

Code description. Climate suitability of the Mediterranean Basin for citrus black spot disease (*Phyllosticta citricarpa*) based on a generic infection model

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Code description

Source code (R language) for manuscript “Climate suitability of the Mediterranean Basin for citrus black spot disease (*Phyllosticta citricarpa*) based on a generic infection model”

For questions, comments or remarks about the code please contact E. Lázaro (lazarole@gva.es)

Source code has been structured in three main folders:

- **era5land**, which contains all the code to reproduce and replicate data extraction from ERA5-Land downloaded files (.nc) and derived environmental variables computation.
- **magarey**, which contains all the code to reproduce and replicate simulations related to the generic infection model of Magarey et al.¹
- **moyo**, which contains all the code to reproduce and replicate simulations related to the degree-day model of Moyo et al.²

ERA5-Land. Environmental data processing

Code organisation:

```
era5land {
  - code {
    1_temperature.R
    2_precipitation.R
    3_dew_point_temperature.R
  }
  - data*
  - results* {
    magarey_data
    moyo_data
  }
}
```

data*: To run the code it is provided a clip of the study area which corresponds to Cyprus. **data*** folder contains:

- ERA5-Land downloaded files (.nc) containing data about air temperature at 2 m (K), dew point temperature at 2 m (K) and total precipitation (m) aggregated over two-year periods from 2009 to 2018. These files were downloaded from <https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-land?tab=form>. Note that the data were downloaded in biannual periods for processing purposes.
- Boundaries of the study area (i.e, for Cyprus).

results*: This folder contains two sub-folders, `magarey_data` and `moyo_data`. Within sub-folder `magarey_data` will be stored environmental variable information in `raster` format about precipitation (mm), temperature (°C) and wet (dummy variable) in hourly frequency organised in sub-folders named 2009-10, 2011-12, 2013-14, 2015-16, 2017-18 depending on the two-year period covered. All files generated are the files what we must use to simulate the generic infection model, i.e. the files stored in this sub-folder will be the ones we must store in `magarey_data`. Within sub-folder `moyo_data` will be stored environmental variable information in `raster` format about maximum, minimum and mean temperature; total precipitation; and vapor pressure deficit daily values in sub-folders named 2009-10, 2011-12, 2013-14, 2015-16, 2017-18 depending on the two-year period. All files generated are the files what we must use to simulate the ascospore maturation and onset of ascospore release model, i.e. the files stored in this sub-folder will be the ones we must store in `moyo_data`.

sessionInfo():

```
> sessionInfo()
R version 3.6.0 (2019-04-26)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows >= 8 x64 (build 9200)

Matrix products: default

locale:
[1] LC_COLLATE=Spanish_Spain.1252 LC_CTYPE=Spanish_Spain.1252 LC_MONETARY=Spanish_Spain.1252 LC_NUMERIC=C
[5] LC_TIME=Spanish_Spain.1252

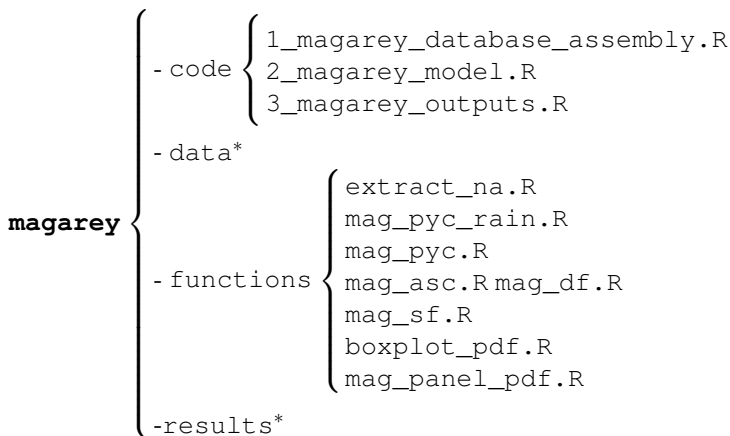
attached base packages:
[1] stats graphics grDevices utils datasets methods base

other attached packages:
[1] rts_1.0-49 RCur1_1.98-1.2 xts_0.11-2 zoo_1.8-6 ncd4_1.1.17 rgdal_1.4-4 raster_3.3-13 sp_1.4-2

loaded via a namespace (and not attached):
[1] compiler_3.6.0 parallel_3.6.0 tools_3.6.0 yaml_2.2.0 Rcpp_1.0.1 codetools_0.2-16 grid_3.6.0
[8] bitops_1.0-6 lattice_0.20-38
```

Generic infection model

Code organisation:



data*:. To run the code it is provided a clip of the study area which corresponds to Cyprus growing regions. **data*** folder contains:

- Environmental variable information in `raster` format about precipitation (mm), temperature (°C) and wet (dummy variable) in hourly frequency and organised in subfolders collecting information corresponding to a two-year period (i.e., 2009-10, 2011-12, 2013-14, 2015-16, 2017-18).
- Boundaries of the study area (i.e, for Cyprus),
- The assembled database over the 10-year period under study. It will be stored after the execution of script `1_magarey_database_assembly.R` in a sub-folder named 2009-18.

results*: All results and auxiliary files necessary to obtain them will be automatically stored in this folder.

sessionInfo():

```
R version 3.6.0 (2019-04-26)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows >= 8 x64 (build 9200)
```

Matrix products: default

```
locale:
[1] LC_COLLATE=Spanish_Spain.1252 LC_CTYPE=Spanish_Spain.1252 LC_MONETARY=Spanish_Spain.1252 LC_NUMERIC=C
[5] LC_TIME=Spanish_Spain.1252
```

```
attached base packages:
[1] stats graphics grDevices utils datasets methods base
```

```
other attached packages:
[1] rgdal_1.4-4 tmap_3.1 ggbreak_0.0.7 ggplot2_3.3.3 sf_0.9-5 dplyr_1.0.6 purrr_0.3.4 ZeBook_1.1 doBy_4.6.11
[10] raster_3.3-13 sp_1.4-2
```

```
loaded via a namespace (and not attached):
 [1] tidy_1.1.0 viridisLite_0.3.0 microbenchmark_1.4-7 shiny_1.5.0 assertthat_0.2.1 yulab.utils_0.0.4
 [7] yaml_2.2.0 pillar_1.6.1 backports_1.1.4 lattice_0.20-38 glue_1.4.2 digest_0.6.19
[13] RColorBrewer_1.1-2 promises_1.1.1 colorspace_1.4-1 ggfun_0.0.4 htmltools_0.5.0 httpuv_1.5.4
[19] Matrix_1.2-17 XML_3.98-1.20 pkgconfig_2.0.2 broom_0.7.0 triangle_0.12 curry_0.1.1
[25] stars_0.4-3 xtable_1.8-4 patchwork_1.1.1 scales_1.0.0 ggplotify_0.1.0 later_1.1.0.1
[31] tibble_3.0.3 generics_0.0.2 ellipsis_0.3.2 withr_2.3.0 leafsync_0.1.0 magrittr_1.5
[37] crayon_1.3.4 mime_0.7 fansi_0.4.0 MASS_7.3-51.4 lwgeom_0.2-5 class_7.3-15
[43] tools_3.6.0 lifecycle_1.0.0 aplot_0.1.2 munsell_0.5.0 Deriv_3.8.5 compiler_3.6.0
[49] e1071_1.7-2 gridGraphics_0.5-1 rlang_0.4.11 classInt_0.4-3 units_0.6-3 grid_3.6.0
[55] tmaptools_3.1 dichromat_2.0-0 rstudioapi_0.13 htmlwidgets_1.3 crosstalk_1.0.0 labeling_0.3
[61] base64enc_0.1-3 leafem_0.1.1 gtable_0.3.0 codetools_0.2-16 abind_1.4-5 deSolve_1.28
[67] DBI_1.1.1 R6_2.4.0 fastmap_1.0.1 utf8_1.1.4 KernSmooth_2.23-15 parallel_3.6.0
[73] Rcpp_1.0.1 png_0.1-7 vctrs_0.3.8 leaflet_2.0.3 tidyselect_1.1.0
```

Ascospore maturation and onset of ascospore release model

Code organisation:

```
magarey {
  - code {
    1_moyo_database_assembly.R
    2_moyo_model_outputs.R
  }
  - data*
  - functions {
    moyo.R
    moyo_df.R
    moyo_sf.R
    moyo_plots_pdf.R
  }
  - results*
}
```

data*: To run the code is it provided a clip of the study area which corresponds to Cyprus growing regions. **data*** folder contains:

- Environmental variable information in `raster` format about maximum temperature (°C), mean temperature (°C), minimum temperature (°C), precipitation (mm) and vpaor pressure deficit (hPa) in daily frequency and organised in subfolders collecting information corresponding to a two-year period (i.e., 2009-10, 2011-12, 2013-14, 2015-16, 2017-18).
- Boundaries of the study area (i.e, for Cyprus),
- The assembled database over the 10-year period under study. It will be stored after the execution of script `1_moyo_database_assembly.R` in a sub-folder named 2009-18.

results*: All results and auxiliary files necessary to obtain them will be automatically stored in this folder.

sessionInfo():

```
R version 3.6.0 (2019-04-26)
Platform: x86_64-w64-mingw32/x64 (64-bit)
Running under: Windows >= 8 x64 (build 9200)
```

Matrix products: default

```
locale:
[1] LC_COLLATE=Spanish_Spain.1252 LC_CTYPE=Spanish_Spain.1252 LC_MONETARY=Spanish_Spain.1252 LC_NUMERIC=C
[5] LC_TIME=Spanish_Spain.1252
```

```

attached base packages:
[1] stats      graphics  grDevices  utils      datasets  methods   base

other attached packages:
[1] tmap_3.1          ggplot2_3.3.3    plyr_1.8.4      sf_0.9-5      lubridate_1.7.9.2  dplyr_1.0.6      raster_3.3-13
[8] sp_1.4-2

loaded via a namespace (and not attached):
 [1] tidyselect_1.1.0  purrr_0.3.4      lattice_0.20-38  colorspace_1.4-1  vctrs_0.3.8      generics_0.0.2
 [7] viridisLite_0.3.0  htmltools_0.5.0  stars_0.4-3     base64enc_0.1-3   yaml_2.2.0       XML_3.98-1.20
[13] utf8_1.1.4        rlang_0.4.11     e1071_1.7-2     pillar_1.6.1      later_1.1.0.1    glue_1.4.2
[19] withr_2.3.0       DBI_1.1.1        RColorBrewer_1.1-2  lifecycle_1.0.0  munsell_0.5.0    gtable_0.3.0
[25] htmlwidgets_1.3   codetools_0.2-16  leafsync_0.1.0  labeling_0.3      fastmap_1.0.1    httpuv_1.5.4
[31] crosstalk_1.0.0   parallel_3.6.0   class_7.3-15    fansi_0.4.0       leafem_0.1.1     Rcpp_1.0.1
[37] KernSmooth_2.23-15  xtable_1.8-4     scales_1.0.0    promises_1.1.1    classInt_0.4-3   lwgeom_0.2-5
[43] leaflet_2.0.3     abind_1.4-5      mime_0.7         png_0.1-7         digest_0.6.19    shiny_1.5.0
[49] tmertools_3.1     grid_3.6.0       rgdal_1.4-4     tools_3.6.0       magrittr_1.5     tibble_3.0.3
[55] dichromat_2.0-0   crayon_1.3.4     pkgconfig_2.0.2  ellipsis_0.3.2    assertthat_0.2.1  rstudioapi_0.13
[61] R6_2.4.0          units_0.6-3      compiler_3.6.0

```

Comments

- The scripts have been created under UTF-8 encoding.
- To run the scripts is it provided a clip of the study area which corresponds to Cyprus growing regions.
- The scripts have been executed with the R version 3.6.0 (2019-04-26); Platform: x86_64-w64-mingw32/x64 (64-bit); Running under: Windows >= 8 x64 (build 9200).
- To execute the code, R scripts should be run in the order specified in the file name (i.e., 1_, 2_, ...)

References

1. Magarey, R., Sutton, T. & Thayer, C. A simple generic infection model for foliar fungal plant pathogens. *Phytopathology* **95**, 92–100 (2005).
2. Moyo, P., du Raan, S. & Fourie, P. H. Models for predicting pseudothecium maturity and ascospore release of *phyllosticta* spp. in south african citrus orchards. *South Afr. J. Sci.* **116**, 1–10 (2020).