Original Research

Research on Crop Ecophysiology
Vol.16/1, Issue 1 (2021), Pages: 64 – 68

Creation of a Spatiotemporal Map of Continent-wide Pesticide Consumption for Crop Production in the Period Between 1990 and 2020 Using the R Software

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Received: 26 October 2020 Accepted: 25 JANUARY 2021

ABSTRACT

Many random variables experience both spatial and temporal variability. In scientific terminology these variables have been called spatiotemporal variables. For example most of the data on agriculture, geography, medicine, etc have a spatiotemporal nature. To have a suitable understanding of these variables, it is a good idea to present them on a map having an animated format. One of the best platforms that can perform this duty is R. The reasons of popularity of R is as follows: R is an open-source, platform-independent, still growing software. It has lots of packages and is great for statistical analysis. R is well suited for Machine Learning, and lets you perform data wrangling. The R contains a package named t-map that can be used to create spatiotemporal maps. In this report, the creation of a spatiotemporal map of pesticide consumption per unit area for crop production in different continents between 1990 and 2020 with the aid of the open source R software has been summarized. The aim of this report to introduce this software Therefore, it focuses only on the methodology of map creation with the final goal of motivating agriculturalists to use this software in presenting their future studies.

Keywords*:* t-map package, R software, Pesticide consumption, Crop production

INTRODUCTION

The statistical environment R (R Core Team, 2013) is an open source tool that brought effortless flexibility to statisticians and engineers to test their ideas quickly, to perform statistical analyses progressively and to visualize their scientific reports nicely. To show the

power of R to perform statistical analysis, it is sufficient to emphasise that the authors of the most famous textbook for spatio-temporal statistics have used the R package "spacetime" developed by Pebesma (2012) for presenting the results of all numerical case studies and applications (Cressie and Wikle (2015). Of course, additional skills are required to go from the casual use of R as the mathematician's pocket calculator to a professional statistical tool for spatio-temporal analysis.

On the other hand, spatiotemporal maps are suitable tools to convey spatial and temporal information to the audience simultaneously. The t-map package of R software can be used to create these maps easily (Tennekes, 2018). Before the development of R, researchers have been utilizing GIS software to present their data in an spatiotemporal map (Cahyadi *et al.*, 2022; Cardone & Di Martino, 2022). The advantage of R comparing to GIS is that R is an open source, command line-based software, while GIS is commercial, click-based software. It is repeatedly heard that a command line-based software can motivate creativity in presenting data more than click-based software. In this report, this software has been briefly introduced to create a map of continent-wide pesticide consumption for crop production from 1990 to 2020.

MATERIALS AND METHODS

To create the spatiotemporal map considered herein, a data frame (named *finalframe*) was developed. This data frame was composed of 11 columns and 248 rows; however, 3 of its columns named "*YEAR*", "*geometry*", "*Pest_Cons_kg_per_km_2*" were used in the process of the creation of the map. Figure 1 taken from the environment console of R shows the overview of the *finalframe* contents.

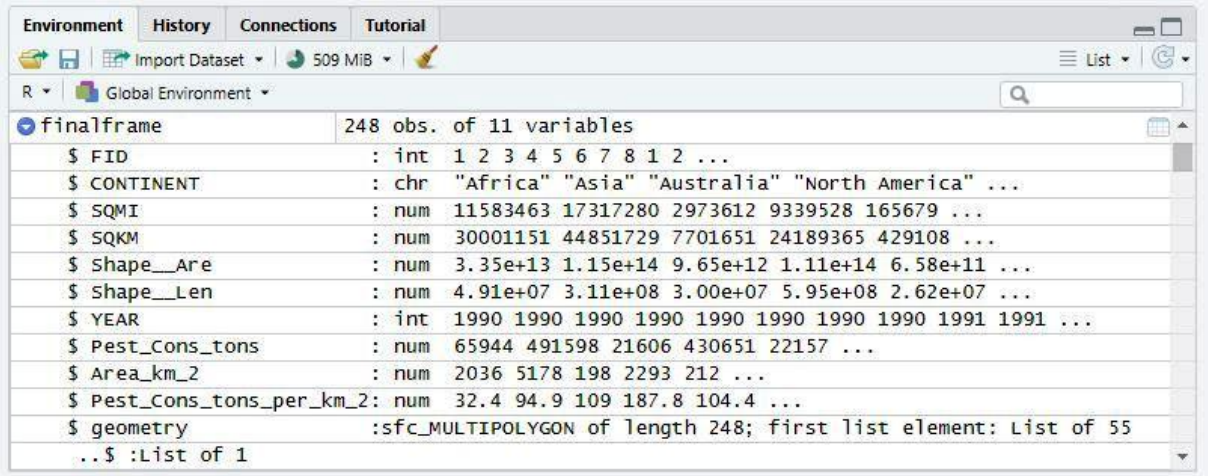

Figure 1- Overview of the *finalframe* contents used to create spatiotemporal maps

The "*YEAR*" column was composed of year numbers from 1990 to 2020 (31 years) each of which was repeated 8 times. 8 is the number of continents (Africa, Asia, Australia, North America, Oceania, South America, Antarctica, and Europe).

The building block of the "*geometry*" column was a shape file (named *World_Continents.shp*) containing polygons that form geographic borders of the 8 continents. The contents of this file were repeated 31 times. 31 is the number of years (from 1990 to 2020).

The third column was the dataset of continent-wide pesticide consumption per unit area of the lands used for crop production in each of the years considered, this column was uploaded to R by an Excel file (named *newcolumn.csv*).

All data were obtained from Internet resources. The pesticide consumption data from URL: *https://www.fao.org/food-agriculture-statistics/data-release/environment/en/*, and the spatial data of continents from URL:

https://opendata.arcgis.com/api/v3/datasets/57c1ade4fa7c4e2384e6a23f2b3bd254_0/downloads/data?format=shp&spatialRefId=4326&where=1%3D1.

Finally, using the following R-codes, a spatiotemporal map was developed.

Codes:

```
install.packages("sf")
install.packages("tmap")
install.packages("dplyr")
install.packages("gifski")
library(sf)
library(tmap)
setwd("C:/...")          #Setting the address of the working directory. The "newcolumn.csv", and
                         #"World_Continent.shp" files must be transferred to the working directory.
newcolumn<-read.csv("newcolumn.csv")
continent<- st_read("World_Continents.shp")
library(dplyr)
modifyframe<-bind_rows(replicate(31, continent, simplify = FALSE))
finalframe<-cbind(modifyframe,newcolumn)
library(gifski)
Pesticide_Cons_spec<-tm_shape(finalframe)+ tm_polygons(col="Pest_Cons_tons_per_km_2")+
tm_facets(along = "YEAR", free.coords = FALSE)+tmap_style("gray")
tmap_animation(Pesticide_Cons_spec, filename = "Pesticide_Cons_spec_col_gray.gif", delay = 30)
```

RESULTS AND DISCUSSION

Figures 2.a and 2.b show the spatial maps of 1990 and 2020, respectively (the animated version of the spatiotemporal map has been attached to the paper as supplementary material).

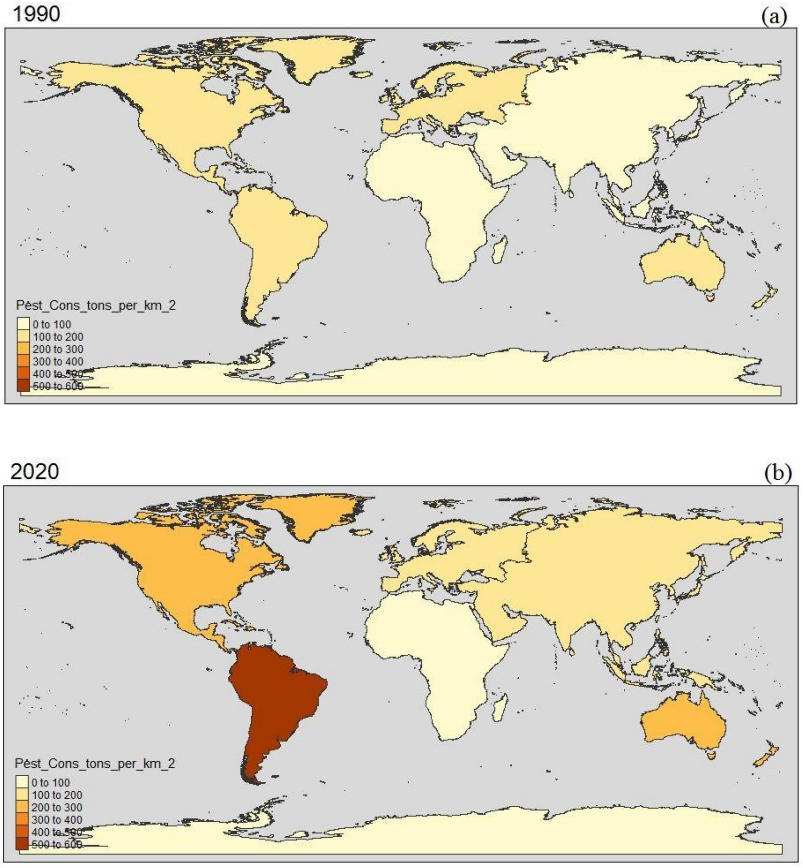

Figure 2- Spatial maps of pesticide consumption per unit area of agricultural lands in different continents in 1990 (a), and 2020 (b) (the animated map has been attached as supplementary material)

The bad news is that globally there is an increasing trend of pesticide consumption in crop production. The good news is that in some continents i.e. Europe and Africa, the consumption of pesticides in agriculture has remained fixed at low level in this period. Therefore, other continents should follow the procedures considered in Europe and Africa in order to achieve the goal of cleaner crop production.

CONCLUSION

To obtain essential information about the spatiotemporal status of the consumption of different production inputs with the aim of correcting false decisions to achieve cleaner production, the capability of the open source R software, as shown in this report, can be used easily.

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