 Mean speed (m/s) and direction (degree) of the wind (period 1973-1999) at Essaouira station. (a) January. (b) February. (c) March. (d) April. (e) May. (f) June. (g) July. (h) August. (i) September. (j) October. (k) November. (l) December

Online Resource 7 Clustering groups using 29 bioclimatic variables (Euclidean distance, and clustering algorithm using Kmeans)

Online Resource 8 Loadings and the accumulated variance explained by PCs

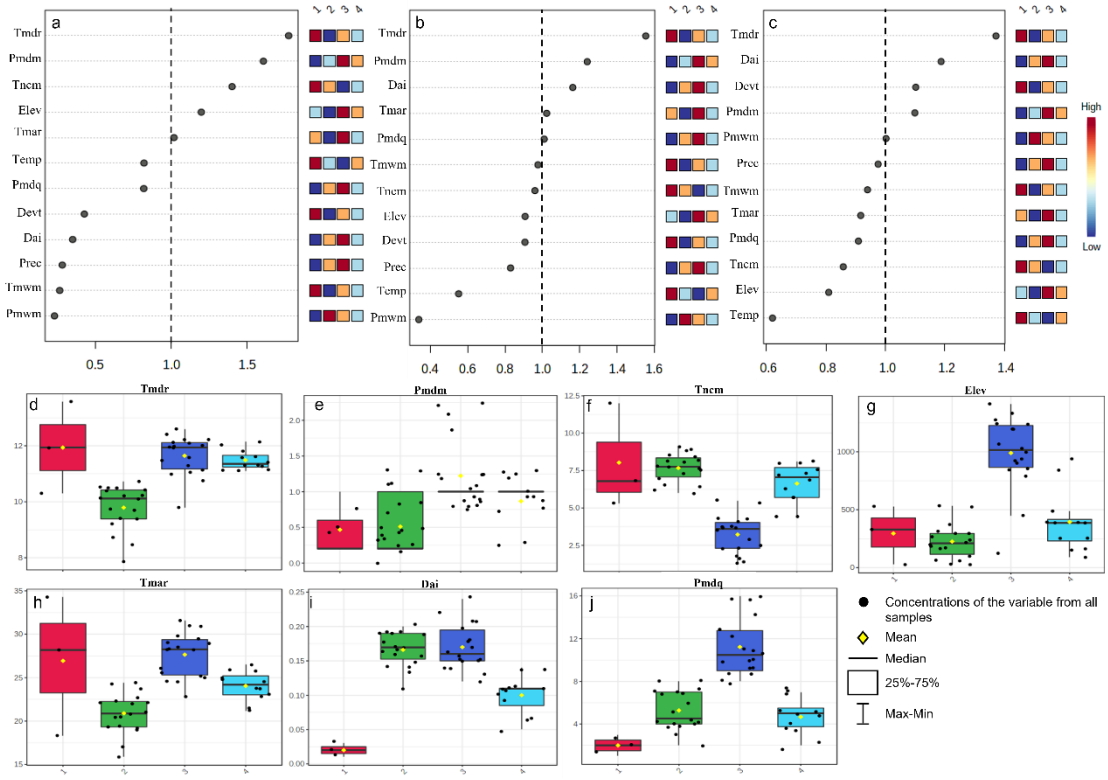
Code	Variable	Principal Component (PC)		
		1	2	3
Temp	Annual Mean Temperature	-0.21	0.21	-0.20
Tmdr	Mean Diurnal Range	0.17	0.25	0.00
Tist	Isothermality	-0.25	-0.07	0.17
Tsst	Temperature Seasonality	0.25	0.18	-0.13
Tmwm	Max Temperature of Warmest Month	0.10	0.30	-0.23
Tncm	Min Temperature of Coldest Month	-0.29	-0.03	-0.10
Tmar	Temperature Annual Range	0.24	0.21	-0.09
Tmwq	Mean Temperature of Wettest Quarter	-0.25	0.12	-0.06
Tmdq	Mean Temperature of Driest Quarter	0.04	0.29	-0.32
Tmwq	Mean Temperature of Warmest Quarter	0.00	0.31	-0.29
Tmcq	Mean Temperature of Coldest Quarter	-0.29	0.04	-0.09
Prec	Annual Mean Precipitation	0.21	-0.21	-0.20
Pmwm	Precipitation of Wettest Month	0.10	0.26	-0.27
Pmdm	Precipitation of Driest Month	0.21	-0.04	0.17
Psst	Precipitation Seasonality	-0.25	0.03	-0.04
Pmwq	Precipitation of Wettest Quarter	0.14	0.26	-0.24
Pmdq	Precipitation of Driest Quarter	0.27	0.09	0.04
Pmwq	Precipitation of Warmest Quarter	0.23	0.06	-0.09
Pmcq	Precipitation of Coldest Quarter	0.12	0.27	-0.24
Elev	Elevation	0.26	-0.01	0.25
Hshd	Hillshade	-0.04	0.04	-0.15
Aspt	Aspect	0.00	0.02	-0.13
Slop	Slope	0.16	0.05	0.34
LSTa	Land Surface Temperature April	0.17	-0.16	0.02
LSTj	Land Surface Temperature July	0.18	-0.20	-0.02
NDVIa	Normalized Difference Vegetation Index April	-0.03	0.10	-0.14
NDVIj	Normalized Difference Vegetation Index July	-0.03	0.01	-0.28
Dai	Global Aridity Index	0.14	0.27	-0.24
Dept	Evapotranspiration	0.08	-0.31	0.07
PV[a]		37.93	27.46	9.20
CP[b]		37.93	65.39	74.59

[a]Proportion of Variance. [b]Cumulative Proportion

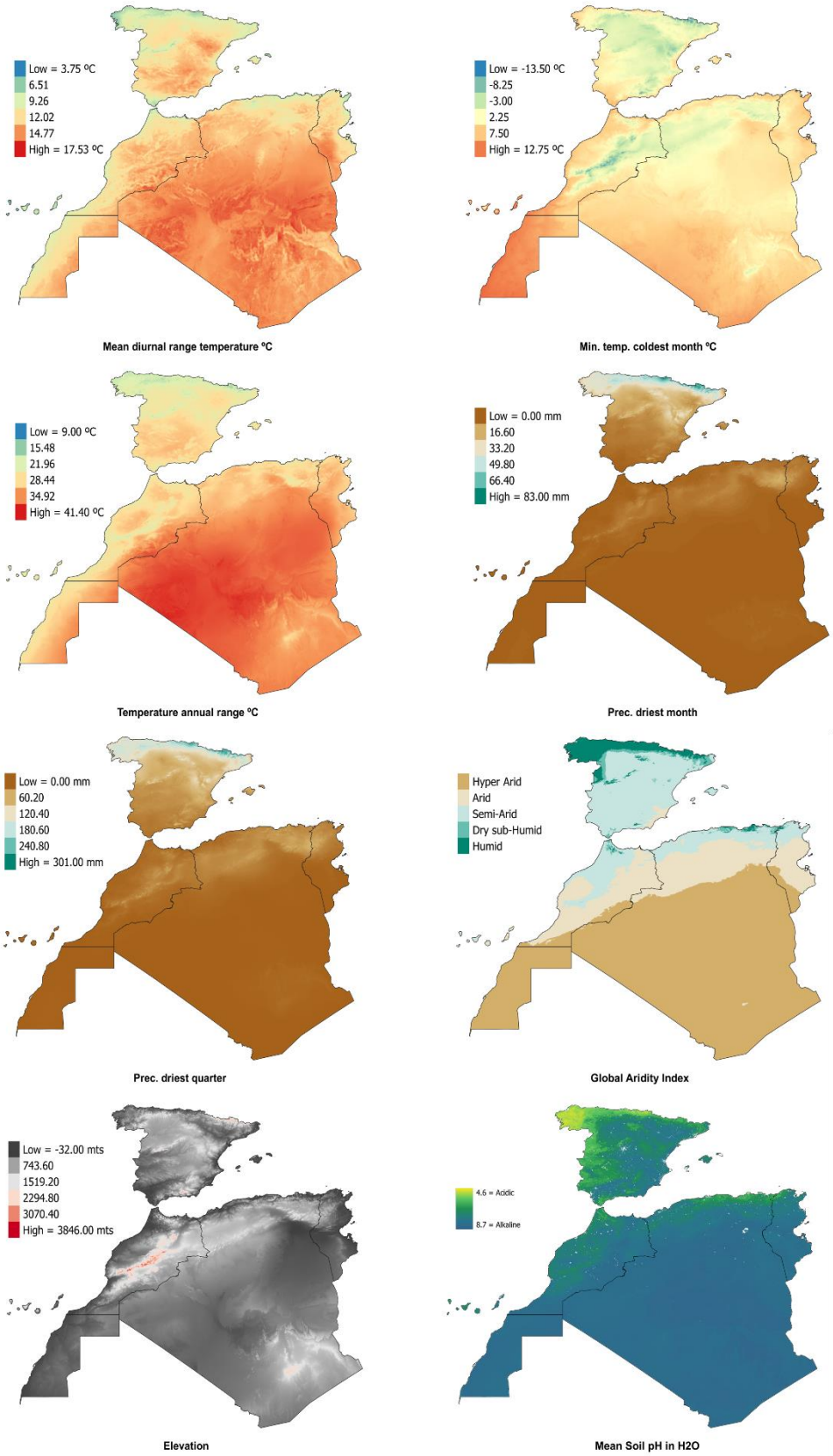
Online Resource 9 Clustering results using *K*means

Class	Group	Provinces (samples in each cluster)
1	Desert (*n* = 2)	Assa-Zag (02). Tindouf (01)*
2	Littoral (*n* = 18)	Agadir (17, 7, 8, 11). Essaouira (6, 9, 10, 12, 13, 14, 15, 16, 18). Nador (19, 20). Safi (4, 5). Berkane Taourirt (21).
3	Mountain (*n* = 18)	Agadir (25). Chichaoua (34). Essaouira (22). Taroudant (23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 36, 38). Tiznit (37). Khemisset (39). Chlef (35)*
4	Sublittoral (*n* = 13)	Chichaoua (42, 43). Chtouka-AitBaha (46). Guelmim (50). Inezgane-Ait Melloul (44). Laayoune** (3). Taroudant (45, 47, 48). Tiznit (40, 41, 49, 51).

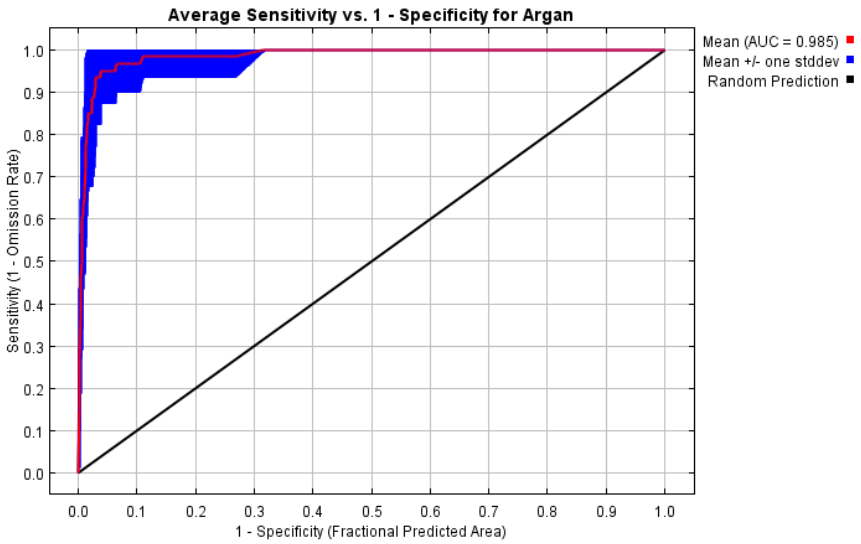
*Localities in Algeria. **Locality in Western Sahara. The rest of the localities belong to Morocco.



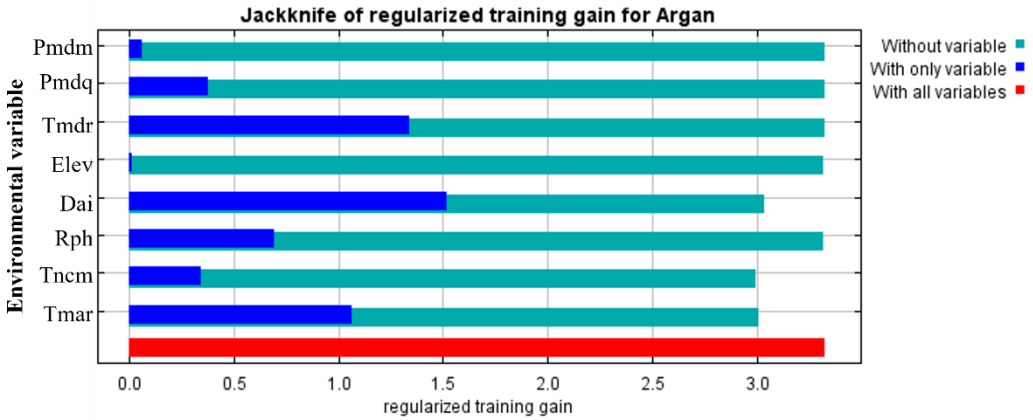
Online Resource 10 Important features identified by PLS-DA. (a) VIP score of Component 1. (b) VIP score of Component 2. (c) VIP score of Component 3. The colored boxes on the right indicate the relative concentrations of the variable in each group: Desert (1), Littoral (2), Mountain (3) and Sublittoral (4). Boxplots (The black dots represent the concentrations of the selected variable from all samples. The notch indicates the 95% confidence interval around the median of each group, defined as +/- 1.58 IQR/sqrt(n). The notch can be used to evaluate differences between groups; if the notches do not overlap, the medians are likely different. Meanwhile, the mean concentration of each group is indicated with a yellow diamond). (d) Mean Diurnal Range Temperature (Tmdr) boxplots. (e) Precipitation of the Driest Month (Pmdm) boxplots. (f) Min Temperature of the Coldest Month (Tncm) boxplots. (g) Elevation (Elev) boxplots. (h) Temperature Annual Range (Tmar). (i) Global Aridity Index (Dai) boxplots. (j) Precipitation of the Driest Quarter (Pmdq) boxplots



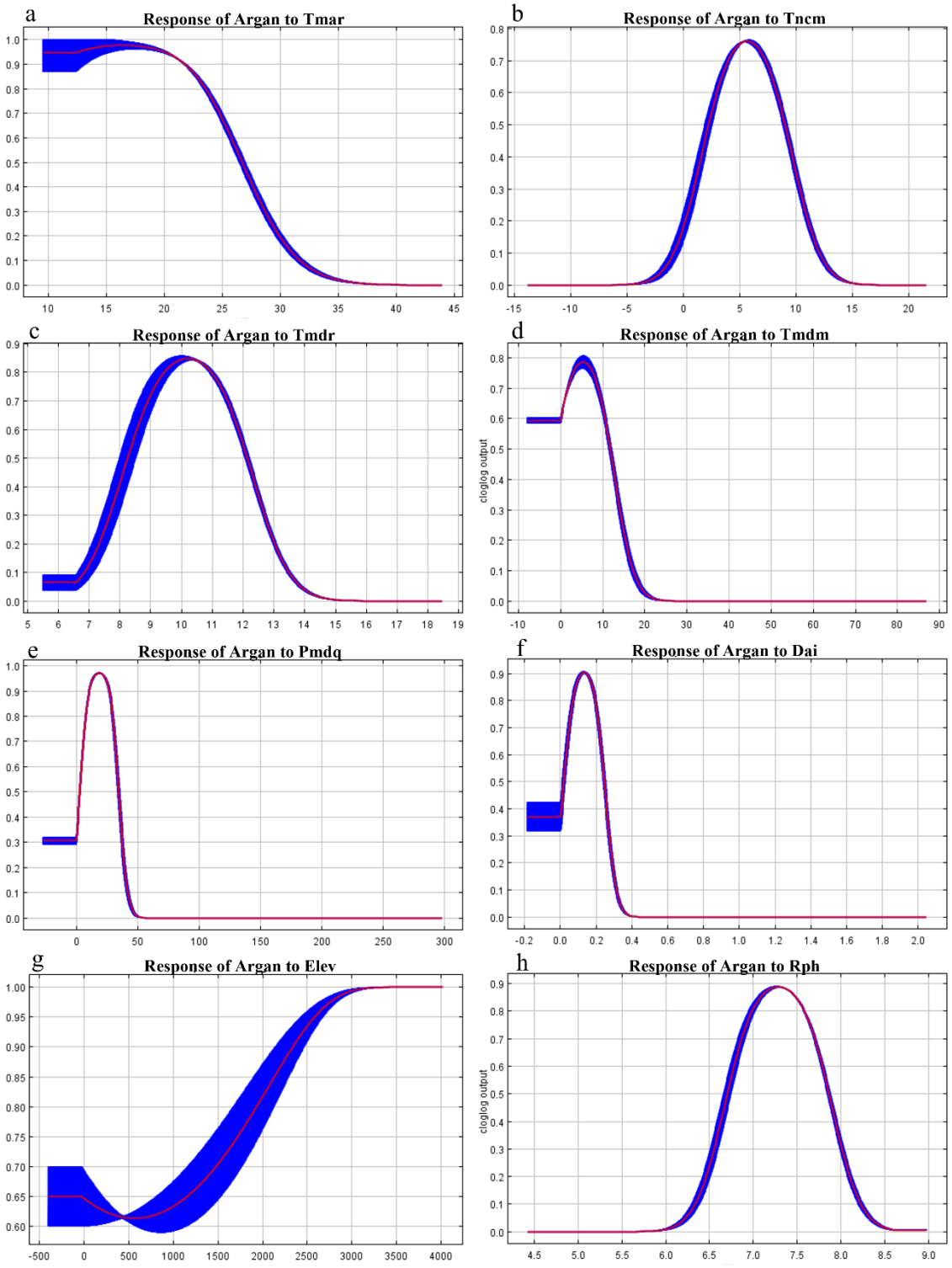
Online Resource 11 Environmental and climatic variables used to build the *A. spinosa* habitat suitability model



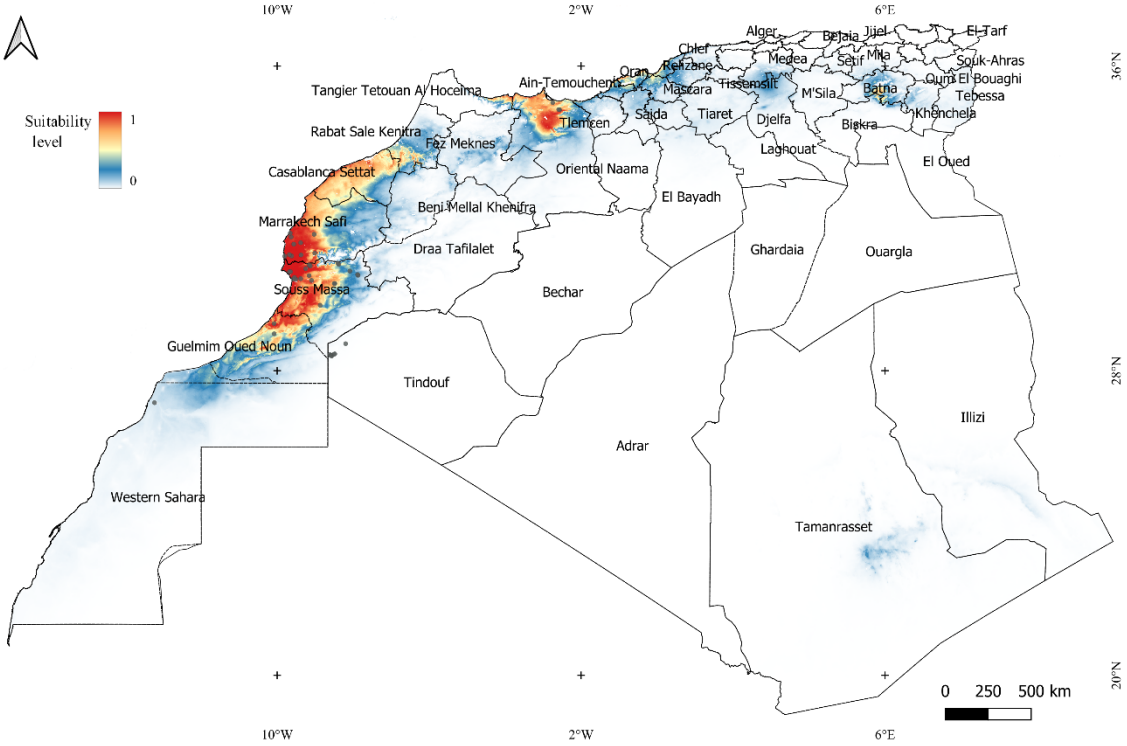
Online Resource 12 The average area under the curve (AUC) for 10 MaxEnt runs. The red line is the mean value. and the blue line represents ±1 standard deviation. The mean AUC value of 0.99 indicates an excellent model



Online Resource 13 Jackknife test of the importance of individual climatic and environmental variables (blue bars) in the development of the MaxEnt model relative to all climatic and environmental variables (red bar). Global Aridity index (Dai) is the most effective single variable for predicting the distribution of the occurrence data

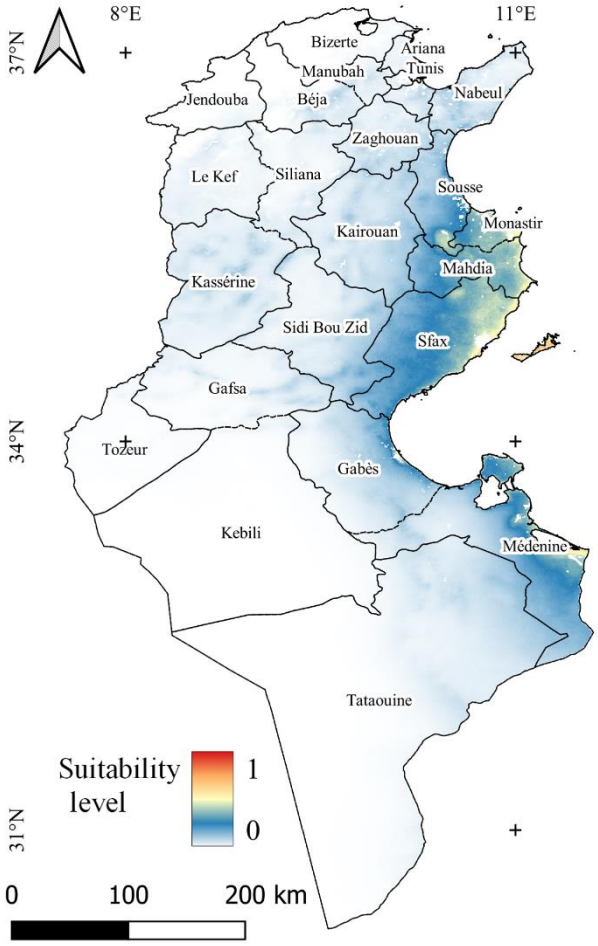


Online Resource 14 Response curves showing the relationships between the probability of presence and climatic and environmental predictors of *A. spinosa*



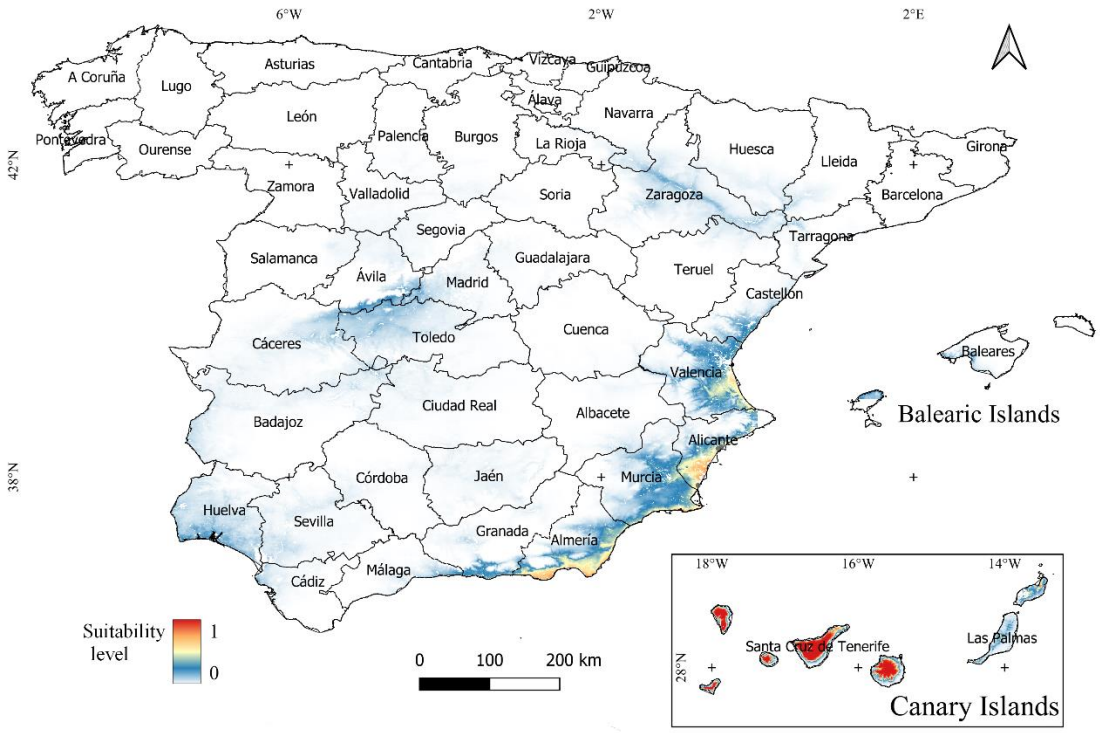
Online Resource 15 Potential distribution of *A. spinosa* in Morocco and Algeria generated by MaxEnt ecological niche modeling using 8 environmental variables: Mean diurnal range (Tmdr), minimum temperature of the coldest month (Tncm), temperature annual range (Tmar), precipitation of the driest month and quarter (Pmdm, Pmdq), elevation (Elev), aridity index (Dai) and Soil pH in H_2O (Dph). Bluer shades represent less suitability and redder ones represent more suitability

Morocco shows an extensive area with a high probability of success for argan in coherence with its greater real presence and the number of localities whose environmental conditions have trained and generated the suitability model. The more temperate and humid climates of the Tingitania and the Rif justify that the model does not identify these regions as suitable for argan (in fact other types of forests replace argan). There is other suitability area in the mediterranean coast, between Oujda (in the mountains of Beni-Snassen where argan is spontaneous) and the S of Oran and to the N of Djelfa. But the High Plateau (Haute Plateau) and the Saharan Atlas block towards the S that suitability and immediately appears the grand extension of the Sahara with both Western and Eastern Great Erg, and the extensive Saharan hamadas and chotts, that eliminate any possibility of argan cultivation.



Online Resource 16 Potential distribution of *A. spinosa* in Tunisia generated by MaxEnt ecological niche modeling using 8 environmental variables: Mean diurnal range (Tmdr), minimum temperature of the coldest month (Tncm), temperature annual range (Tmar), precipitation of the driest month and quarter (Pmdm, Pmdq), elevation (Elev), aridity index (Dai) and Soil pH in H_2O (Dph). Bluer shades represent less suitability and redder ones represent more suitability

Regarding Tunisia, the model recognizes the suitability from the Boukornine National Park (covered by a dense forest of *Tetraclinis articulata* with risk of forest fires and extinction) to the small chain of soft reliefs between Gabés and Tetaouine in the SE of the country.



Online Resource 17 Potential distribution of *A. spinosa* in Spain generated by MaxEnt ecological niche modeling using 8 environmental variables: Mean diurnal range (Tmdr), minimum temperature of the coldest month (Tncm), temperature annual range (Tmar), precipitation of the driest month and quarter (Pmdm, Pmdq), elevation (Elev), aridity index (Dai) and Soil pH in H_2O (Dph). Bluer shades represent less suitability and redder ones represent more suitability

The introduction of the pH variable reasonably eliminates the suitability of the western Iberian territory corresponding to the Hercinic Massif (half W of the Peninsula) of acidic soils. Inside, the growing area would go up the valley of the Guadalquivir until Cordoba avoiding Sierra Morena. The greatest probability of success would be in the province of Almeria, especially in two areas: the environment of Cabo de Gata and Campo de Nijar and the coastal region between El Ejido and Roquetas.