Teaching Guide

Course	GEOSTATISTICAL ANALYSIS		
Subject	Applied Spatial Data Analysis		
Module	Specialization		
Degree	Mediterranean Forestry and Natural Resources Management (MEDFOR)		
Plan Code	506	**Course Code**	53029
Timetable	3rd Period Jan 9th to Feb 3th	**Type**	OP-Optional
Level	Master (Erasmus Mundus)	**Year**	2 (3rd semester)
ECTS	6		
Language	English		
Lecturers	Dr. Julián Gonzalo Jiménez & Dr. Nikolaos Nanos		
Contact (E-mail, telephone…)	jgonzalo@pvs.uva.es +34-979-108416		
Tutorials timetable	Monday 10:00-13:00 & Wednesday 10:00-13:00		
Department	Plant Production and Forest Resources		

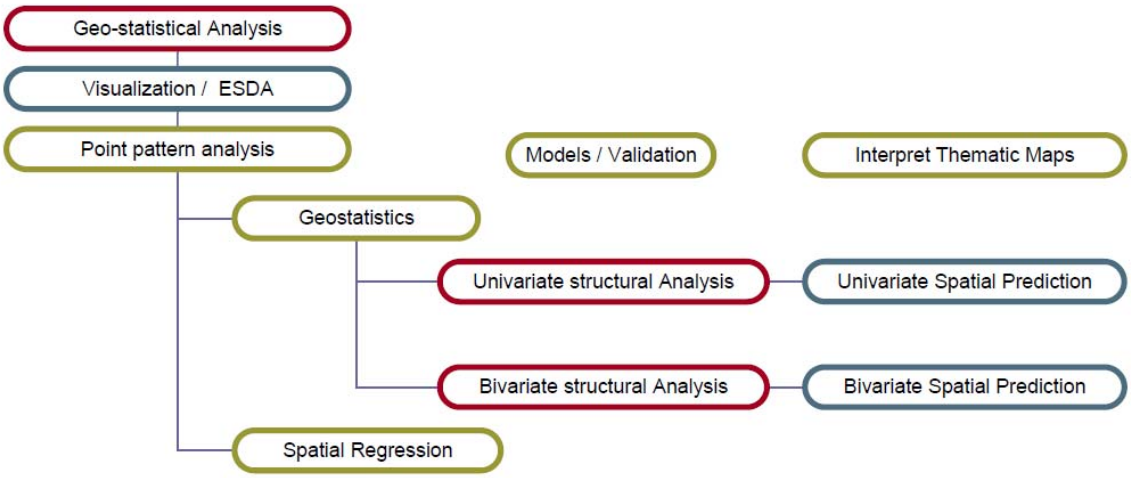
1. Guidance

1.1 Contextualizing

Although thematic maps are becoming easily available, frequently, GIS specialists have to construct by themselves specialized maps of some variable of interest. Examples may include maps of average annual precipitation or average population density, which are judged necessary for decision making in land management. These types of maps are not directly available in the web or in specialized databases but, instead, may be constructed using some short of information, such as data from meteorological stations or population surveys. Geostatistical analysis provides a set of tools that can be used to construct such thematic information.

The course focuses on Geo-statistical analyses applied to land management; it is structured in four main chapters that cover (i) visualization and exploration of spatial data, (ii) point patterns analysis, (iii) geostatistics and (iv) spatial regression techniques. The statistical theory is reduced to such an extent that permits the comprehension of practical exercises. Practical sessions are conducted using either ArcMap (Geostatistical Analyst and Spatial Analyst) or the "Spatstat" package of "R".

Conceptual Scheme



2. Competences

2.1 General

- To know and apply knowledge in practice, analyzing, synthesising, organizing and planning.
- Being able to communicate verbally and in writing, both in specialized and non-expert forums
- Being able to make decisions and solve problems
- Being able to work in a multi-scale (regional, national or international) context
- Being able to work in multidisciplinary teams
- Develop creativity and leadership skills

2.2 Specific

- To provide scientific knowledge of different disciplines that address the challenges and specific needs of the Mediterranean forestry sector
- To develop new adaptive management strategies based on knowledge of functions and processes of Mediterranean forest ecosystems
- To develop natural hazards' new models in a changing world

3. Learning Outcomes

On successful completion of the module, students will be able to:

1. Identify the main features of a spatial data set.
2. Demonstrate presence (or absence) of spatial correlations among the analyzed variables.
3. Construct models and estimation maps for the analyzed variable(s).
4. Formulate hypotheses on the factors that generated the spatial pattern observed in the data-set.

4. Specific Course Contents

1. INTRODUCTION TO SPATIAL DATA ANALYSIS

1. Introduction.
2. Types of spatial data.
3. Spatial data analysis objectives.
4. The structure of the course.
5. Example data sets.
6. References for further reading.

2. VISUALIZING AND EXPLORING SPATIAL DATA

1. Spatial data visualization and estimation of local, neighbourhood and zonal statistics (ArcMap Spatial Analyst).
2. Examining the data-distribution: Histograms, General and Normal QQ-Plot and Spatial statistics to measure Geographic Distributions.
3. Outliers detection: Histograms, Box Plots, Voronoi maps, Anselin Local Moran's I.
4. Analyzing patterns of spatial distribution. Cluster hunting.
5. Trend analysis of continuous data.
6. Examining Spatial Autocorrelation. Semivariogram/Covariance Cloud. Crosscovariance Cloud (Spatial Correlation).

3. POINT PATTERN ANALYSIS WITH "R"

1. Getting started in "R" (Working directories and sessions, Starting R)
2. Basic data operations (Importing Data, Vectors, Matrices, Data frames and lists, Deleting objects).
3. Basic data manipulation (Operations in subsets, Basic summary statistics).
4. Plotting in R (General scatter plots, Histograms).
5. The "Spatstat" package (Installation, Data import and visualization).

4. UNMARKED POINT PATTERNS

1. Exploratory analysis (Quadrat methods, Kernel estimation, Implementation in "R").
2. Summary functions (Empty-space function, Accounting for edge effects, G-function, K-function, Implementation in "R").
3. Randomization envelopes (Implementation in "R").
4. Model fitting (Poisson processes, Models for clustered patterns).

5. MULTITYPE AND MARKED POINT PATTERNS

1. Introduction to marked and multitype point pattern analysis.
2. Exploratory analysis and modelling (G-cross functions, K-cross functions, The mark correlation function, Model fitting).
3. Analysis of marked and multitype point patterns in "R" (Generating marked point patterns, Manipulating marked point patters, Exploratory analysis, Summary functions, Model fitting).

6. GEOSTATISTICS. UNIVARIATE STRUCTURAL ANALYSIS.

1. Introduction (geostatistical data, basic statistics).
2. Exploring spatial autocorrelation (The variogram cloud, Sample variogram, The physical interpretation of the variogram, Anisotropy, Indicator variograms).
3. Variogram Modelling (Fitting variogram models, Modeling directional variograms, Non-stationary variogram modelling).
4. Univariate structural analysis in ArcMap (Variogram cloud calculation, Sample variogram calculation, Specifying variogram models).

7. GEOSTATISTICS. UNIVARIATE SPATIAL PREDICTION.

1. Geostatistical interpolation methods. Univariate spatial prediction. Core concepts.
2. Methods to evaluate the quality of the results.
3. Local estimation without secondary information: Simple kriging, Ordinary kriging, Indicator Kriging, Probability Kriging, Disjunctive Kriging, Block Kriging, Dual kriging, Kriging with a trend model.
4. Local estimation with exhaustive secondary information: Kriging within strata, Simple kriging with varying local means, Kriging with an external drift.

8. GEOSTATISTICS. BIVARIATE STRUCTURAL ANALYSIS.

1. Introduction (Concepts and notation).
2. Exploring spatial cross correlation (Sample cross-variogram and cross covariance, Cross-variogram maps, Directional cross-variograms, Application to indicator transformations).
3. Modeling a coregionalization (The linear model of Coregionalization, Coregionalization matrices, Fitting the LMC for the Cd concentration of the Ebro river).
4. Bivariate structural analysis in ArcMap (Data input, Bivariate structural analysis, Modelling a coregionalization, Indicator structural analysis and modelling in ArcMap).

9. GEOSTATISTICS. BIVARIATE SPATIAL PREDICTION

1. Geostatistical interpolation methods. Bivariate spatial prediction. Core concepts.
2. The cokriging approach: Simple cokriging, Ordinary cokriging, Standarized ordinary cokriging, Colocated cokriging, Principal component kriging, Factorial Kriging, Multivariate factorial kriging.

10. SPATIAL REGRESSION

1. Introduction and core concepts.
2. Simple regression and trend surface modelling.
3. Geographically weighted regression.
4. Spatial autoregressive modelling.
5. Conditional autoregressive and Bayesian modelling.

5. Time and content organization

DU1. INTRODUCTION TO SPATIAL DATA ANALYSIS		
Learning Objectives	a) CONCEPTUAL Recognize the components of a spatial data-set. Acquire knowledge of the different types of spatial data sets.	
	b) PROCEDURAL Given a data-set the student will be able to determine the type of analysis to be done and the corresponding objectives. Plan the type of data to be collected given the objective of the analysis.	
	c) ATTITUDINAL Acquire skills for spatial data analysis.	
Contents	1. Introduction. 2. Types of spatial data. 3. Spatial data analysis objectives. 4. The structure of the course. 5. Example data sets. 6. References for further reading.	
Methodology	Oral presentation by the instructor using a Power-point presentation. Class discussion on examples of spatial data sets in everyday life.	
Activities	THEORY: the instructor presents the chapter contents based on multimedia material that includes explanations of theoretical concepts, figures and statistics of various data sets. Some of these data sets are going to be used as practical exercises and independent work in the subsequent chapters of the course.	1h
	INDEPENDENT WORK: students are advised to work with different data-sets, analyze them and present a short report.	4h
Resources	Power point presentation: *\DU1\1POWER POINT\DU1.ppt*	
Assessment Criteria And Methods	Critical knowledge to asses: Recognize the components and the different types of spatial data sets. Determine the most adequate type of analysis and its objectives. Methods: Continuous assessment based on independent laboratory work. Reports.	
Bibliography	Bailey, C.T. & Gatrell, C.A. (1995). *Interactive spatial data analysis.* Longman, Essex, 413 pp. Cressie, N. A. C. (1993). *Statistics for spatial data* (Revised Edition ed.). New York: John Wiley & Sons. Haining, R. (2003). *Spatial Data Analysis. Theory and Practice.* Cambridge.	

DU2. VISUALIZING AND EXPLORING SPATIAL DATA		
Learning Objectives	a) CONCEPTUAL Acquire basic knowledge of the spatial data visualization and the core methods of Exploratory Spatial Data Analysis (ESDA) with the *Geostatistical Analyst* extension of ArcGIS.	
	b) PROCEDURAL Given a data-set the student will be able to execute a complete exploratory spatial data analysis following a correct guideline to find outliers, trends, or clusters that could determine subsequent analyses.	
	c) ATTITUDINAL Analyze data in an orderly fashion before modelling or interpolation.	
Contents	1. Spatial data visualization and estimation of local, neighbourhood and zonal statistics (ArcMap Spatial Analyst). 2. Examining the data-distribution: Histograms, General and Normal QQ-Plot and Spatial statistics to measure Geographic Distributions. 3. Outliers detection: Histograms, Box Plots, Voronoi maps, Anselin Local Moran's *I*. 4. Analyzing patterns of spatial distribution. Cluster hunting. 5. Trend analysis of continuous data. 6. Examining Spatial Autocorrelation. Semivariogram/Covariance Cloud. Crosscovariance Cloud (Spatial Correlation).	
Methodology	Instructor-based presentation in the computer lab. Students work in their own PC´s.	
Activities	THEORY: Multimedia presentation covering the theoretical ESDA concepts and methods. Applied examples are also presented in class.	-
	PRACTICE: The instructor explains the ESDA environment in *Geostatistical Analyst*. Students conduct ESDA procedures following the geostatistical commands proposed by the instructor.	4h
	INDEPENDENT WORK: students are advised to work with different data-sets, analyze them and present a short report.	8h
Resources	Power point presentation: *\DU2\2POWER POINT\DU2.ppt* Examples: *\DU2\2DATA USED FOR THEORY\data2.mdb* Exercises and Data-sets: *\DU2\2INDEPENDENT WORK\data2.mdb*	

DU2. VISUALIZING AND EXPLORING SPATIAL DATA *cont.*	
Assessment Criteria And Methods	Critical knowledge to asses: correct use and interpretation of the ESDA methods and results. Methods: Continuous assessment based on independent laboratory work. Reports.
Bibliography	Andrienko, N. & Andrienko, G. (2006). *Exploratory Analysis of Spatial and Temporal Data. A Systematic Approach.* Springer. Box, G. E. P., Hunter, W. G., & Hunter, J. S. (1978). *Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building*, John Wiley and Sons. Cleveland, W. S. (1993). *Visualizing Data*, Hobart Press. Du Toit, S.H.C., Steyn, A.G.W. & Stumpf, R.H. (1986). *Graphical Exploratory Data Analysis,* Springer-Verlag. Evans, M., Hastings, N. & Peacock, B. (2000). *Statistical Distributions*, 3rd. Ed., John Wiley and Sons. Tukey, J . (1977). *Exploratory Data Analysis*, Addison-Wesley. Velleman, P. & Hoaglin, D . (1981). *The ABC's of EDA: Applications, Basics, and Computing of Exploratory Data Analysis*, Duxbury.

DU3. POINT PATTERN ANALYSIS WITH "R"		
Learning Objectives	a) CONCEPTUAL Acquire basic knowledge of the "R" statistical-computing language and the "Spatstat" package.	
	b) PROCEDURAL Conduct basic data manipulation with "R".	
	c) ATTITUDINAL Learn how to overcome problems when writing statistical code in "R".	
Contents	1. Getting started in "R" (Working directories and sessions, Starting R). 2. Basic data operations (Importing Data, Vectors, Matrices, Data frames and lists, Deleting objects). 3. Basic data manipulation (Operations in subsets, Basic summary statistics). 4. Plotting in R (General scatter plots, Histograms). 5. The "Spatstat" package (Installation, Data import and visualization).	
Methodology	Instructor-based exposition in the computer lab. Students work in their own PC´s following the instructor´s "R" commands.	
Activities	PRACTICE: The instructor explains the "R" environment. Students install the package in their PC´s and conduct basic data manipulation following the statistical commands proposed by the instructor.	2h
	INDEPENDENT WORK: students are advised to work with different data-sets and import data, analyze them and present a short report.	8h
Resources	Power point presentation: *\DU3\3POWER POINT\DU3.ppt* Examples: *\DU3\3DATA USED FOR THEORY\altitude.csv* and *trees.csv* Exercises and Data-sets: *Geostatistical_analysis\DU31\3INDEPENDENT WORK\montejo.xls* and *humidity.xls* The "R" core-package: http://www.r-project.org/ . The "spatstat" package: http://www.spatstat.org/.	
Assessment Criteria And Methods	Methods: Continuous assessment based on independent laboratory work. Reports.	
Bibliography	Baddeley, A. & Turner, R. (2005). Spatstat: An R package for analyzing spatial point patterns, J*ournal of Statistical Software,* 12: 1:42. Crawley, J.M. (2007). *The R Book*, Wiley, 950 pages.	

D.U.4. UNMARKED POINT PATTERNS		
Learning Objectives	a) CONCEPTUAL Acquire knowledge of the available methods and tools for analyzing unmarked point patterns.	
	b) PROCEDURAL Analyze and investigate the properties of a spatial point pattern. Estimate and model a spatial point process given a data set. Determine adequate sampling procedures for estimating spatial point processes.	
	c) ATTITUDINAL Be able to self-update his/her knowledge on this topic. Recognize the applicability and limitations of the results of his/her analyses and advice the future users of his/her output.	
Contents	1. Exploratory analysis (Quadrat methods, Kernel estimation, Implementation in "R"). 2. Summary functions (Empty-space function, Accounting for edge effects, G-function, K-function, Implementation in "R"). 3. Randomization envelopes (Implementation in "R"). 4. Model fitting (Poisson processes, Models for clustered patterns).	
Methodology	THEORY: Instructor-lead presentation. COMPUTER LAB PRACTICE: Students analyse read data sets in the computer laboratory. The instructor guides the analysis by presenting the steps to be taken. Students work individually or in groups of 2 students/PC. INDEPENDENT WORK: Students analyse independently the data provided.	
Activities	THEORY: Multimedia presentations covering the theoretical concepts regarding (i) exploring, (ii) summarizing, (iii) testing for Complete Spatial Randomness and (iv) modelling of unmarked point patterns. Applied examples are also presented in class.	1
	COMPUTER LAB PRACTICE: Apply the theoretical concepts in practice. Students are given a data set. The instructor explains the steps to be carried out by the students in order to conduct a full analysis. All the theoretical concepts of part I are covered in this practice. Data analysis is carried out in the R language. Some specific methods are also carried out in Arc Map's Spatial Analyst.	8h
	INDEPENDENT WORK: students are advised to work with different data-sets and import data, analyze them and present a short report.	10h

D.U.4. UNMARKED POINT PATTERNS *cont.*	
Resources	Power point presentation: *\DU4\4POWER POINT\DU4.ppt* Examples: *\DU4\4DATA USED FOR THEORY\ altitude.csv* and *trees.csv* Exercises and Data-sets: *\DU4\4INDEPENDENT WORK\ montejo.xls* and *humidity.xls* The "R" and "spatstat" package, ArcMap (+spatial analyst)
Assessment Criteria and Methods	Methods: Continuous assessment based on independent laboratory work. Reports.
Bibliography	Baddeley, A., Turner, R. (2005). Spatstat: An R package for analyzing spatial point patterns, *Journal of Statistical Software*, 12: 1:42 Bailey, C.T. & Gatrell, C.A. (1995). *Interactive spatial data analysis.* Longman, Essex, 413 pp. Cressie, N.A.C. (1993). *Statistics for spatial data.* John Wiley & Sons, New York, 900 pp. Diggle, PJ. (2003). *Statistical Analysis of Spatial Point Patterns*, Second Edition, Arnold Publishers Gatrell, C.A., Bailey, C.T., Diggle, P., Rowlingson, B.S. (1996). Spatial point pattern analysis and its application in geographical epidemiology. *Trans.Inst.Br.Geogr* 21: 256:274

D.U.5. MULTITYPE AND MARKED POINT PATTERNS		
Learning Objectives	a) CONCEPTUAL Learn the available methods for analyzing multitype and/or marked point patterns.	
	b) PROCEDURAL Analyze, investigate, estimate and model a marked and/or multitype point pattern. Plan future sampling strategies for studying marked and/or multitype point patterns.	
	c) ATTITUDINAL Recognize the applicability and limitations of the results of his/her analyses and advice the future users of his/her output. Be able to self-update his/her knowledge.	
Contents	1. Introduction to marked and multitype point pattern analysis. 2. Exploratory analysis and modelling (G-cross functions, K-cross functions, The mark correlation function, Model fitting). 3. Analysis of marked and multitype point patterns in "R" (Generating marked point patterns, Manipulating marked point patters, Exploratory analysis, Summary functions, Model fitting).	
Methodology	THEORY: Instructor-lead presentation of the theoretical concepts. COMPUTER-LAB PRACTICE: Students analyse read data sets in the computer laboratory. The instructor is guiding the analysis by presenting the steps to be taken. INDEPENDENT WORK: Students analyse independently the data to be provided.	
Activities	THEORY: Multimedia presentations covering the theoretical concepts regarding (i) exploring, (ii) summarizing, (iii) testing for Complete Spatial Randomness and (iv) modelling of marked and/or multitype point patterns. Examples of applications are also presented in class.	1
	COMPUTER LAB PRACTICE: Apply the theoretical concepts in practice. Students are given a data set and work individually or in groups of 2 students/PC. The instructor explains the steps to be carried out by the students in order to conduct a full analysis. All the theoretical concepts of part I are covered in this practice. Data analysis is carried out in the computer lab using the R language. Arc Map is not used.	8h
	INDEPENDET WORK: students are advised to work with different data-sets and import data, analyze them and present a short report.	10h

D.U.5. MULTITYPE AND MARKED POINT PATTERNS *cont.*	
Resources	Power point presentation: *\DU5\5POWER POINT\DU5.ppt* Examples: *\DU5\5DATA USED FOR THEORY\trees.csv* Exercises and Data-sets: *\DU5\5INDEPENDENT WORK\ montejo.xls* Additional resources: PC´s, projector and screen, R software, statstat package: http://www.spatstat.org/.
Assessment Criteria and Methods	Methods: Continuous assessment based on independent laboratory work to be taken by students. Reports.
Bibliography	Baddeley, A. & Turner, R. (2005). Spatstat: An R package for analyzing spatial point patterns, *Journal of Statistical Software*, 12: 1:42 Bailey, C.T. & Gatrell, C.A. (1995). *Interactive spatial data analysis.* Longman, Essex, 413 pp. Cressie, N.A.C. (1993). *Statistics for spatial data.* John Wiley & Sons, New York, 900 pp. Diggle, P.J. (2003). *Statistical Analysis of Spatial Point Patterns*, Second Edition, Arnold Publishers Gatrell, C.A., Bailey, C.T., Diggle, P., Rowlingson, B.S. (1996). Spatial point pattern analysis and its application in georgraphical epidemiology. *Trans.Inst.Br.Geogr* 21: 256:274

D.U.6. GEOSTATISTICS. UNIVARIATE STRUCTURAL ANALYSIS		
Learning Objectives	a) CONCEPTUAL Understand the tools and methods for univariate structural analysis.	
	b) PROCEDURAL Conduct a geostatistical structural analysis in the univariate case, given a data set. Plan additional or new data collection if necessary.	
	c) ATTITUDINAL Acquire skills in numerical spatial analysis. Interpret the results of the analysis, extract their main features and present them to non-specialists.	
Contents	1. Introduction (geostatistical data, basic statistics). 2. Exploring spatial autocorrelation (The variogram cloud, Sample variogram, The physical interpretation of the variogram, Anisotropy, Indicator variograms). 3. Variogram Modelling (Fitting variogram models, Modeling directional variograms, Non-stationary variogram modelling). 4. Univariate structural analysis in ArcMap (Variogram cloud calculation, Sample variogram calculation, Specifying variogram models).	
Methodology	THEORY: Instructor-lead presentation of the theoretical concepts.	
Activities	THEORY: Multimedia presentations covering the theoretical concepts (1 to 4). Examples of applications are also presented in class.	1h
	COMPUTER LAB PRACTICE: Apply the theoretical concepts in practice. Students are given a data set and work individually or in groups of 2 students/PC. The instructor explains the steps to be carried out by the students in order to conduct a full analysis.	4h
	INDEPENDENT WORK: Students analyse independently the data to be provided and present a report	10h
Resources	Power point presentation: *\DU6\6POWER POINT\DU6.ppt* Examples: *\DU6\6DATA USED FOR THEORY\metal.dbf* and *Ebro limit.shp* Exercises and Data-sets: *\DU6\6INDEPENDENT WORK\metal.dbf* and *Ebro limit.shp* Additional resources: PC, projector and screen.	

D.U.6. GEOSTATISTICS. UNIVARIATE STRUCTURAL ANALYSIS *cont.*	
Assessment Criteria and Methods	Continuous assessment based on independent laboratory work to be taken by students
Bibliography	Bailey, C.T. & Gatrell, C.A. (1995). *Interactive spatial data analysis.* Longman, Essex, 413 pp. Chilés, J.P. and Delfiner, P. (1999). *Geostatistics: modeling spatial uncertainty.* John Wiley & Sons, New York, 695 pp. Goovaerts, P. (1997). *Geostatistics for natural resources evaluation. Applied geostatistics series.* Oxford University Press, New York. Isaaks, E.H. and Srivastava, R.M. (1989). *An introduction to applied geostatistics.* Oxford University Press, New York, 561 pp.

D.U.7. GEOSTATISTICS. UNIVARIATE SPATIAL PREDICTION		
Learning Objectives	a) CONCEPTUAL Understand the methods of univariate spatial prediction (kriging: geostatistical interpolation methods).	
	b) PROCEDURAL Conduct a geostatistical interpolation analysis in the univariate case, given a data set.	
	c) ATTITUDINAL Acquire skills in geostatistical interpolation. Interpret the results of the analysis and present them to non-specialists.	
Contents	1. Geostatistical interpolation methods. Univariate spatial prediction. Core concepts. 2. Methods to evaluate the quality of the results. 3. Local estimation without secondary information: Simple kriging, Ordinary kriging, Indicator Kriging, Probability Kriging, Disjunctive Kriging, Block Kriging, Dual kriging, Kriging with a trend model. 4. Local estimation with exhaustive secondary information: Kriging within strata, Simple kriging with varying local means, Kriging with an external drift.	
Methodology	THEORY: Instructor-lead presentation of the theoretical concepts. COMPUTER-LAB PRACTICE: Students analyse a real data set in the computer lab. The instructor is guiding the analysis by presenting the steps to be taken. Discussion on the results of the analyses is important. Arc Map is used (*Geostatistical Analyst*). INDEPENDENT WORK: The instructor advices the students when they had problems in analysing their data sets. Students recognize their problems and learn how to resolve them.	
Activities	THEORY: Multimedia presentations covering the theoretical methods. Examples of applications are also presented in class.	2h
	COMPUTER-LAB PRACTICE: Apply the theoretical concepts in practice (including the theory of the previous chapter of Univariate structural analysis). Students are given a data set and work individually or in groups of 2 students/PC.	8h
	INDEPENDENT WORK: Students analyse independently the data to be provided and present a report.	10h

D.U.7. GEOSTATISTICS. UNIVARIATE SPATIAL PREDICTION *cont.*	
Resources	Power point presentation: *\DU7\7POWER POINT\DU7.ppt* Examples: *\DU7\7DATA USED FOR THEORY\data7.mdb* Exercises and Data-sets: *\DU7\7INDEPENDENT WORK\data7.mdb*
Assessment Criteria and Methods	Critical knowledge to assess: correct use and interpretation of the univariate kriging methods and results. Methods: Continuous assessment based on independent laboratory work. Reports.
Bibliography	Bailey, C.T. & Gatrell, C.A. (1995). *Interactive spatial data analysis.* Longman, Essex, 413 pp. Chilés, J.P. & Delfiner, P. (1999). *Geostatistics: modeling spatial uncertainty.* John Wiley & Sons, New York, 695 pp. Goovaerts, P. (1997). *Geostatistics for natural resources evaluation. Applied geostatistics series.* Oxford University Press, New York. Isaaks, E.H. & Srivastava, R.M. (1989). *An introduction to applied geostatistics.* Oxford University Press, New York, 561 pp.

D.U.8. GEOSTATISTICS. BIVARIATE STRUCTURAL ANALYSIS		
Learning Objectives	a) CONCEPTUAL Learn the available tools and models for a multivariate structural analysis.	
	b) PROCEDURAL Conduct a geostatistical structural analysis in the multivariate case using a given data set.	
	c) ATTITUDINAL Acquire skills in numerical spatial analysis. Interpret the results of the analysis, extract their main features and expose them to non-specialists.	
Contents	1. Introduction (Concepts and notation) 2. Exploring spatial cross correlation (Sample cross-variogram and cross covariance, Cross-variogram maps, Directional cross-variograms, Application to indicator transformations). 3. Modeling a coregionalization (The linear model of Coregionalization, Coregionalization matrices, Fitting the LMC for the Cd concentration of the Ebro river). 4. Bivariate structural analysis in ArcMap (Data input, Bivariate structural analysis, Modelling a coregionalization, Indicator structural analysis and modelling in ArcMap).	
Methodology	THEORY: Instructor-lead presentation of the theoretical concepts.	
Activities	THEORY: Multimedia presentations covering the theoretical concepts. Examples of applications are also presented in class.	1 h
	COMPUTER LAB PRACTICE: Apply the theoretical concepts in practice. Students are given a data set and work individually or in groups of 2 students/PC. The instructor explains the steps to be carried out by the students in order to conduct a full analysis.	4h
	INDEPENDENT WORK: Students analyse independently the data to be provided and present a report.	10h
Resources	Power point presentation: *\DU8\8POWER POINT\DU8.ppt* Examples: *\DU8\8DATA USED FOR THEORY\ metal.dbf* and *Ebro limit.shp* and *mdtEbro200m* Exercises and Data-sets: *\DU8\8INDEPENDENT WORK\ metal.dbf* , *Ebro limit.shp* and *mdtEbro200m* Additional resources: PC, projector and screen.	

D.U.8. GEOSTATISTICS. BIVARIATE STRUCTURAL ANALYSIS *cont.*	
Assessment Criteria and Methods	Methods: Continuous assessment based on independent laboratory work to be taken by students.
Bibliography	Bailey, C.T. and Gatrell, C.A. (1995). *Interactive spatial data analysis*. Longman, Essex, 413 pp. Chilés, J.P. and Delfiner, P. (1999). *Geostatistics: modeling spatial uncertainty*. John Wiley & Sons, New York, 695 pp. Goovaerts, P. (1997). *Geostatistics for natural resources evaluation. Applied geostatistics series.* Oxford University Press, New York. Isaaks, E.H. and Srivastava, R.M. (1989). *An introduction to applied geostatistics.* Oxford University Press, New York, 561 pp.

D.U.9. GEOSTATISTICS. BIVARIATE SPATIAL PREDICTION		
Learning Objectives	a) CONCEPTUAL Understand the methods of multivariate spatial prediction (kriging: geostatistical interpolation methods).	
	b) PROCEDURAL Conduct a geostatistical interpolation analysis in the multivariate case, given a data set.	
	c) ATTITUDINAL Acquire skills in geostatistical interpolation. Interpret the results of the analysis and present them to non-specialists.	
Contents	1. Geostatistical interpolation methods. Bivariate spatial prediction. Core concepts. 2. The cokriging approach: Simple cokriging, Ordinary cokriging, Standarized ordinary cokriging, Colocated cokriging, Principal component kriging, Factorial Kriging, Multivariate factorial kriging.	
Methodology	THEORY: Instructor-lead presentation of the theoretical concepts. COMPUTER-LAB PRACTICE: Students analyse a real data set in the computer lab. The instructor guides the analysis by presenting the steps to be taken. Discussion on the results of the analyses is important. Arc Map is used. INDEPENDENT WORK: The instructor advices the students when they had problems in analysing their data sets. Students recognize their problems and learn how to resolve them.	
Activities	THEORY: Multimedia presentations covering the theoretical methods. Examples of applications are also presented in class.	2h
	COMPUTER-LAB PRACTICE: Apply the theoretical concepts in practice (including the theory of the previous chapter of Bivariate structural analysis). Students are given a data set and work individually or in groups of 2 students/PC.	8h
	INDEPENDENT WORK: Students analyse independently the data to be provided and present a report.	10h

D.U.9. GEOSTATISTICS. BIVARIATE SPATIAL PREDICTION *cont.*	
Resources	Power point presentation: *\DU9\9POWER POINT\DU9.ppt* Examples: *\DU9\9DATA USED FOR THEORY\data9.mdb* Exercises and Data-sets: *\DU9\9INDEPENDENT WORK\ data9.mdb* Additional resources: PC´s, projector and screen, ArcMap (+*Geostatistical Analyst*, +*Spatial Analyst*).
Assessment Criteria and Methods	Critical knowledge to asses: correct use and interpretation of the multivariate kriging methods and results. Methods: Continuous assessment based on independent laboratory work to be taken by students. Reports.
Bibliography	Bailey, C.T. & Gatrell, C.A. (1995). *Interactive spatial data analysis*. Longman, Essex, 413 pp. Chilés, J.P. & Delfiner, P. (1999). *Geostatistics: modelling spatial uncertainty*. John Wiley & Sons, New York, 695 pp. Goovaerts, P. (1997). *Geostatistics for natural resources evaluation. Applied geostatistics series.* Oxford University Press, New York. Isaaks, E.H. & Srivastava, R.M. (1989). *An introduction to applied geostatistics*. Oxford University Press, New York, 561 pp.

D.U.10. SPATIAL REGRESSION		
Learning Objectives	a) CONCEPTUAL Understand the methods of spatial regression analysis and modelling.	
	b) PROCEDURAL Determine adequate regression procedures for modelling spatial variables (simple, multiple, multivariate, SAR, CAR, logistic, Poisson, etc.). Conduct a complete spatial regression analysis given a data set.	
	c) ATTITUDINAL Acquire skills in spatial regression methods. Interpret the results of the analysis and present them to non-specialists.	
Contents	1. Introduction and core concepts. 2. Simple regression and trend surface modelling. 3. Geographically weighted regression. 4. Spatial autoregressive modelling. 5. Conditional autoregressive and Bayesian modelling.	
Methodology	THEORY: Instructor-lead presentation of the theoretical concepts. COMPUTER-LAB PRACTICE: Students analyse a real data set in the computer lab. The instructor is guiding the analysis by presenting the steps to be taken. Discussion on the results of the analyses is important. Arc Map is used. INDEPENDENT WORK: The instructor advices the students when they had problems in analysing their data sets. Students recognize their problems and learn how to resolve them.	
Activities	THEORY: Multimedia presentations covering the theoretical methods. Examples of applications are also presented in class.	1h
	COMPUTER-LAB PRACTICE: Apply the theoretical concepts in practice. Students are given a data set and work individually or in groups of 2 students/PC.	4h
	INDEPENDENT WORK: Students analyse independently the data to be provided and present a report.	10h

DU10. SPATIAL REGRESSION *cont.*	
Resources	Power point presentation: *\DU10\10POWER POINT\DU10.ppt* Examples: *\DU10\10DATA USED FOR THEORY\data10.mdb* Exercises and Data-sets: *\DU10\10INDEPENDENT WORK\ data10.mdb* Additional resources: PC´s, projector and screen, ArcMap (+*Geostatistical Analyst*, +*Spatial Analyst*).
Assessment Criteria and Methods	Critical knowledge to asses: correct use and interpretation of the spatial regression methods and results. Methods: Continuous assessment based on independent laboratory work to be taken by students. Reports.
Bibliography	Anselin, L. (2002). Under the hood: Issues in the specification and interpretation of spatial regression models. *Agricultural Economics, 17(3)*, 247-67. Bailey, T.C. & Gatrell A.C. (1995). *Interactive spatial data analysis*. Longman, Harlow, UK. Cressie, N.A.C. (1993). *Statistics for spatial data.* John Wiley & Sons, New York, 900 pp. Getis A. D. & Griffith D.A. (2002). Comparative spatial filtering in regression analysis. *Geog. Anal.,* 34, 130-40. Haining, R. (2003) . *Spatial Data Analysis. Theory and Practice.* Cambridge. Lichstein, J.W., Simons, T.R., Shriner, S.A., Franzreb, K.E. (2002). Spatial autocorrelation and autoregressive models in Ecology. *Ecological Monographs,* 72, 445-63.