EAS 543
Environmental Spatial Analysis
Fall 2021

Course Information
Credits: 3
Meeting days: Tuesdays and Thursdays (11:30 am to 1:00 pm)
Location: This is an online (synchronous) course. Link in the lecture CANVAS site.
Prerequisites: EAS 531 (Principle of GIS) and EAS 538 (Natural Resources Statistics) or equivalent.

Instructor
Instructor: Dr. Silvia Cordero-Sancho.
Email: corderos@umich.edu
I will do my best to reply to your email with 24 hours.

***Office hours**:*
Wednesday: 1:00 to 2:00 pm.
Find link to meeting in the EAS 543 001 FA 2021 canvas site.
If this time does not work for you, email me.

Resources
All class resources will be available in the course CANVAS sites:
- EAS 543 001: All material referent to lecture and class projects.
- EAS 543 002: All material referent to lab sessions.

Textbook
O'Sullivan D and Unwin D 2010 Geographic information analysis (Hoboken, N.J: John Wiley & Sons)
Access online from the library:

1. COURSE DESCRIPTION

EAS 543 will introduce you to statistical methods associated with the analysis of spatial data. The main difference between statistical methods explored in courses like EAS 538 is that EAS 543 considers the influence the spatial location of a set of observations. With the inclusion of the spatial component, we could ask and answer questions such as: *are my features independently allocated*? *Are the features in my study area spatially clustered*? *Is my data spatially autocorrelated*? And if so, *how does it affect my analysis*?

By the end of this course, you will have a new set of spatial analytical skills. You will be able to select the more suitable methodologies to assess spatial patterns, spatial associations, spatial clustering, spatial trends and conduct spatial inference analysis. The course has two main components: a theoretical one and a practical one. For the theoretical one, we will discuss spatial statistics theory, learn about applications, and explore six spatial commonly employed statistical methods. We will discuss the concept of spatial autocorrelation (SA) and learn about its influence on spatial trends.

The second component is the practical one. We will employ R with RStudio, and GeoDA software. We will learn how to manipulate, display, analyze spatial and non-spatial datasets. Class examples are designed to show you how to analyze spatial datasets in the R environment with the help of several packages, including data cleaning and preparation, analysis, interpretation of results, visualization, and summarization of results.

The class deliverables include lab reports (individual work) and two group activities: 1) a final project and the discussion of an academic paper.

1.1. COURSE GOALS AND LEARNING OBJECTIVES

The main goal of this course is to provide you with theoretical and practical experience. At the end of this course, you will be able to:

- Understand the theoretical spatial statistical principles.
- Understand the concept of spatial autocorrelation and the relevance of this concept to the spatial analysis procedures.
- Be able to explain the applications of the spatial statistical methods reviewed in class.
- Gain hands-on experience analyzing spatial data (e.g., pre-processing data, analysis, and synthesis).

Important notes

1 Carefully read the syllabus and check the CANVAS sites.

2 Always use your university email!

3 Respond to the class surveys.

4 Install the required software (Table 1) before our first lab session (09/02/2021)

Table 1. List of required freeware software for EAS 543-Fall 2021

Software	Version	Link	Done [4]
R Studio Desktop [1]	1.4	MAC and WIN: https://www.rstudio.com/products/rstudio/	
R [2]	4.1.0	MAC and WIN: https://cran.r-project.org/	
GeoDa	1.18.0	MAC and WIN: https://geodacenter.github.io/download.html	
TinyTex [3]		https://yihui.org/tinytex/ Follow instructions "*For R Users*"	
Google Earth Engine account		If you do not have one, create an account in Google Earth Engine. See instructions in EAS 543 001 FA 2021/Files/Software/**GEE_AFS_inst.pdf**). If you enrolled in EAS 541 (W-2020, W-2021), you do not need to do this step.	

Notes:

[1] If you need help installing R and R studio, refer to: https://libguides.wustl.edu/c.php?g=385216&p=2612134

[2] If you have R and R Studio installed, check that you are running a current version (i.e., R version 4.1.0 or newer). If you need help updating R, check: EAS 543 001 FA 2021 /Files/Software/**UpdatingRandRstudio_2021.pdf)**

[3]. *If you already have another LaTeX compiler installed on your computer you do not need to install TinyTex.*

4 For your own control, use this column to check your progress ✓

2. METHODOLOGY

This course includes learning different statistical methods employed with spatial data. We will review the theoretical background and explore applications of the methods assessed in class. In addition, we will use freeware software to conduct statistical analysis of spatial data. You will gain practical experience by completing lab reports and work in your own mini-research project.

3. ACTIVITIES AND ASSIGNMENTS

There are three main activities designed to gain practical theoretical and practical experience. Some of these activities will be completed individually (i.e., lab reports). Others are group activities (i.e., leading a scientific paper discussion and a research project.)

Lab reports. There are six lab reports. Topics are listed in Table 2 and datelines in Table 3.

Leading a scientific paper discussion. This will be conducted in pairs. Each group will select a specific topic a reading and present in the corresponding discussion session. Each session will cover different topics.

- For specifics of this activity, carefully read EAS543_2021_LPD.PDF.
- Use the Google-spreadsheet to sign up for a topic/date. Remember to use your university account.

Group Research Project. The project will be conducted in groups of three students. Each group will develop a project during the semesters employing one of the spatial statistic methods assessed in class. The groups will work on their projects in and out of the classroom. There are four sessions in the class calendar (Table 2) dedicated to this activity.

- More details in EAS543_2021_GRP.PDF.
- Project working days and datelines related to the project on Table 3.
- The instructor will help you to organize into groups.

Deliverables:

1) Two assignments (RGP-Task 1 and RGP-Task 2, to complete during the semester.)
2) A poster, poster presentation, code, plus project metadata (to complete at the end of the semester.)

4. EVALUATION AND GRADING SYSTEM

- Labs: 60% (n=6)
- Scientific paper discussion: 10%
- Group research project: 30%

Percentage	Letter Grade	Percentage	Letter Grade	Percentage	Letter Grade	Percentage	Letter Grade
97.0 - 100	A+	85.5 - 89.4	B+	75.5 - 79.4	C+	65.5 - 69.5	D+
91.0 - 96.9	A	81.0 - 85.4	B	71.0 - 75.4	C	61.0 - 65.4	D
89.5 - 90.9	A-	79.5 - 80.9	B-	69.5 - 70.9	C-	59.5 - 60.9	D-

5. COURSE POLICIES

Attendance: I welcome all the students to join me during the live Zoom sessions during this semester. If you cannot make it, please let me know. **The zoom recording will be available only for one week.**

Questions are welcome at any time. You can type the question on the chat or raise your virtual hand. Be patient as there is not a GSI to help moderate the chat.

Participation: Students are expected to participate. Participation is encouraged and expected during the discussion sessions and lecture times. Students are responsible for completing the required reading materials (Table 4) by the assigned due date.

Accommodations: I will make every effort to accommodate the needs of students with hearing, visual, or other physical impairments. Likewise, I will try to accommodate major religious holidays. **Be sure to let me know your needs in advance**.

Late and Missing Assignments: If you cannot submit your assignment on time (e.g., illness, family or medical emergency, childcare concerns, internet problems, mental health, etc.), **contact me as soon as possible.**

- **If you are experiencing issues with your assignment, contact me ahead of the dateline. It is more challenging to assist you after the assignment deadline**.
- Late assignments are accepted **for two weeks after the due date**. Late assignments will receive **5 points deductions** for each late week.

Safety and respect: *I would like that all students feel safe being themselves in the time we are going to share as part of EAS 543, this include the time we meet for class and the time you will share completing the group activities. Therefore, I invite you to treat each other with the same measure of respect, consideration and support you expect from your classmates and instructor.*

During lecture and lab sessions, disconnect from unnecessary distractions, including social media, texting, phone calls, TV, video games, etc.

Mental health: Talking about mental health is not easy. Even admitting that we might need help is not always as simple as it sounds. It is normal to feel down occasionally, but it is not normal to feel down constantly. If you feel completely overwhelmed by your schoolwork or simple life, remember that the university has multiple resources to support you. This link summarizes all the available student services.

Remember that the Counseling & Phycological Services (CAPS) phone line is available 24/7 (734-764-8312)

Other university resources (safety):

Here are a couple of services to have in hand in case you need other safety help resources:

Hate crimes: 911 or DPSS (734- 763-1131). Also, check Rackham's "Resources Guide for Graduate Students."

Sexual & Gender-based misconduct: 911, DPSS (734- 763-1131) or SAPAC (734-936-3333, this is a 24-hour service.)

6. ACADEMIC HONESTY

We will adhere to the Rackham Academic and Professional Integrity Policy. Please refer to https://rackham.umich.edu/academic-policies/section8/

Policies will be strictly enforced.

Table 2. EAS 453 Class Schedule
(Notice that different activities have been color-coded to help you organize your schedule.)

Week	Session 1	Topic	Session 2	Topic
1	31 August	Intro to principals of environmental spatial statistics	2-Sep	Topic 1: Group projects organization. Topic 2: Review: Data manipulation
2	7-Sep	Working with Spatial data.	9-Sep	Lab 1: Spatial data in R environment
3	14-Sep	Spatial Point Pattern Analysis (SPPA)	16-Sep	Lab 2: Spatial Point Pattern Analysis Lab
4	21-Sep	Spatial Association Analysis (LISA)	23-Sep	Lab 3: Spatial Association Analysis (LISA)
5	28-Sep	Spatial Clustering Methods	30-Sep	Group Research Project Time
6	5-Oct	SPPA + LISA + Spatial Clustering Applications (paper discussion session)	7-Oct	Data preparation: introduction to RGEE: RS review & Google Earth Engine and R Integration
7	12-Oct	Introduction to Spatial Regression	14-Oct	Lab 4: Clustering Analysis Lab
8	19-Oct	*Study break*	21-Oct	Group Research Project Time
9	26-Oct	Spatial regression methods (continuation)	28-Oct	Regression with GeoDa and R (demo)
10	2-Nov	Spatial Regression Applications (paper discussion session)	4-Nov	Lab 5: Spatial Regression
11	9-Nov	Introduction to Spatial Interpolation (Kriging)	11-Nov	Data preparation: Spatial interpolation Kriging
12	16-Nov	Spatial interpolation (Kriging) Applications (paper discussion session)	18-Nov	Lab 6: Spatial interpolation (Kriging)
13	23-Nov	How to create a poster with R and *posterdown*.	25-Nov	*Thanksgiving*
14	30-Nov	Group Research Project Time	2-Dec	Group Research Project Time
15	7-Dec	Group Research Project Poster Presentations	9-Dec	Group Research Project Poster Presentations
16		*Examination week (there is no test for this course)*		

Important datelines:

Table 3. Datelines for labs and group research project

Date	Assignment
09/16/2021	Lab 1
09/23/2021	Lab 2
09/30/2021	Lab 3
10/05/2021	Scientific paper discussion [1]
10/07/2021	RGP-Task 1
10/21/2021	Lab4
10/28/2021	RGP Task 2
11/02/2021	Scientific paper discussion [1]
11/11/2021	Lab 5
11/16/2021	Scientific paper discussion [1]
11/30/2021	Lab 6
12/07/2021	Research Group Project poster presentation
12/09/2021	Research Group Project poster presentation

[1] ***Note****: be aware that not all datelines for the paper discussion are listed in this table.*

Table 4. Required readings and auxiliary materials

Topic	Date	Readings & Other Resources
Spatial Data	**08/31/2021**	**Required Material:** O'Sullivan D and Unwin D J 2010 The Pitfalls and Potential of Spatial Data *Geographic Information Analysis* (John Wiley & Sons, Ltd) pp 33–54 Online: http://onlinelibrary.wiley.com/doi/abs/10.1002/9780470549094.ch2 Kedron P, Frazier A E, Trgovac A B, Nelson T and Fotheringham A S 2021 Reproducibility and Replicability in Geographical Analysis Geographical Analysis 53 135–47 Online: https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/10.1111/gean.12221
		Other resources Pebesma, E.E., 2019. Simple Features in R [WWW Document]. URL https://cran.r-project.org/web/packages/sf/vignettes/sf1.html#what_is_a_feature (accessed 10.4.19). *R & RStudio Cheatsheets (2019-pdf format):* 1) RStudio Keyboard, 2)Shiny, 3) R Markdown, 4) Data Import, 5) Data Transformation (dplyr), 6) Data Visualization (ggplot2), 7) Apply function s with 'plurr', 8) String manipulation 'stringr', 9) Dates and times with 'lubridate', 10) Package Development, 11) Deep Learning with 'Keras', 12) Data Science in Spark with Keras, 13) Data Science in Spark with Sparklyr, 14) Tidy evaluation with rlang, 15) caret package, 16) sf package, 17) cartography package. *R-Packages Documentation (online vignettes & reference manuals)* *Package 'sf'* Vignettes: https://cran.r-project.org/web/packages/sf/vignettes/sf1.html#what_is_a_feature Manual: https://cran.r-project.org/web/packages/sf/sf.pdf *Package 'tmap'* Vignettes: https://cran.r-project.org/web/packages/tmap/vignettes/tmap-getstarted.html Manual: https://cran.r-project.org/web/packages/tmap/tmap.pdf *Package 'dplyr'* Vignettes: https://cran.r-project.org/web/packages/dplyr/vignettes/dplyr.html Manual: https://cran.r-project.org/web/packages/dplyr/dplyr.pdf

Topic	Date	Readings & Other Resources
Spatial data and R	**09/07/2021**	**Required Material:** O'Sullivan D and Unwin D J 2010 Fundamentals-Maps as Outcomes of Processes *Geographic Information Analysis* (John Wiley & Sons, Ltd) pp 93–119 Online: https://onlinelibrary-wiley-com.proxy.lib.umich.edu/doi/10.1002/9780470549094.ch4
		Other Resources: O'Sullivan D and Unwin D J 2010 Fundamentals-Mapping It Out *Geographic Information Analysis* (John Wiley & Sons, Ltd) pp 55–91 Online:
Spatial Point Pattern Analysis (SPPA)	**09/14/2021**	**Required Material:** O'Sullivan D and Unwin D J 2010 Point Pattern Analysis *Geographic Information Analysis* (John Wiley & Sons, Ltd) pp 121–56 Online: http://onlinelibrary.wiley.com/doi/abs/10.1002/9780470549094.ch5
		Other resources Funwi-Gabga, N., Mateu, J., 2011. Understanding the nesting spatial behaviour of gorillas in the Kagwene Sanctuary, Cameroon. Stoch Environ Res Risk Assess 26, 793–811. https://doi.org/10.1007/s00477-011-0541-1 Law, R., Illian, J., Burslem, D.F.R.P., Gratzer, G., Gunatilleke, C.V.S., Gunatilleke, I. a. U.N., 2009. Ecological information from spatial patterns of plants: insights from point process theory. Journal of Ecology 97, 616–628. https://doi.org/10.1111/j.1365-2745.2009.01510.x Perry, G.L.W., Miller, B.P., Enright, N.J., 2006. A comparison of methods for the statistical analysis of spatial point patterns in plant ecology. Plant Ecology 187, 59–82. https://www.jstor.org/stable/20146996 Velázquez, E., Martínez, I., Getzin, S., Moloney, K.A., Wiegand, T., 2016. An evaluation of the state of spatial point pattern analysis in ecology. Ecography 39, 1042–1055. https://doi.org/10.1111/ecog.01579 *R-Packages Documentation (online vignettes & reference manuals)* *Package 'spatstat'* Vignettes: https://cran.r-project.org/web/packages/spatstat/vignettes/getstart.pdf Manual: https://cran.r-project.org/web/packages/spatstat/spatstat.pdf *Package 'maptools'* Manual: https://cran.r-project.org/web/packages/maptools/maptools.pdf

Topic	Date	Readings & Other Resources
		Online resources: *Spatsat website:* http://spatstat.org/ *Programita (*SPPA software*):* http://programita.org/ *Recommended Textbooks:* Baddeley, A., Rubak, E., Turner, R., 2015. Spatial Point Patterns: Methodology and Applications with R. Chapman and Hall/CRC. Illian, D.J., Penttinen, P.A., Stoyan, D.H., Stoyan, D., 2008. Statistical Analysis and Modelling of Spatial Point Patterns, 1st ed. Wiley & Sons, West Sussex, England.
Spatial Association (LISA)	**09/21/2021**	**Required Material:** O'Sullivan D and Unwin D J 2010 Local Statistics *Geographic Information Analysis* (John Wiley & Sons, Ltd) pp 215–38 Online: http://onlinelibrary.wiley.com/doi/abs/10.1002/9780470549094.ch8
		Other resources Anselin, L., 1995. Local Indicators of Spatial Association—LISA. Geographical Analysis 27, 93–115. https://doi.org/10.1111/j.1538-4632.1995.tb00338.x Ord, J.K., Getis, A., 1995. Local Spatial Autocorrelation Statistics: Distributional Issues and an Application. Geographical Analysis 27, 286–306. https://doi.org/10.1111/j.1538-4632.1995.tb00912.x *R-Packages Documentation (online vignettes & reference manuals)* *Package 'spdep'* *Vignette:* https://cran.r-project.org/web/packages/spdep/vignettes/CO69.html Manual: https://cran.r-project.org/web/packages/spdep/spdep.pdf Geoda Sofware: https://geodacenter.github.io/ Anselin, L., Syabri, I., Kho, Y., 2006. GeoDa: An Introduction to Spatial Data Analysis. Geographical Analysis 38, 5–22. https://doi.org/10.1111/j.0016-7363.2005.00671.x

Topic	Date	Readings & Other Resources
Spatial Clustering	**09/28/2021**	**Required Material:** Han, J., Kamber, M., & Pei, J. (2012). 10 - Cluster Analysis: Basic Concepts and Methods. In J. Han, M. Kamber, & J. Pei (Eds.), *Data Mining (Third Edition)* (pp. 443–495). Morgan Kaufmann. https://doi.org/10.1016/B978-0-12-381479-1.00010-1 Arévalo, P., Bullock, E. L., Woodcock, C. E., & Olofsson, P. (2020). A Suite of Tools for Continuous Land Change Monitoring in Google Earth Engine. *Frontiers in Climate*, 2, 576740. https://doi.org/10.3389/fclim.2020.576740
		Other resources *R-Packages Documentation (online vignettes & reference manuals)* *Package 'rgee'* *Citation:* Aybar, C., Wu, Q., Bautista, L., Yali, R., & Barja, A. (2020). rgee: An R package for interacting with Google Earth Engine. *Journal of Open Source Software.* *Vignettes:* https://cran.r-project.org/web/packages/rgee/vignettes/rgee01.html https://cran.r-project.org/web/packages/rgee/vignettes/rgee02.html https://cran.r-project.org/web/packages/rgee/vignettes/rgee03.html
Spatial Regression	**10/12/2021**	**Required Material:** O'Sullivan D and Unwin D J 2010 Area Objects and Spatial Autocorrelation *Geographic Information Analysis* (John Wiley & Sons, Ltd) pp 187–214 Online: http://onlinelibrary.wiley.com/doi/abs/10.1002/9780470549094.ch7 Bivand, R., 2013. Chapter 9: Modelling Areal Data, in: Applied Spatial Data Analysis with R. Springer, New York, pp. 263-318.

Topic	Date	Readings & Other Resources
	10/26/2021	**Required materials:** Bivand, R. (2009). Applying Measures of Spatial Autocorrelation: Computation and Simulation. *Geographical Analysis,* 41(4), 375–384. https://doi.org/10.1111/j.1538-4632.2009.00764.x Dormann, C. F., McPherson, J. M., Araújo, M. B., Bivand, R., Bolliger, J., Carl, G., Davies, R. G., Hirzel, A., Jetz, W., Daniel Kissling, W., Kühn, I., Ohlemüller, R., R. Peres-Neto, P., Reineking, B., Schröder, B., Schurr, F. M., & Wilson, R. (2007). Methods to account for spatial autocorrelation in the analysis of species distributional data: A review. Ecography, 30(5), 609–628. https://doi.org/10.1111/j.2007.0906-7590.05171.x
		Other resources *R-Packages Documentation (online vignettes & reference manuals)* *Package 'spdep'* *Citation:* Bivand, Roger S. and Wong, David W. S. (2018) Comparing implementations of global and local indicators of spatial association TEST, 27(3), 716-748. URL https://doi.org/10.1007/s11749-018-0599-x Roger S. Bivand, Edzer Pebesma, Virgilio Gomez-Rubio, 2013. *Applied spatial data analysis with R, Second edition.* Springer, NY. https://asdar-book.org *Vignette:* https://cran.r-project.org/web/packages/spdep/vignettes/CO69.html Manual: https://cran.r-project.org/web/packages/spdep/spdep.pdf *Package 'visreg'* *Vignette:* https://cran.r-project.org/web/packages/visreg/vignettes/quick-start.html *Manual:* https://cran.r-project.org/web/packages/visreg/visreg.pdf Geoda Sofware: https://geodacenter.github.io/ Anselin, L., Syabri, I., Kho, Y., 2006. GeoDa: An Introduction to Spatial Data Analysis. Geographical Analysis 38, 5–22. https://doi.org/10.1111/j.0016-7363.2005.00671.x

Topic	Date	Readings & Other Resources
Introduction to Spatial Interpolation (Kriging)	**11/16/2021**	**Required Material:** O'Sullivan D and Unwin D J 2010 Knowing the Unknowable: The Statistics of Fields *Geographic Information Analysis* (John Wiley & Sons, Ltd) pp 277–314 Online: http://onlinelibrary.wiley.com/doi/abs/10.1002/9780470549094.ch10 Bivand, R., 2013. Chapter 8: Interpolation and Geostatistics, in: Applied Spatial Data Analysis with R. Springer, New York, pp. 213–256.
		Other resources *R-Packages Documentation (online vignettes & reference manuals)* *Package 'gstat'* *Vignette:* https://cran.r-project.org/web/packages/gstat/vignettes/gstat.pdf Manual: https://cran.r-project.org/web/packages/gstat/gstat.pdf