Sorensen

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# Overview

Sorensen.R module re-implements a model created by Sorensen *et al.* (2008), in which numbers of female caribou (*Rangifer tarandus caribou*) in a population can be predicted based on the amount of anthropogenic and natural disturbance across their population’s range.The module can be run on a neutral simulated landscape, or using Canadian ecoregion landscape data.

# Usage

It is not meaningful to run this module on its own. The module uses key information from several other modules about a given ecodistrict, should the module be used to predict caribou populations for a specific area, as well as to run burn events and to determine the length of time since an area/raster map cell was disturbed by fire.

The following parameters are given:

**IND:** a constant that describes the percentage of the landscape that is within 250m of industrial activity such as roads, forestry, and oil wells and pipelines. In the landscapes studied by Sorensen *et al.* (2008) the average IND was found to be 54.2%, so this is the default value for this parameter.

**N0:** The number of female caribou in the population at time 0, or the start of the simulation. Environment Canada (2012) states that current evidence suggests that “more than 300 boreal caribou are needed for self-sustaining local populations.” Farnell *et al.* (1994) found that in the two populatons they studied there was a larger number of cow caribou than bull caribou, with an average of only 42 bulls for every 100 cows. The default initial number female of caribou in the population is therefore given as 187.

**minHabitatAge:** The minimum amount of time that must pass following fire disturbance for an area to be suitable for use by caribou. This is due to the absence of suitable lichen in young forests. Sorensen *et al.* (2008) used the value of 50 years, giving our default for the parameter.

### Here the module is run using a neutral, simulated landscape:

It is necessary to stipulate the size of the flammableMap and make nFlammable have an equal number of cells.

library(igraph)

##   
## Attaching package: 'igraph'

## The following objects are masked from 'package:stats':  
##   
## decompose, spectrum

## The following object is masked from 'package:base':  
##   
## union

library(SpaDES.core)

## Loading required package: quickPlot

## Loading required package: reproducible

##   
## Attaching package: 'reproducible'

## The following object is masked from 'package:igraph':  
##   
## %>%

library(SpaDES)

## using reproducible 0.1.4  
## using quickPlot 0.1.3  
## using SpaDES.core 0.1.1  
## loading SpaDES.tools 0.1.1  
## loading SpaDES.addins 0.1.1

## Default paths for SpaDES directories set to:  
## cachePath: C:\Users\RALAS6\AppData\Local\Temp\RtmpeahIft/SpaDES/cache  
## inputPath: C:\Users\RALAS6\AppData\Local\Temp\RtmpeahIft/SpaDES/inputs  
## modulePath: C:\Users\RALAS6\AppData\Local\Temp\RtmpeahIft/SpaDES/modules  
## outputPath: C:\Users\RALAS6\AppData\Local\Temp\RtmpeahIft/SpaDES/outputs  
## These can be changed using 'setPaths()'. See '?setPaths'.

library(magrittr)

##   
## Attaching package: 'magrittr'

## The following object is masked from 'package:reproducible':  
##   
## %>%

library(raster)

## Loading required package: sp

##   
## Attaching package: 'raster'

## The following object is masked from 'package:magrittr':  
##   
## extract

library(spatial.tools)

## Loading required package: parallel

## Loading required package: iterators

## Loading required package: foreach

##   
## Attaching package: 'foreach'

## The following object is masked from 'package:SpaDES.core':  
##   
## times

## Loading required package: rgdal

## rgdal: version: 1.2-16, (SVN revision 701)  
## Geospatial Data Abstraction Library extensions to R successfully loaded  
## Loaded GDAL runtime: GDAL 2.2.0, released 2017/04/28  
## Path to GDAL shared files: C:/Users/RALAS6/Documents/R/win-library/3.3/rgdal/gdal  
## GDAL binary built with GEOS: TRUE   
## Loaded PROJ.4 runtime: Rel. 4.9.3, 15 August 2016, [PJ\_VERSION: 493]  
## Path to PROJ.4 shared files: C:/Users/RALAS6/Documents/R/win-library/3.3/rgdal/proj  
## Linking to sp version: 1.2-7

library(rgdal)  
  
moduleDir <- file.path("C:/Users/RALAS6/Documents/Modelling Forest Landscapes Class/Labs/scfmModules/")  
  
inputDir <- file.path("inputs") %>% reproducible::checkPath(create = TRUE)  
outputDir <- file.path(moduleDir, "outputs")  
cacheDir <- file.path(outputDir, "cache")  
times <- list(start = 0, end = 50)   
  
parameters <- list(  
 Sorensen = list( N0 = 100, #decide initial herd size  
 IND = 30, #decide % of landscape has been disturbed by anthropogenic factors  
 minHabitatAge = 50), #decide the age a forest must be to provide caribou habitat  
 ageModule = list(initialAge=75,   
 .plotInitialTime=0),  
 scfmSpread = list(.plotInitialTime=0,  
 pOverRide=0.29))  
  
scfmPars <- list(pSpread=0.235,  
 p0=0.115,  
 naiveP0=0.15,   
 pIgnition=0.00001,   
 maxBurnCells=NA  
 )  
  
modules <- list( "scfmIgnition", "scfmEscape", "scfmSpread", "ageModule", "mapBurns", "Sorensen")  
  
objects <- list(scfmPars = scfmPars,  
 nNbrs = 8,  
 flammableMap = raster(raster::extent(0,100,0,100),nrow=100, ncol=100, vals=0),  
 landscapeAttr = list(cellSize=6.25, nFlammable=100\*100) #make the nFlamable the same dimensions as the flammableMap  
 )  
  
paths <- list(  
 cachePath = cacheDir,  
 modulePath = moduleDir,  
 inputPath = inputDir,  
 outputPath = outputDir  
)  
  
mySim <- simInit(times = times,   
 params = parameters,   
 modules = modules,  
 objects = objects,   
 paths = paths  
 )

## Loading required package: data.table

##   
## Attaching package: 'data.table'

## The following object is masked from 'package:raster':  
##   
## shift

## Loading required package: RColorBrewer

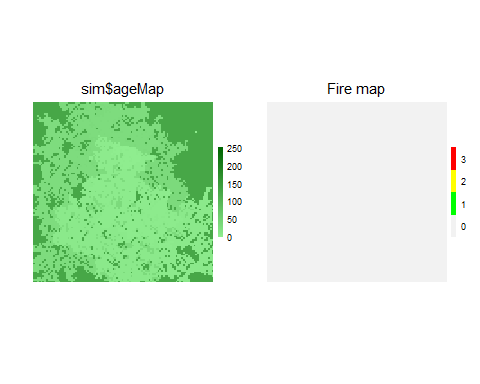
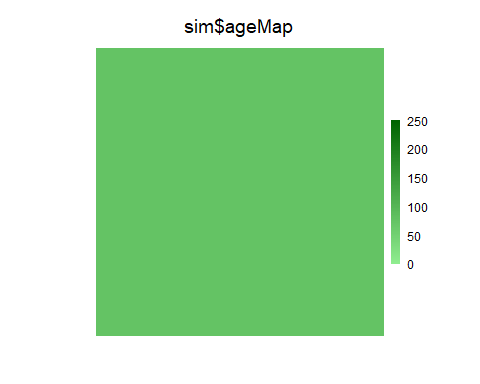
## Running .inputObjects for scfmEscape

## Running .inputObjects for scfmSpread

## Running .inputObjects for ageModule

## Running .inputObjects for Sorensen

mySim<-spades(mySim)



mySim$herdTable[]

## Lt Nt  
## 1 Initial herd size: 100.00000  
## 2 1.094 109.40000  
## 3 1.094 119.68360  
## 4 1.094 130.93386  
## 5 1.094 143.24164  
## 6 1.094 156.70636  
## 7 1.094 171.43675  
## 8 1.094 187.55181  
## 9 1.094 205.18168  
## 10 1.094 224.46876  
## 11 1.094 245.56882  
## 12 1.094 268.65229  
## 13 1.09397 293.89754  
## 14 1.09397 321.51509  
## 15 1.09397 351.72787  
## 16 1.09397 384.77974  
## 17 1.09397 420.93749  
## 18 1.00154 421.58573  
## 19 1.00151 422.22233  
## 20 1.00151 422.85988  
## 21 0.92729 392.11374  
## 22 0.92729 363.60315  
## 23 0.92729 337.16556  
## 24 0.92729 312.65026  
## 25 0.92729 289.91746  
## 26 0.92729 268.83756  
## 27 0.92729 249.29038  
## 28 0.92729 231.16448  
## 29 0.92729 214.35651  
## 30 0.92729 198.77064  
## 31 0.92729 184.31803  
## 32 0.92729 170.91627  
## 33 0.92729 158.48895  
## 34 0.92729 146.96521  
## 35 0.92729 136.27937  
## 36 0.92729 126.37050  
## 37 0.92729 117.18210  
## 38 0.92729 108.66179  
## 39 0.92729 100.76099  
## 40 0.92729 93.43466  
## 41 0.92729 86.64103  
## 42 0.92729 80.34136  
## 43 0.92729 74.49974  
## 44 0.8894 66.26007  
## 45 0.8894 58.93170  
## 46 0.8894 52.41386  
## 47 0.8894 46.61688  
## 48 0.88319 41.17157  
## 49 0.88319 36.36232  
## 50 0.88316 32.11374  
## 51 0.8831 28.35965  
## 52 0.8831 25.04440

### Here the module is run using landcover data from an ecodistrict:

It is necessary to stipulate the preferred ecodistrict and provide the ecodistrict shapefile.

library(igraph)  
library(SpaDES.core)  
library(SpaDES)  
library(magrittr)  
library(raster)  
library(spatial.tools)  
library(rgdal)  
  
moduleDir <- file.path("C:/Users/RALAS6/Documents/Modelling Forest Landscapes Class/Labs/scfmmodules/")  
  
inputDir <- file.path("inputs") %>% reproducible::checkPath(create = TRUE)  
outputDir <- file.path(moduleDir, "outputs")  
cacheDir <- file.path(outputDir, "cache")  
times <- list(start = 0, end = 50)   
  
#dsn <- file.path(inputDir, "Ecodistricts")  
 shape <- readOGR(dsn = 'C:/Users/RALAS6/Documents/Modelling Forest Landscapes Class/Labs/inputs/Ecodistricts', layer = "ecodistricts")  
 studyArea<-shape[shape$ECODISTRIC==262,] #decide what ecodistrict to look at   
   
parameters <- list(  
 Sorensen = list( N0 = 187, #decide initial herd size  
 IND = 30, #decide % of landscape has been disturbed by anthropogenic factors  
 minHabitatAge = 50), #decide the age a forest must be to provide caribou habitat  
 scfmSpread = list(pOverRide=0.28))  
  
modules <- list("scfmCrop", "scfmLandcoverInit", "scfmRegime", "scfmDriver","scfmIgnition", "scfmEscape", "scfmSpread", "ageModule", "mapBurns", "Sorensen")  
  
objects <- list(studyArea=studyArea,  
 nNbrs=8)  
paths <- list(  
 cachePath = cacheDir,  
 modulePath = moduleDir,  
 inputPath = inputDir,  
 outputPath = outputDir  
)  
  
mySim <- simInit(times = times,   
 params = parameters,   
 modules = modules,  
 objects = objects,   
 paths = paths  
 )

## Loading required package: rgeos

## rgeos version: 0.3-26, (SVN revision 560)  
## GEOS runtime version: 3.6.1-CAPI-1.10.1 r0   
## Linking to sp version: 1.2-7   
## Polygon checking: TRUE

## Using or creating cached copy of .inputObjects for scfmCrop

## Using or creating cached copy of .inputObjects for scfmLandcoverInit

## Running .inputObjects for scfmRegime

## loading cached result from previous readOGR call.

## Running .inputObjects for scfmDriver

## Running .inputObjects for scfmEscape

## Running .inputObjects for scfmSpread

## Running .inputObjects for ageModule

## Running .inputObjects for Sorensen

mySim<-spades(mySim)  
  
mySim$herdTable[]

## Lt Nt  
## 1 Initial herd size: 187.000000  
## 2 0.885414358349399 165.572485  
## 3 0.88327768732082 146.246482  
## 4 0.882856146799988 129.114605  
## 5 0.882681337342297 113.967052  
## 6 0.882892107602713 100.620611  
## 7 0.882196865416696 88.767188  
## 8 0.879689598337812 78.087572  
## 9 0.878966386638564 68.636351  
## 10 0.877832622441539 60.251228  
## 11 0.877120398765346 52.847581  
## 12 0.876020597548672 46.295569  
## 13 0.876321269815901 40.569792  
## 14 0.876335254572516 35.552739  
## 15 0.876112497377858 31.148199  
## 16 0.877324176647454 27.327068  
## 17 0.879006343086036 24.020666  
## 18 0.878907450878542 21.111943  
## 19 0.879403909738385 18.565925  
## 20 0.880017241207084 16.338334  
## 21 0.879814462236162 14.374702  
## 22 0.880921255831144 12.662981  
## 23 0.887564015223406 11.239206  
## 24 0.888980471286298 9.991435  
## 25 0.891324915841732 8.905615  
## 26 0.923036350378088 8.220206  
## 27 0.92941639612822 7.639994  
## 28 0.930839844569419 7.111611  
## 29 0.93194364143084 6.627621  
## 30 0.933753668501333 6.188565  
## 31 0.934761569888821 5.784833  
## 32 0.937665404708867 5.424238  
## 33 0.937885165169965 5.087312  
## 34 0.938517475951213 4.774531  
## 35 0.940181661988432 4.488927  
## 36 0.938888072001518 4.214600  
## 37 0.939643248858744 3.960220  
## 38 0.937754307804493 3.713714  
## 39 0.938340668671148 3.484729  
## 40 0.937107013355442 3.265564  
## 41 0.961603312389495 3.140177  
## 42 0.96559596040316 3.032142  
## 43 0.966077435595201 2.929284  
## 44 0.966548921675374 2.831296  
## 45 0.970385739543897 2.747449  
## 46 0.977149367189763 2.684669  
## 47 0.980345882987543 2.631904  
## 48 0.98113202609156 2.582245  
## 49 0.98022501473394 2.531181  
## 50 0.980491724020817 2.481802  
## 51 0.98403785873398 2.442187  
## 52 0.985534227691816 2.406859

# Events

**Init:** Initiates the Sorensen Module. It also creates the herdTable dataframe, and adds the first row of data, giving the initial caribou herd size.

**SorensenE:** Calculates BURN, the percentage of the forest that is younger than a given age (parameter minHabitatAge), and that is not an unburnable feature, such as a lake. Lambda (Lt), the rate of population increase, is then calculated using the following formula:

Lt = Lt <- 0.03 - (0.0032 \* IND) - (0.0030 \* BURN)

Using Lt the new caribou population size is calculated (Nt). The values for Lt and Nt are recorded in herdTable.

# Data dependencies

## Input data

The module requires an ageMap (a raster which details the age of the forest) a flammableMap (a map which is exposed to a burn regime) and landscapeAttr, (which provides details which of the landscape cells are covered by lakes, rather than forest).

## Output data

The Sorensen module produces the herdTable dataframe, which documents the caribou population growth, and resulting herd size (breeding females only) over the simulated time steps (years). The module also produces Nt (herd size) as an output.

# Links to other modules

The Sorensen module links to the modules “scfmCrop”, “scfmLandcoverInit”, “scfmRegime” and “scfmDriver” if it is modelling a specific ecodistrict, as well as “scfmIgnition”, “scfmEscape”, “scfmSpread”, “ageModule” and “mapBurns”.

# References

Environment Canada. 2012. Recovery Strategy for the Woodland Caribou (\*Rangifer tarandus caribou), Boreal population, in Canada. Species at Risk Act Recovery Strategy Series. Environment Canada, Ottawa. xi + 138pp.

Farnell, R., Barichello, N., Eglil, K., and Kuzyk, G. 1994. Population ecology of two woodland caribou herds in the southern Yukon. The Sixth North American Caribou Workshop, Prince George, British Columbia, Canada, 1-4 March, 1994.

Sorensen, T., McLoughlin, P., Hervieux, D., Dzus, E., Nolan, J., Wynes, B., Boutin, S. 2007. Determining Sustainable Levels of Cumulative Effects of Boreal Caribou. Journal of Wildlife Management 72(4):900-905.