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Algerian *Inuleae* tribe species distribution modeling under influence of current and future climate conditions

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Abstract. This study aims to predict the impact of bioclimatic variables in current and future climatic scenarios on the distribution of *Inuleae* tribe species. Modeling the distribution of 30 species of the *Inuleae* tribe in Algeria was carried out with a maximum entropy model. Two models with 99 occurrence points were obtained with mean values of Area Under a Curve (AUC) of 0.987±0.01 and 0.971±0.02, reflecting excellent predictive power. Three bioclimatic variables contributed mainly to the first model and four - to the second one with cumulative contributions of 83.8% and 79%, respectively elucidating differences between species of the two major climatic zones in Algeria: the Tell and the Sahara. Two-dimensional niches of Algerian *Inuleae* species allowed to distinguish these two groups with the distribution of 18 Tell species, characterized by high rainfall (14-18°C, 400-1000 mm) and the other 12 species – distributed in hot and dry environments (17-24°C, 20-200 mm). Modeling the distribution under future conditions showed that habitats of the Saharan region would be much less suitable for these species with a variation in the annual mean temperature increase up to 20% and a decrease in annual precipitation, which could raise to 11 and 15%.

Key words: *Inuleae*, species distribution model, Algerian Tell and Sahara, Maximum entropy, RCP scenarios

1. Introduction

In recent years, prediction and mapping of favorable habitats and potential distributions of species have become important in biogeography and ecology to assess: the impact of climate change and to identify species collection areas or zones suitable for forest production (Elith *et al.* 2011; Pramanik *et al.* 2018); reasons why modeling tools of distribution of species have become much more popular and used in ecology and its applications; if generated models will establish relationships between the occurrence of species and the environmental and biophysical conditions of the study areas (Rodrigues *et al.* 2015; Pramanik *et al.* 2018); if this will help define the niche from the environmental values corresponding to presence points and calculate similarities between environmental values in a given raster cell as well as that of the niche of modeled species (Khanum *et al.* 2013; Pramanik *et al.* 2018).

Inuleae tribe (Asteraceae) comprises about 66 genera and approximately 690 species of which its largest genera are: *Inula* and *Pulicaria* (Nylinder & Anderberg 2015). Studies have focused on systematic aspects and phylogenetic relationships within this tribe (Osman 2006; Torices & Anderberg 2009; Nylinder & Anderberg 2015), while the distribution and habitat of their species have not yet been studied despite the importance and influence of climatic, environmental and biophysical factors on the distribution of species and inter/intra specific genetic or chemical variations.

Algerian studies on *Inuleae* tribe species focused much more on biochemical aspects by extraction and identification of secondary metabolites such as essential oils, phenols and lipids (Belloum *et al.* 2013; Belyagoubi-Benhammou *et al.* 2014; Elhouiti *et al.* 2017; Benomari *et al.* 2019), and also by valorization of their biological activities. On the other hand, some studies of rediscovery (Babali & Bouazza 2016) and investigation by studying the vegetation associations (Benhouhou *et al.* 2003), biodiversity and phytogeography (Yahi *et al.* 2012; Chehma 2014) could elucidate some ecological aspects for this tribe.

Table 1. List of species studied with coordinates in decimal degrees and regions of occurrence in Algeria

Species	Longitude	Latitude	Region
Chiliadenus rupestris (Pomel) S. Brullo	-1.40247	34.89764	Ghar Rouban (Tlemcen)
Chiliadenus rupestris (Pomel) S. Brullo	-1.7816	34.5994	Ghar Rouban (Tlemcen)
Chiliadenus rupestris (Pomel) S. Brullo	-1.72855	34.87675	Maghnia (Tlemcen)
Chiliadenus rupestris (Pomel) S. Brullo	-1.2674	34.89286	Tlemcen
Chiliadenus rupestris (Pomel) S. Brullo	-1.83914	35.08956	Ghazaouet (Tlemcen)
Pulicaria vulgaris Gaertn.	6.73119	35.35747	Aurès (Batna)
Pulicaria vulgaris Gaertn.	3.4522	36.73817	Corso (Boumerdès)
Pulicaria vulgaris subsp. *pomeliana* (Faure & Maire) E. Gamal-Eldin	2.72894	36.61338	Chaïba (Tipaza)
Pulicaria vulgaris subsp. *pomeliana* (Faure & Maire) E. Gamal-Eldin	-1.34664	34.78933	Terni (Tlemcen)
Pulicaria filaginoides Pomel	-0.46329	35.70149	Hassi Ameur (Oran)
Pulicaria mauritanica Coss.	-1.91643	31.96824	Djebel Antar (Béchar)
Pulicaria mauritanica Coss.	-1.50204	32.09525	Djebel Grouz (Béchar)
Pulicaria mauritanica Coss.	1.02224	33.72799	Djebel Mekter (Ainsefra)
Pulicaria mauritanica Coss.	-0.11656	32.77047	Djebel Aissa (Naâma)
Pulicaria mauritanica Coss.	-0.87994	32.47374	Djebel Mzi (Laghouat)
Pulicaria mauritanica Coss.	-0.43417	32.77896	Tiout (Naâma)
Pulicaria mauritanica Coss.	-0.61678	32.75719	Ain Safra
Pulicaria odora (L.) Rchb.	5.01627	36.7528	Ain-Skhoune (Bejaïa)
Pulicaria odora (L.) Rchb.	4.62741	36.63326	Akfadou (Bejaïa)
Pulicaria odora (L.) Rchb.	1.35694	35.40912	Djebel Saffalou (Tiaret)
Pulicaria odora (L.) Rchb.	4.61342	36.59082	Djenane (Bejaïa)
Pulicaria arabica (L.) Cass.	4.4668	35.68513	M'sila
Pulicaria arabica (L.) Cass.	3.67832	36.70722	Issers (Boumerdès)
Pulicaria sicula (L.) Moris	3.33087	36.75091	Reghaia (Alger)
Pulicaria sicula (L.) Moris	2.95979	36.52166	Mitidja
Pulicaria sicula (L.) Moris	5.34871	36.32616	Djebel Mégriss (Sétif)
Pulicaria sicula (L.) Moris	8.43115	36.86968	Calle
Pulicaria sicula (L.) Moris	6.86997	36.86215	Skikda
Pulicaria sicula (L.) Moris	6.69153	36.37591	Canstantine
Pulicaria sicula (L.) Moris	7.71798	36.92448	Annaba
Pulicaria uniseriata N.Kilian	3.67626	36.68864	Issers (Boumerdès)
Pulicaria uniseriata N.Kilian	4.20169	36.63371	Larbaâ Nath Irathen (TiziOuzou)
Pulicaria uniseriata N.Kilian	4.1703	36.37291	El Adjiba (Bouira)
Francoeuria crispa (Forsk.) Cass.	3.70544	32.50244	Anit el Chebrog (Ghardaïa)
Francoeuria crispa (Forsk.) Cass.	4.43676	32.7375	El Guerrara (Ghardaïa)
Francoeuria laciniata Coss. &Dur.	5.76851	34.89652	Biskra
Francoeuria laciniata Coss. &Dur.	3.02982	33.66252	Laghouat
Perralderia coronopifolia Coss.	4.16485	32.17143	Oued Metlili (Ghardaïa)
Perralderia coronopifolia Coss.	3.58789	32.48972	Ghardaïa
Perralderia coronopifolia Coss.	3.77784	32.85029	Berrain (Ghardaïa)
Perralderia coronopifolia Coss.	-3.28989	29.46076	Tabelbala (Béchar)
Perralderia coronopifolia Coss.	7.92904	25.68039	Tassili n'Ajjer (Illizi)
Perralderia coronopifolia subsp. *purpurascens* (Coss.) Maire	4.15335	32.40309	Zelfana (Ghardaïa)
Perralderia coronopifolia subsp. *purpurascens* (Coss.) Maire	-0.58867	32.51271	Moghrar-Tahtani (Naâma)
Dittrichia graveolens (L.) W. Greuter	2.97073	36.71823	Alger
Dittrichia viscosa subsp. *viscosa* (L.) Greuter	-0.49456	35.64217	Oran
Dittrichia viscosa subsp. *viscosa* (L.) Greuter	3.13029	36.68926	Sidi-Rzine (Alger)
Dittrichia viscosa subsp. *viscosa* (L.) Greuter	5.49387	36.60043	Taza (Jijel)
Dittrichia viscosa subsp. *viscosa* (L.) Greuter	-1.39243	34.7389	Forêt d' Hafir (Tlemcen)
Dittrichia viscosa subsp. *viscosa* (L.) Greuter	-0.54691	32.90369	Ain Safra
Inula montana Bal. & Bourg. ex Boiss.	-0.85213	33.03261	Ain Safra
Inula montana Bal. & Bourg. ex Boiss.	-1.39346	34.75146	Forêt d' Hafir (Tlemcen)
Inula obtusifolia A. Kerner	8.4702	36.88495	Calle
Inula conyzae (Griess.) DC.	5.62131	36.6666	Selma ben Ziada (Jijel)
Limbarda crithmoides subsp. *crithmoides* (L.) Dumort.	-1.45828	35.28836	Rachgoun (Aïn Témouchent)
Limbarda crithmoides subsp. *crithmoides* (L.) Dumort.	-1.99217	35.07235	Ouled Ben Ayad (Tlemcen)
Limbarda crithmoides subsp. *crithmoides* (L.) Dumort.	2.77761	36.67095	Douaouda (Tipaza)
Limbarda crithmoides subsp. *crithmoides* (L.) Dumort.	-1.38058	35.30673	Beni Saf (Aïn Témouchent)

Limbarda crithmoides subsp. *crithmoides* (L.) Dumort.	-1.30435	35.28212	Sid Safi (Aïn Témouchent)
Limbarda crithmoides subsp. *crithmoides* (L.) Dumort.	5.48782	36.59919	Taza (Jijel)
Gymnarrhena micrantha Desf.	3.7096	32.57852	Ghardaïa
Gymnarrhena micrantha Desf.	-2.07659	31.00875	Oued Menouaaraar (Béchar)
Pulicaria crispa (Forsk.) Benth. exOliv.	7.94518	25.76873	Tassili n'Ajjer (Illizi)
Pulicaria crispa (Forsk.) Benth. exOliv.	5.6123	33.43648	Touggourt (Ouargla)
Pulicaria crispa (Forsk.) Benth. exOliv.	-2.08345	31.05934	Oued Menouaaraar (Béchar)
Rhantherium adpressum (Desf.) Coss. & Dur.	5.63427	34.87342	Djebel Maaouia (Biskra)
Rhantherium adpressum (Desf.) Coss. & Dur.	-0.62553	32.67614	Ain Safra
Rhantherium adpressum (Desf.) Coss. & Dur.	3.73201	32.86528	Berraian (Ghardaïa)
Rhantherium adpressum (Desf.) Coss. & Dur.	2.7969	33.65143	Laghouat
Rhantherium adpressum (Desf.) Coss. & Dur.	2.8817	30.5958	Goléa (Ghardaïa)
Rhantherium adpressum (Desf.) Coss. & Dur.	5.3419	31.9628	Ouargla
Rhantherium adpressum (Desf.) Coss. & Dur.	4.2261	32.3961	Zelfana (Ghardaïa)
Asteriscus graveolens (Forssk.) Less.	3.63897	32.47049	Ghardaïa
Asteriscus graveolens (Forssk.) Less.	4.6426	32.7901	Guerrara (Ghardaïa)
Asteriscus graveolens (Forssk.) Less.	9.48721	24.52457	Djanet (Illizi)
Asteriscus graveolens (Forssk.) Less.	5.53505	31.74428	Ouargla
Asteriscus maritimus (L.) Less.	-1.98393	35.07214	Ouled Ben Ayad (Tlemcen)
Asteriscus maritimus (L.) Less.	-1.40241	35.2996	Beni Saf (Aïn Témouchent)
Asteriscus maritimus (L.) Less.	-1.35026	35.2975	Sid Safi (Aïn Témouchent)
Asteriscus maritimus (L.) Less.	-1.35397	34.74313	Forêt d' Hafir (Tlemcen)
Asteriscus aquaticus (L.) Less.	3.58868	36.59207	Lakhdaria (Bouira)
Asteriscus aquaticus (L.) Less.	1.34214	36.10415	Chélif
Asteriscus aquaticus (L.) Less.	2.79375	36.29277	Médéa
Asteriscus aquaticus (L.) Less.	4.89193	36.08251	Bibans (Bordj Bou Arreridj)
Asteriscus pygmaeus (DC.) Coss. & Dur.	3.82333	35.0138	Mergueb (M'sila)
Asteriscus pygmaeus (DC.) Coss. & Dur.	3.67441	32.44019	Ghardaïa
Asteriscus pygmaeus (DC.) Coss. & Dur.	-0.716	33.26763	Aïn Ben-Khellil (Naâma)
Asteriscus pygmaeus (DC.) Coss. & Dur.	-0.75565	32.71382	Ain Safra
Anvillea garcinii subsp. *radiata* (Coss. & Dur.) A. Anderberg	3.517	30.02819	Goléa (Ghardaïa)
Anvillea garcinii subsp. *radiata* (Coss. & Dur.) A. Anderberg	-0.343	32.4601	Ain Safra
Anvillea garcinii subsp. *radiata* (Coss. & Dur.) A. Anderberg	-2.45583	31.91252	Boukaïs (Béchar)
Anvillea garcinii subsp. *radiata* (Coss. & Dur.) A. Anderberg	-2.2749	31.94516	Lahmar (Béchar)
Anvillea garcinii subsp. *radiata* (Coss. & Dur.) A. Anderberg	8.31047	26.12683	Tassili n'Ajjer (Illizi)
Pulicaria vulgaris subsp. *vulgaris* Gaertn.	3.45303	36.74978	Corso (Boumerdès)
Pulicaria vulgaris subsp. *vulgaris* Gaertn.	3.34246	36.7681	Reghaia (Alger)
Pulicaria clausonis Pomel	2.71375	36.61503	Chaïba (Tipaza)
Pulicaria clausonis Pomel	2.70025	36.63756	BouIsmaïl (Tipaza)
Pulicaria undulata (L.) C.A.Mey.	9.46086	24.56052	Djanet (Illizi)
Pulicaria undulata (L.) C.A.Mey.	8.04268	26.01828	Tassili n'Ajjer (Illizi)

Representative Concentration Pathways (RCP) are scenarios developed by the Intergovernmental Panel on Climate Change (IPCC) and used to model future climate taking into consideration volume of greenhouse gases emitted, air pollutants and land-use change. Models are generated to predict future climatic conditions and, based on these General Circulation Models (GCM), climate layers were established to help model the impact of climate change on species distribution (Van Vuuren *et al.* 2011).

The objective of this study was to predict, by modeling the ecological niche, the distribution of *Inuleae* tribe species reported present in Algeria under the effect of different climatic conditions in order to be able to determine actual niches and factors influencing this distribution.

2. Materials and methods

Points of presence were extracted from the digitized herbarium of the National Museum of Natural History of France (MNHN) (https://science.mnhn.fr/institution/mnhn/collection/p/item/search/) and Algerian studies, which take *Inuleae* species as objects of study, with a total of 99 points of presence for 30 species and subspecies (Table 1). The search for these species was based, first, on the work of Battandier & Trabut (1888), followed by verification of scientific names in the "Catalogue of life checklist" (http://www.catalogueoflife.org/annual-checklist/2018/search/all). Geoplaner website (https://www.geoplaner.com/) was used to geo-reference herbarium records; coordinates of locations were checked following Hijmans *et al.* (1999) and are considered to be correct.

Climate data were downloaded from WorldClim Version 2 (http://www.worldclim.org/) (Fick & Hijmans 2017), these were mean monthly data of minimum, mean and maximum temperature and precipitation of 1970-2000 available at a spatial resolution of ~1 km (30 seconds). A total of 19 WorlClim bioclimatic variables derived from monthly climate data were used in predicting the potential distribution of *Inuleae* tribe species. Some of them were basic climatic parameters; others incorporated seasonal aspects and others for limiting environmental factors.

Inuleae tribe species distribution and habitat assessment were determined by the maximum entropy method (MaxEnt version 3.4.1) (Phillips *et al.* 2006) with its very good performance, especially regarding small samples (Elith *et al.* 2006). MaxEnt uses presence data to calculate the effective niche and probability of occurrence of a species based on the maximum entropy theory. According to the two zones; Tell or Sahara, two distribution models were run with max iteration at 500, regularization multiplier in default value (1), and in logistic ASC output format. The rest of the setting in these models was used as default.

The MaxEnt results presented constitute the mean of 10 randomized replications for each model. The Jackknife test was performed to measure the importance of each variable in the models. Predictive power of the models was evaluated by Area under a curve (AUC) of the Receiver Operating Characteristic (ROC) curve for presence records that were divided into 80% training and 20% test data. To predict habitat suitability under future conditions, a climate projection was made up to 2070 with Community Climate System Model (CCSM) data at 30 seconds resolution for all greenhouse gas emission scenarios: RCP 2.6, 4.5, 6.0 and 8.5 applying 10 percentile training presence threshold rule.

3. Results

3.1. Distribution in present climate conditions:

Two distribution models were obtained for the Tell (model 1) and Sahara (model 2) species. AUC training mean values of the 10 replications were 0.987±0.01 and 0.971±0.02, respectively, indicating very good performance in comparison with randomly generated models. The obtained potential distribution models are shown in Fig. 1. MaxEnt results indicate that highly contributing environmental variables in model 1 (Table 2) were BIO19 (precipitation of coldest quarter) with 66.1%, BIO18 (precipitation of the warmest quarter) with 10%, BIO17 (precipitation of the driest quarter) with 12.8%. On the other hand, variables with a high contribution in model 2 were BIO4 (temperature

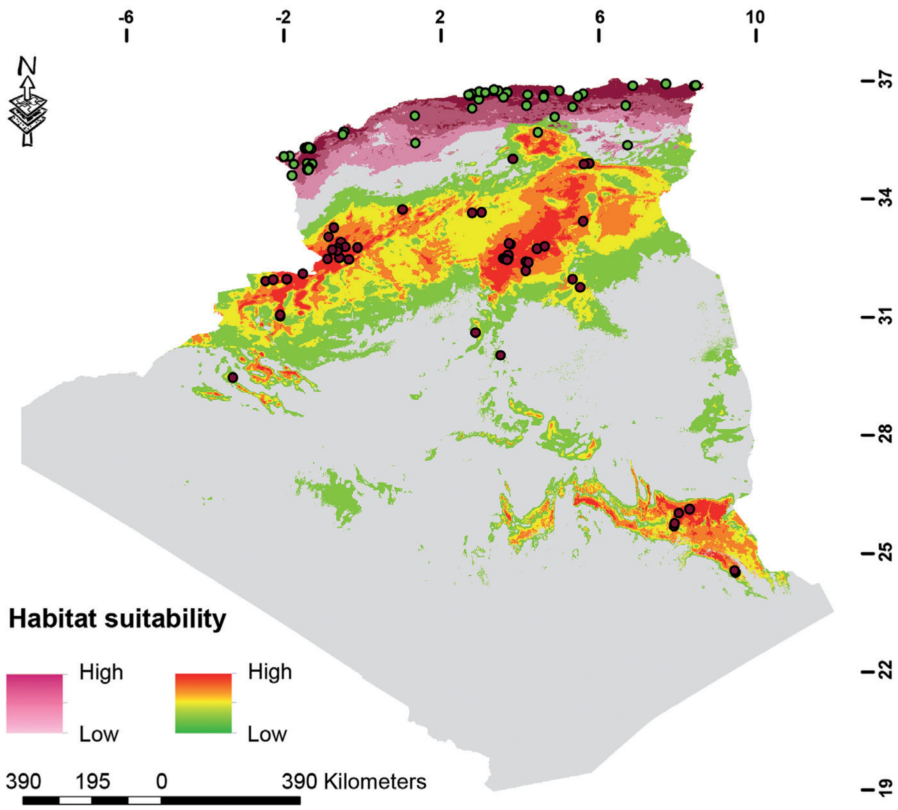

Fig. 1. Prediction model of potential distribution of the *Inuleae* tribe species in Algeria

Table 2. Relative contributions and permutation importance of the bioclimatic variables in MaxEnt models, the values are the means of 10 replications, Jackknife tests values expressed as AUC for models using each variable alone

Variable	Tell			Sahara		
	Percent contribution	Permutation importance	Jackknife of AUC	Percent contribution	Permutation importance	Jackknife of AUC
BIO1 (Annual Mean Temperature)	0.2	7.3	0.92	0	0	0.70
BIO2 (Annual Mean Diurnal Range)	4.9	4.5	0.94	20.7	20.4	0.89
BIO3 (Isothermality (BIO1/BIO7)*100)	0.1	0.1	0.66	5.7	1	0.92
BIO4 (Temperature Seasonality (Standard Deviation))	0.6	2.6	0.86	33.1	40.9	0.77
BIO5 (Max Temperature of Warmest Month)	1.2	14.6	0.90	0	0	0.84
BIO6 (Min Temperature of Coldest Month)	2.5	9.6	0.74	0.1	0.1	0.60
BIO7 (Annual Temperature Range (BIO5-BIO6)	0.6	0.1	0.91	3.1	3.8	0.70
BIO8 (Mean Temperature of Wettest Quarter)	0.3	8.5	0.87	2	6.9	0.77
BIO9 (Mean Temperature of Driest Quarter)	0.1	0.5	0.85	3.5	4.8	0.85
BIO10 (Mean Temperature of Warmest Quarter)	0.6	21.1	0.91	0.5	0	0.76
BIO11 (Mean Temperature of Coldest Quarter)	0	0	0.80	0	0	0.70
BIO12 (Annual Precipitation)	1.5	0.1	0.95	0	0	0.71
BIO13 (Precipitation of Wettest Month)	0.3	0	0.95	0.2	0.3	0.64
BIO14 (Precipitation of Driest Month)	0.2	0.1	0.94	12.4	0	0.76
BIO15 (Precipitation Seasonality (coefficient of variation)	1.9	11.9	0.84	0.9	2.1	0.78
BIO16 (Precipitation of Wettest Quarter)	1.1	2.1	0.95	0	0	0.63
BIO17 (Precipitation of Driest Quarter)	7.7	0.9	0.92	12.8	0.6	0.81
BIO18 (Precipitation of Warmest Quarter)	10	15.4	0.92	0.7	9.6	0.56
BIO19 (Precipitation of Coldest Quarter)	66.1	0.5	0.95	4.4	9.4	0.79

seasonality) with 33.1%, BIO2 (annual mean diurnal range) with 20.7%, BIO17 (precipitation of the driest quarter) with 12.8% and BIO14 (precipitation of the driest month) with 12.4%. Cumulative contributions of these bioclimatic variables were 83.8% and 79% for the two models, respectively. The results of jackknife test revealed that other parameters had more contribution for a higher AUC value like BIO2, BIO7, BIO12, BIO13, BIO14 and BIO16 for model 1 and BIO3, BIO9, BIO17 and BIO19 for model 2.

Effective niches of Tell species showed characteristics different from those of the Sahara (Fig. 2). Their mean

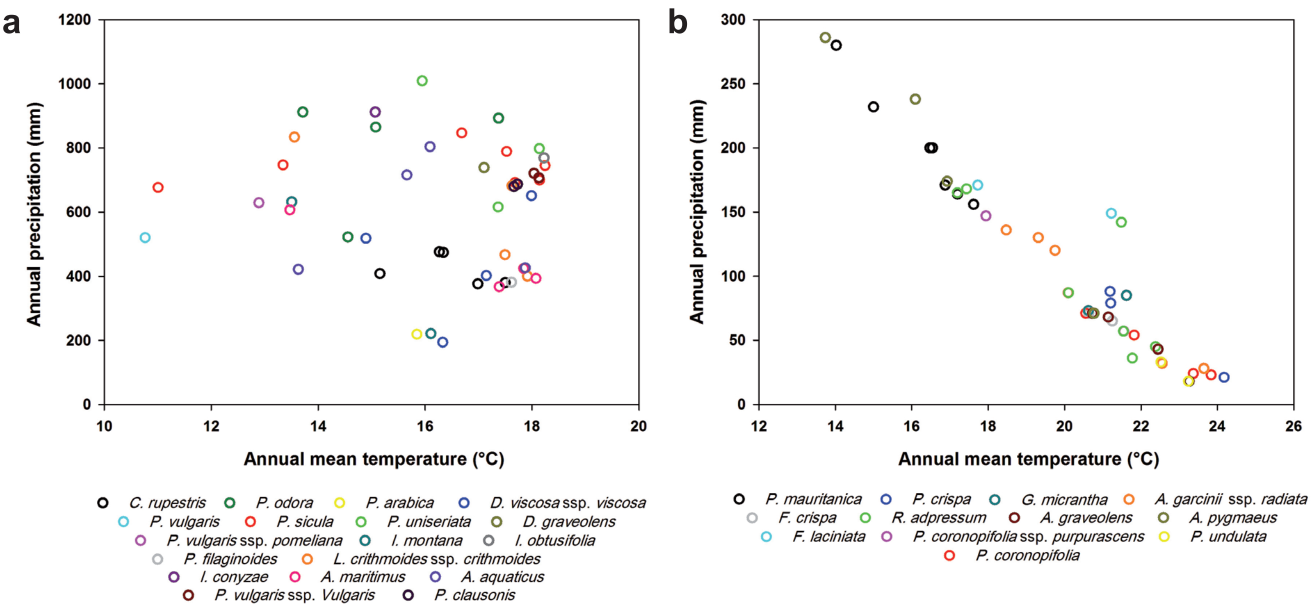

Fig. 2. Two-dimensional niches of various species of the Algerian tribe *Inuleae*

Explanations: a – the Tell species, b – the Sahara species

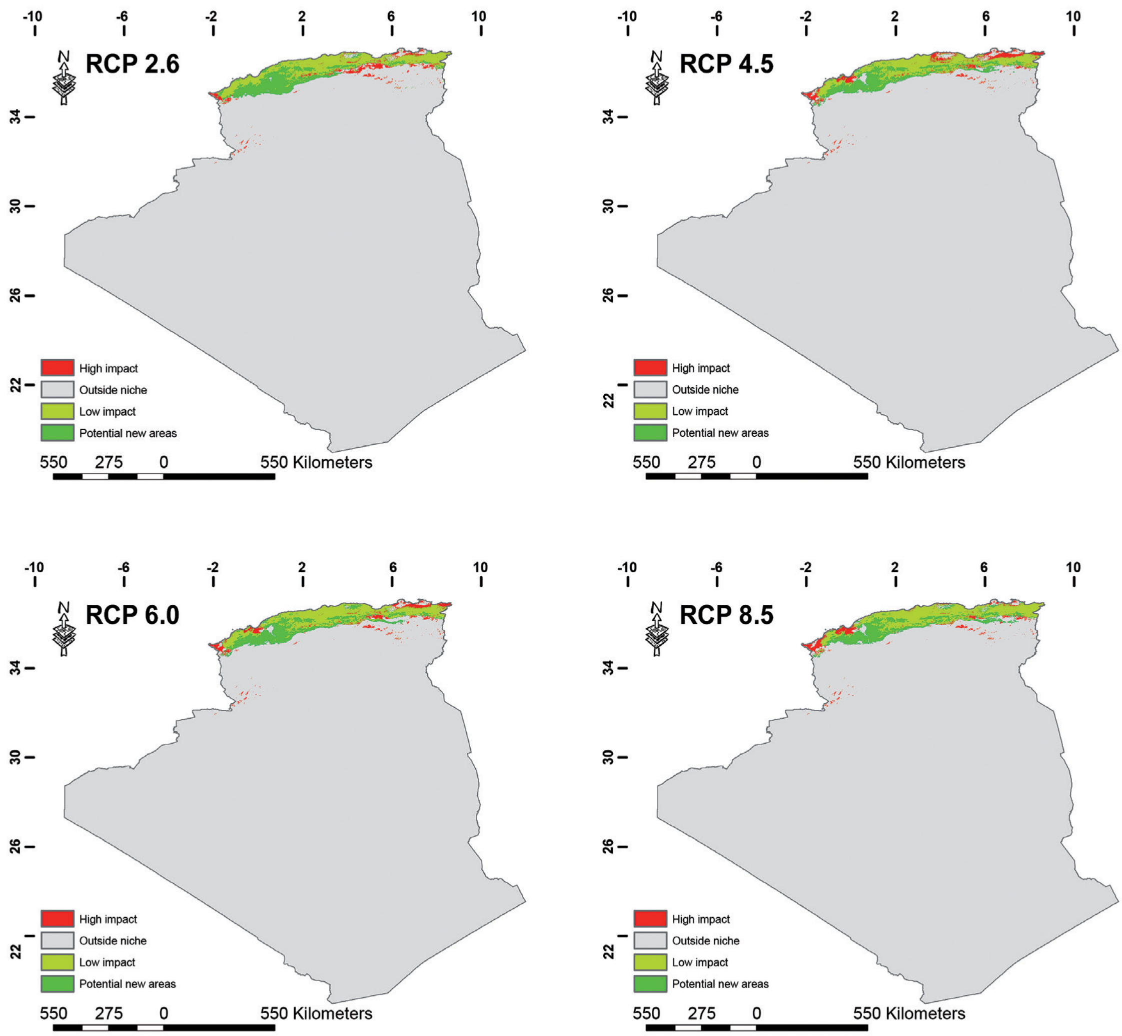

Fig. 3. Prediction of future habitat suitability for the Algerian *Inuleae* tribe species in the RCP climate scenarios

annual temperatures ranged from 14-18°C and the annual precipitation was 400-1000 mm. On the other hand, these characteristics extended from 17-24°C and from 20-200 mm for those of the Sahara. So the Tell species were restricted to temperate zones with a significant annual rainfall, while the climate niches of the Sahara species were limited to hot and dry environments.

These results shows that 12 species (*Pulicaria mauritanica* Coss., *Francœuria crispa* (Forsk.) Cass., *Francœuria laciniata* Coss. & Dur., *Perralderia coronopifolia* Coss., *Perralderia coronopifolia* subsp. *Purpurascens* (Coss.) Maire, *Gymnarhena micrantha* Desf., *Pulicaria crispa* (Forsk.) Benth. ex Oliv., *Rhanterium adpressum* (Desf.) Coss. & Dur., *Asteriscus graveolens* (Forssk.) Less., *Asteriscus pygmaeus* (DC.) Coss. & Dur., *Anvillea garcinii* subsp. *Radiata* (Coss. & Dur.) A. Anderberg, *Pulicaria undulate* (L.) C.A.Mey.) belonged to the climate niches of the Sahara, while 18 species (*Chiliadenus rupestris* (Pomel) S. Brullo, *Pulicaria filaginoides* Pomel, *Pulicaria Arabica* (L.) Cass., *Dittrichia graveolens* (L.) W. Greuter, *Dittrichia viscosa* subsp. *Viscosa* (L.) Greuter, *Inula obtusifolia* A. Kerner, *Limbarda crithmoides* subsp. *Crithmoides* (L.) Dumort., *Asteriscus maritimus* (L.) Less., *Pulicaria vulgaris* subsp. *Vulgaris* (L.) Greuter, *Pulicaria clausonis* Pomel, *Pulicaria vulgaris* Gaertn., *Pulicaria vulgaris* subsp. *Pomeliana* (Faure & Maire) E. Gamal-Eldin, *Pulicaria odora* (L.) Rchb., *Pulicaria sicula* (L.) Moris, *Pulicaria uniseriata* N. Kilian, *Inula montana* Bal. & Bourg. ex Boiss., *Inula conyzae* (Griess.) DC., *Asteriscus aquaticus* (L.) Less.) belonged to the Tell zone. It was found that two genera *Asteriscus* (16 observations) and *Pulicaria* (37 observations) were able to cross the barrier between the Tell and the Sahara and adapt to different climatic conditions.

3.2. Distribution under influence of climate changes

Results of the distribution modeling of *Inuleae* tribe species in the four RCP scenarios are shown in Fig. 3. It turned out that habitats of these species were highly influenced by climate change, as arid and sub-Saharan

Table 3. Variations in areas and mean values of predicted changes of six bioclimatic variables influencing the distribution of the tribe *Inuleae* in the obtained models

	Tell					Sahara				
	Present	RCP				Present	RCP			
		2.6	4.5	6.0	8.5		2.6	4.5	6.0	8.5
Areas										
High impact areas (ha)	-	1114.7	1471.5	1185.4	1044.1	-	-	-	-	-
Low impact areas (ha)	-	4271.4	3914.6	4200.7	4342.1	-	-	-	-	-
Potential new areas (ha)	-	3227.5	3037.9	3144.9	3044.9	-	-	-	-	-
Factors										
Annual Mean Temperature (°C)	16.5	17.7	18.5	18.6	19.7	19.6	21.1	22.0	22.1	23.4
Mean Diurnal Range	8.9	9.0	9.2	9.2	9.2	14.0	14.1	14.2	14.2	14.2
Temperature Seasonality	581.1	585.1	593.1	592.9	616.8	810.8	802.4	826.9	822.1	849.8
Annual Precipitation (mm)	717.7	691.3	611.2	635.8	606.9	122.2	121.3	113.1	114.1	108.4
Precipitation Seasonality	65.5	62.9	65.3	63.0	64.1	51.6	45.9	47.8	47.9	50.2
Precipitation of Driest Quarter (mm)	29.7	30.3	23.7	27.4	23.4	13.5	13.8	12.9	12.9	11.5

species were most affected by these changes and the Tell species were affected by both these changes and the anthropogenic factor. Bioclimatic variables that contributed to current and future variation are presented in Table 3. The annual mean temperature increased between the models with a rate of variation reaching 20% as opposed to the annual precipitation where a decrease went up to 11 and 15%. The coefficient of temperature variation (temperature seasonality) expressed in percentage showed high variability in the two zones, a remark also noted for the precipitation seasonality, which represented an index as a percentage variation of this parameter. As a result, these changes affected the Sahara species most since they were in low-resource, which made their environments even more hostile.

For species in the Tell zone, large areas may have become potential new distribution areas (Table 3), but these areas decreased going from 2.6 to 8.5 scenario. On the other hand, low impact areas increased between these two scenarios, while climate alterations led to variations in high impact areas according to the four scenarios. High impact areas on *Inuleae* species expanded according to RCP 4.5 which can be interpreted by the increase in precipitation seasonality (65.3), decrease in the annual precipitation (611.2 mm) and increase in annual mean temperature (18.5°C). According to RCP 8.5, increase in temperature seasonality and decrease in annual precipitation decreased new potential areas of distribution and slightly influenced areas of current occurrence in comparison with the other scenarios.

4. Discussion

The MaxEnt model identified possible occurrences as sites where conditions were similar to those where species naturally occurred using presence points. AUC mean values reflected significance and predictive power of the two generated models (Araújo *et al.* 2005). The models for predicted distribution of *Inuleae* tribe species represented in Fig. 1 show suitable habitats for Tell species in Northern Algeria and suitable habitats for Saharan species in central and southern Algeria as well as other habitats with low suitability, which were very low occurrence possibilities sites, taking into account limitations of dispersion such as geographical barriers (Tell atlas and Saharan Atlas) and anthropic pressure, which can affect species occurrence even under favorable climatic conditions (Stambouli-Meziane & Bouazza 2012; Sitayeb & Belabbes 2018).

It is clear that competition, dispersal, niche size, and spatiotemporal distribution of environmental conditions play a role in determining the repartition of species in relation to the distribution of favorable habitats. Pulliam (2000), discussed the fact that, according to the theory, species can be absent in a favorable habitat and present in an unfavorable habitat, which makes the concept of the real niche much broader than the fundamental niche.

By analyzing climatic niches of different species, two graphs (Fig. 2) represent two major characteristics in Algeria: the Tell and the Sahara. The Tell forms a band more than 100 km wide along the Mediterranean coast of Morocco, in the west, up to Tunisia; to the east, the Sahara is more extensive with sand dunes, plains and rocky plateaus (Beniston 1984).

Two mountain ranges cross Algeria from West to East – the Tell Atlas and the Saharan Atlas. Consequently, the topography of Algeria is made up of three important structures; Tell north of the Tell Atlas to the coast, Hautes Plaines between the Tell Atlas and the Saharan

Atlas and Sahara, which extends south of the Saharan Atlas representing more than 80% of the country. The Mediterranean climate covers the Tell, while the desert climate covers the South of Algeria (Despois & Raynal 1975).

Faced with climate change, species in arid and Saharan areas are more or less vulnerable given the specificity of habitats and characteristics of the history of their lives as long generation time, limited dispersal abilities and genetic diversity (Richardson *et al.* 2012), so these species will be faced with the challenge of quick adaption to survive in new conditions. Species responses to these changes differ from one another and consist in plastic mechanisms (phenological plasticity) through individual life time or genetic mechanisms while taking change strategies on three axes: temporal, spatial and *in situ* (Bellard *et al.* 2012).

Comparing the areas of high impact, low impact and new potential distribution with mean values of bioclimatic factors according to the four RCP scenarios, it can be noticed that climatic changes between the present and RCP 2.6 can be positive for the expansion of Tell species in new areas. However, as temperature continues to rise and precipitation continues to decrease, low impact areas get larger with restriction of potential new distribution areas. This remark was also recorded by Zhang *et al.* (2018) for the distribution of *Paeonia delavayi* and *Paeonia rockii* between RCP 2.6 and RCP 8.5.

The extension of the Sahara with permanently variable parameters (Scheiter & Higgins 2009; Thomas & Nigam 2018) and a maximum temperature of the hottest period exceeding 50°C, favorable habitats of *Inuleae* tribe species will be narrowed even more than by half, which makes the occurrence of these species increasingly weak and pushes threatened species like *Pulicaria filaginoides* Pomel to a more rapid extinction than expected. According to Thuiller *et al.* (2006), 47% of Namibian plant species are predicted to be vulnerable to anthropogenic climate change if they are assumed unable to migrate, knowing that these changes in addition to the distribution they will alter the phenology because plants and their physiology are not too tolerated to heat and its variation (Araújo *et al.* 2013).

The predicted habitat suitability of *Inuleae* tribe species under current and future bioclimatic variable influences could be helpful for management and conservation strategies remembering that most of these species have diverse uses in local traditional medicine and represent important fodder sources (Chehma & Youcef 2009). This study shows vulnerability of Saharan species to climate change predicted by the four RCP scenarios, which implies their valorization and the study of their adaptation modes in presence of other environmental factors.

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