Species Distribution Modeling Instructions Using SDMtoolbox for ArcGIS Pro

1. Download current climate variables
    a. https://worldclim.org/data/worldclim21.html
    b. Bioclimatic variables
    c. Bio 2.5m
2. Download future climate variables
    a. https://worldclim.org/data/cmip6/cmip6_clim2.5m.html
    b. https://wcrp-cmip.org/cmip-model-and-experiment-documentation/#models <- more model info
    c. 2041-2060
    d. Download ssp245 bc (realistic scenario)
        i. Choose 5 models
            1. MPI-ESM1-2-HR (Germany)
            2. UKESM1-0-LL (New Zealand, UK, Korea)
            3. GISS-E2-1-G (NASA/USA)
            4. BCC-CSM2-MR (China)
            5. EC-Earth3-Veg (Europe)
3. Expand future climate variables using R script

In ArcGIS: (Steps 5-11 necessary only once)

4. CSV to Shapefile
    a. CSV file of occurrence data
    b. All *Vellozia* for clipping purposes to start

Climate data

5. 1b. Extract by Extent (Folder)
    a. Input folder: each folder with climate data (present and future) (one folder at a time)
    b. Output type: ASCII
    c. Check box to scrub headings
6. 2a. Raster to ASCII (Folder)
    a. Raster type: tif
    b. Check folder: only ASC files necessary, delete the rest
7. Raster tools → 3d. Define Projection as WGS84 (Folder)
8. SDM Tools → Universal SDM Tools → Explore Climate Data → Remove Highly Correlated Variables
    a. Input present climate data
    b. Write down which climate variables to keep OR delete unnecessary climate variables
        i. Pearson's R of 0.7
        ii. Keep 1, 2, 3, 12, 15, 18
            1. Annual Mean Temp, Mean Diurnal Range, Isothermality, Annual Precipitation, Precipitation Seasonality, Precipitation of Warmest Quarter

9. Take the mean for future climate variables: Analysis → Tools → Raster Calculator (search)
    a. Put all the future climate variables on the map
    b. Take the average for each future climate variable using the Raster Calculator
10. Convert Raster to ASCII (Folder)
11. (Repeat step 7) Raster tools → 3d. Define Projection as WGS84 (Folder)
    a. For newly averaged future climate data

Done with climate data

12. SDM Tools → 1. Universal Tools → Spatially Rarefy Occurrence Data for SDMs → Single Distance → Spatially Rarefy Occurrence Data for SDMs (reduce spatial autocorrelation)
    a. Resolution to Rarefy: 5km (this is the minimum)
    b. Equidistance Projection: South America
    c. Only rarefy species with more than 10 records. If there are 10 or less records for a species, skip this step (so that we aren't accidentally lowering the number of records below 5)
13. Make bias file: SDM Tools →2. MaxEnt Tools → Background Selection via Bias Files→ Background Selection: Sample by Buffered Local Adaptive Convex-Hull
    a. Use rarefied CSV file NOT the shapefile
    b. *V. tubiflora*: 50km buffer distance, alpha value 5
    c. Buffer distance: 20km - if AUC was low, try again with 50km buffer distance
    d. Alpha value: 5
14. SDM Tools →2. MaxEnt Tools → Modeling in MaxEnt → Run MaxEnt: Spatially Jackknife
    a. Species Occurrence Table: Rarefied CSV file
    b. Environmental Data Folder: Current climate data
    c. Projection Climate Layers: Future climate data
    d. Create Response Curves
    e. No extrapolation
    f. Apply threshold: most commonly used is "maximum test sensitivity plus specificity"
    g. Replicate type:
        i. >= 100 data points (before rarefying) → subsample
        ii. < 100 data points (before rarefying) → crossvalidate
    h. RUN

In local folder:

15. Run Step1_Optimize_MaxEnt_Model_Parameters
16. Run Step2_Run_Optimized_MaxEnt_Models
17. Open "Final"
    a. HTML document is a summary
    b. _threshold documents are a binary representation of species range
        i. Run in ArcGIS → Symbology → Unique Values
    c. ASC files are a scale representation of species range

In ArcGIS:

18. SDM Tools → Maxent → Distribution Changes Between Binary SDMs → Distribution Changes Between Binary SDMs
    a. Shows the difference between the current and future species range
    b. Write the difference between the file names
    c. Save raster as TIF (not ASC)
19. Biodiversity Measurements → Input Binary SDMs → Output Shapefile - Grid → Estimate Richness and Endemism (WE and CWE)
    a. Summarizes richness/distribution for multiple species/the whole genus
    b. Must do separately for current and future
    c. Convert binary SDM files from ASCII to TIFF file
        i. ASCII to Raster (Folder)
        ii. TIFF file
        iii. Raster type: Integer
    d. Resolution: 0.6 DD
    e. Output type: TIF

<u>How to run in Maxent directly:</u>

1. Samples: file w/ species and coordinates
2. Environmental layers: current climate data
3. Projection layers: future climate data
4. Check:
    a. Create response curves
    b. Make pictures of predictions
5. Settings:
    a. Basic:
        i. Replicates: 5
        ii. If subsample:
            1. Random test percentage: 20
    b. Experimental:
        i. Write background predictions