**Supplementary material**

**Climate change induced range shifts of three allergenic ragweeds (*Ambrosia* L.) in Europe and potential impact on human health**

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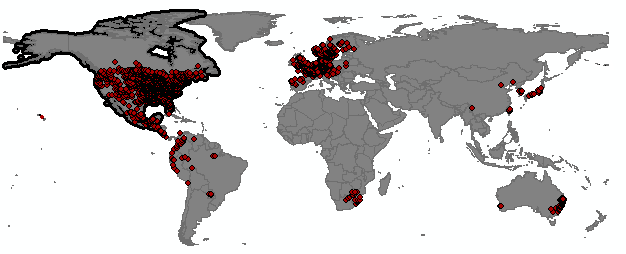
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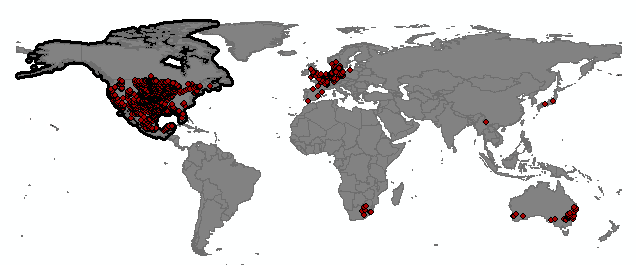
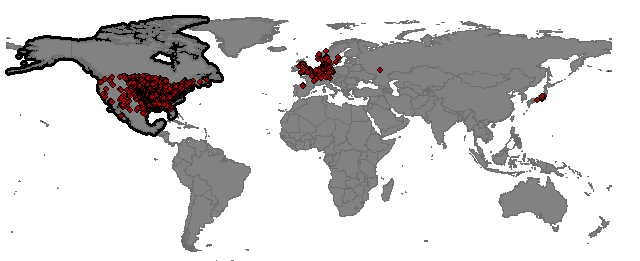
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**Figure S1** Maps showing occurrence records of *A. artemisiifolia, A. psilostachya* and *A. trifida*. Points represent the ‘cleaned’ species occurrence records (*see main text*). The points within the outlined frame illustrate the native dataset, whereas all points illustrate the global dataset.

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*A. trifida*



*A. psilostachya*

*A. artemisiifolia*

**Table S1** Distribution of the ragweed species (outside their North American native range). Data sources: Global Invasive Species Database (www.iucngisd.org) for *A. artemisiifolia*, European and Mediterranean Plant Protection Organization (www.eppo.int) and Delivering Alien Invasive Species Inventories for Europe (www.europe-aliens.org) for *A. artemisiifolia, A. psilostachya* and *A. trifida*

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| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Species | Europe |  | Asia | Africa | Central, North- and South America |  | | Oceanaria | |
|  | Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Liechtenstein, Lithuania, Luxemburg, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Russia (Krasnodar territory), Scotland, Slovakia, Slovenia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, (former Yugoslavia)  Austria, Belgium, Croatia, Czech Republic, Denmark, England, Estonia, Finland, France, Germany, Hungary, Italy, Latvia, Netherlands, Norway, Poland, Russia (South of European Russia), Scotland, Spain, Sweden, Switzerland, United Kingdom    Austria, Belgium, Czech Republic, Denmark, France, Germany, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Russia (South of European Russia), Scotland, Sweden, Switzerland, Ukraine, United Kingdom (Yugoslavia) | | Azerbaijan, China, India, Japan, Kazakhstan, Korea, Russia (Primorski territory), Taiwan, Turkey  Kazakhstan  Georgia, Japan,  Israel | Mauritius  Mauritius | Argentina, Brazil, Bolivia, Chile, Colombia, Cuba, Guadeloupe, Guatemala, Jamaica, Martinque, Paraguay, Peru, Uruguay | | Australia  New Zealand  Australia | |
| *A. artemisiifolia* |
| *A. psilostachya* |
|  |
| *A. trifida* |

**Table S2** Model predictive ability based on median Area Under the receiver operating Curve (AUC) values of the model in native range for common ragweed (*Ambrosia artemisiifolia*), perennial ragweed (*A. psilostachya*) and giant ragweed (*A. trifida*). AUC values were derived from average test AUC values for MAXENT models of 15 replicates based on occurrence records from the native North American range combined with records from the invasive European range and records from the invasive European range only.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Model AUC** | | |
|  | Common ragweed Perennial ragweed Giant ragweed | | |
| North American + European range | 0.74 0.77 0.79 | | |
| European range only | 0.81 | 0.91 0.87 |

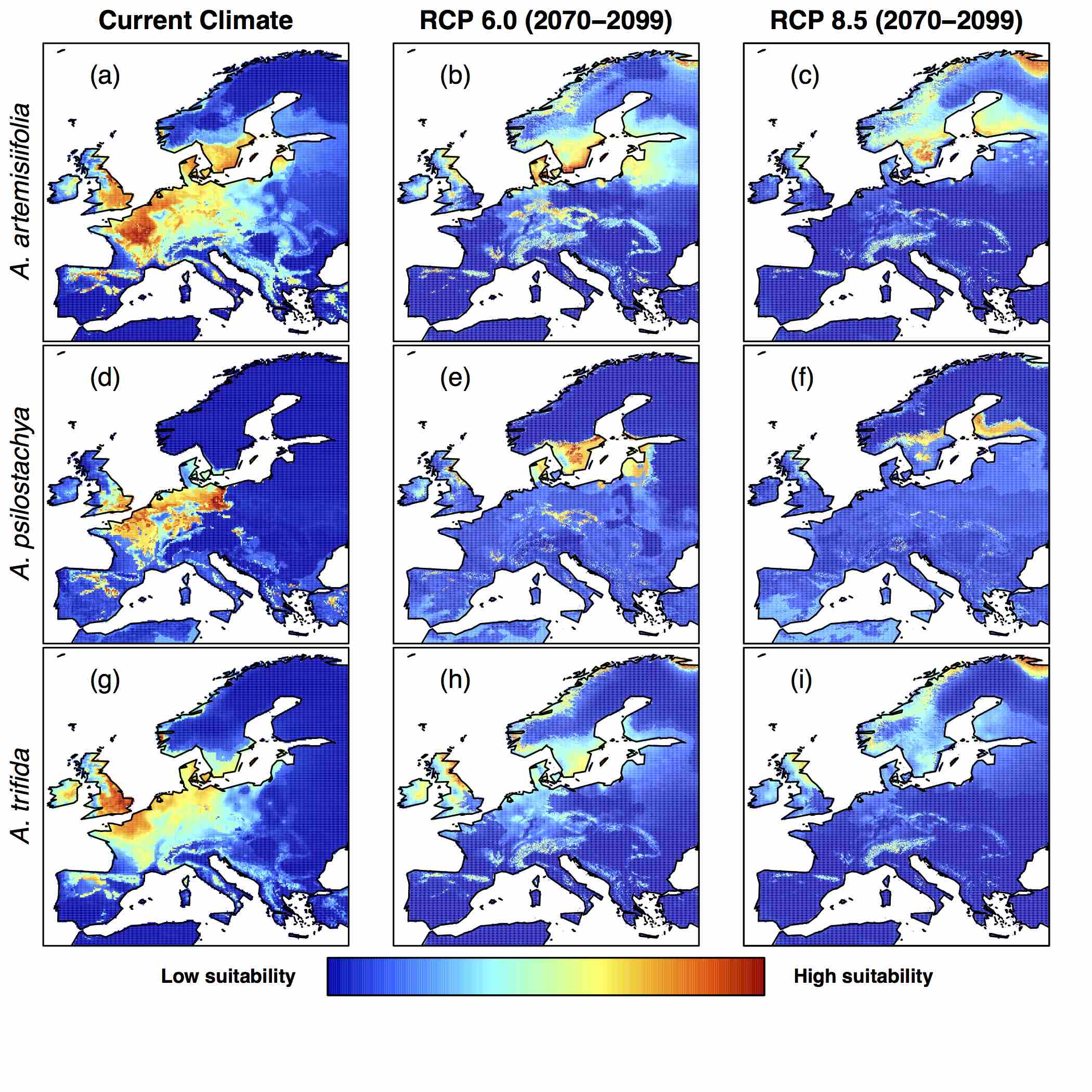
**Appendix S1: Extended methods**

**Explanatory variables: {Riahi, 2007 #2428}**Three bioclimatic parameters, of known importance for the geographical distribution of plants, were used to describe the species climatic requirements in this study. Specifically, we used monthly values of mean temperature and precipitation from the CRU CL 2.0 dataset at a 10’ resolution (http://www.cru.uea.ac.uk/cru/data/hrg/; period 1961-1990; New et al.2002) to derive the following variables: Growing Degree Days (GDD; computed with a 5°C base following Prentice et al. 1992, Zimmermann & Kienast 1999), Water Balance (WBAL; computed as the yearly sum of the monthly differences between precipitation and potential evapotranspiration, following Lugo et al. 1999, Skov & Svenning 2004) and Absolute Minimum Temperature (Tmin; estimated from the mean temperature of the coldest month after Prentice et al. 1992). Climate change projections used in this study were based on averages taken across all available global circulation models provided by the IPCC AR5 (IPCC) for representative concentration pathways (RCPs) 6.0 and 8.5 (Fujino et al. 2006; Riahi et al. 2007; Hijioka et al. 2008).

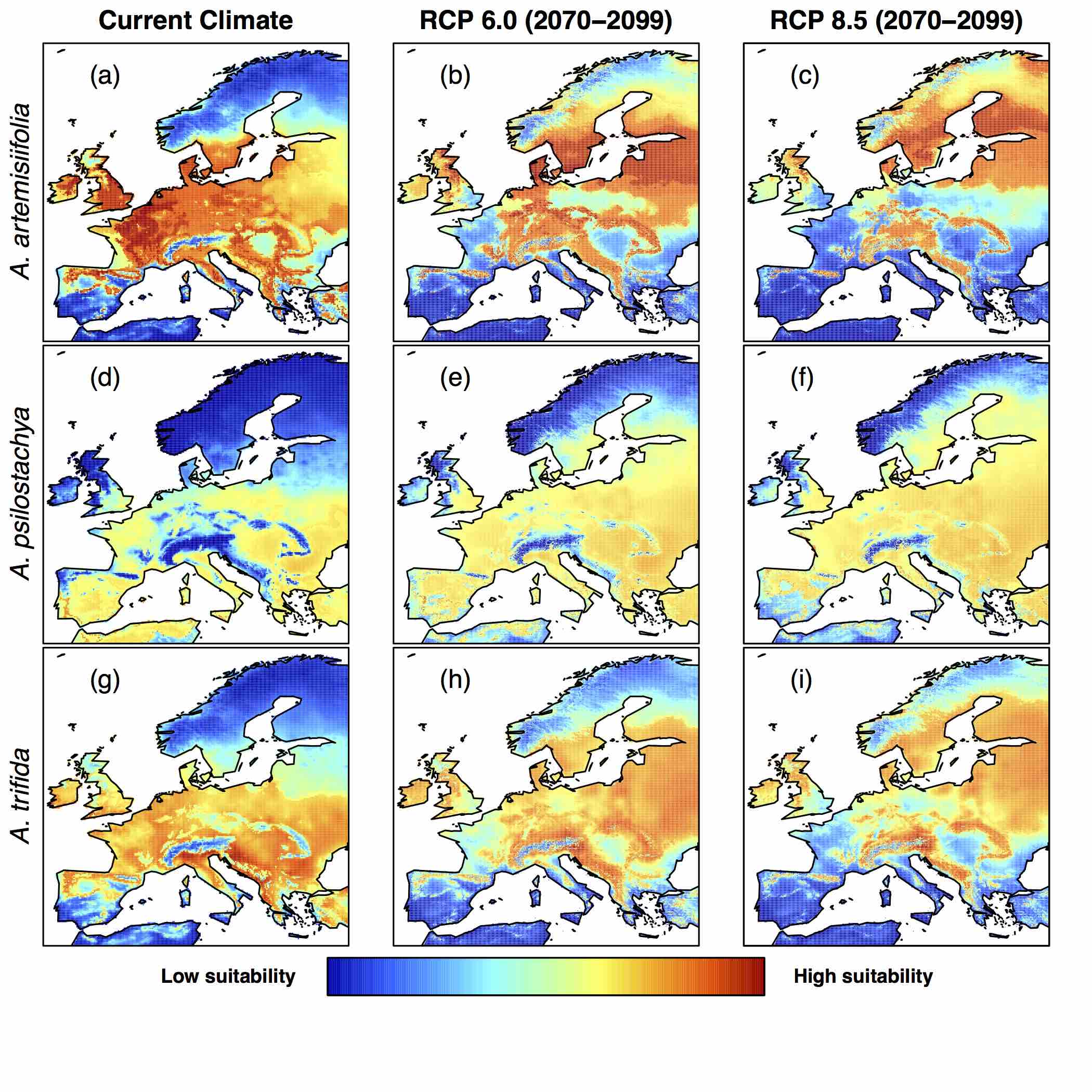
**MAXENT** **settings:**

We used ENMeval (Muscarella et al. 2014) for species-specific tuning of MAXENT models. Specifically, for each species, we built models with all combinations of regularization multiplier values ranging from 0.5 to 4 (in increments of 0.5) and all possible feature class combinations. For each model, we used the ‘checkerboard2’ method to partition data into test and training bins for evaluation. We then selected the ‘optimal’ model settings (regularization and feature classes) for each species based on the model with the lowest AICc. Then, we reran the model with the ‘optimal’ settings using 15 replicate runs. We used the following other settings: Jack-knife test = true, replicates = 15 (replicated run type = subsample), random seed = true, remove duplicate presence records = true, write plot data = true, extrapolate = false, maximum iterations = 5000.

**Figure S2 Models trained on distribution records in Europe.** Habitat suitability of common ragweed (*A. artemisiifolia*) (a-c)*,* perennial ragweed(*A. psilostachya*) (d-f)and giant ragweed (*A. trifida*) (g-i) in Europe under current climate conditions, and future climates (projections for years 2070-2099) assuming RCP 6.0 and RCP 8.5. Maps show average MAXENT values, derived from 15 replicates.



**Figure S3 Models trained on distribution records in Europe and North America combined.** Habitat suitability of common ragweed (*A. artemisiifolia*) (a-c)*,* perennial ragweed(*A. psilostachya*) (d-f)and giant ragweed (*A. trifida*) (g-i) in Europe under current climate conditions, and future climates (projections for years 2070-2099) assuming RCP 6.0 and RCP 8.5. Maps show average MAXENT values, derived from 15 replicates.



**Figure S4** High allergy risk’ (HAR) areas of common ragweed *A. artemisiifolia*) (a-c)*,* perennial ragweed(*A. psilostachya*) (d-f)and giant ragweed (*A. trifida*) (g-i) in Europe under current climate conditions, and projected future climates (for years 2070-2099) under RCP 6.0 and RCP 8.5. Letters indicate locations of major cities (a=Madrid, b=London, c=Paris, d=Hamburg, e=Rome, f=Berlin, g=Vienna , h=Bucharest, i=Istanbul, j=Saint Petersburg).

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**Figure S5** Original jackknife results.

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**Figure S6** Mess analysis results.



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