Universität Trier

M.SC. ENVIRONMENTAL SCIENCES

WITH THREE FOCAL POINTS:

I. ENVIRONMENTAL
MONITORING AND POLLUTION ASSESSMENT (ES I)

II. ENVIRONMENTAL
REMOTE SENSING AND MODELLING (ES II)

III. ENVIRONMENTAL
CONSERVATION AND RESTORATION MANAGEMENT (ES III)

Last Update: Summer 2020

Trier University

Module Handbook

Master Degree Program

M.Sc. Environmental Sciences

With three Focal Points

I. Environmental Monitoring and Pollution Assessment (ES I)
II. Environmental Remote Sensing and Modelling (ES II)
III. Environmental Conservation and Restoration Management (ES III)

Involved disciplines

- Analytical & Ecological Chemistry
- Soil Science
- Geobotany & Vegetation Science
- Geology
- Hydrology
- Environmental Remote Sensing & Geoinformatics
- Environmental Meteorology

Last update: Summer 2020

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INTRODUCTION

The Faculty of Regional and Environmental Science with 18 Departments, is one of the largest university centers in Germany for education and research in human and physical geography and in environmental bio- and geosciences.

The Environmental Sciences master program (M.Sc. ES) has three Focal Points:

• **Environmental Monitoring and Pollution Assessment (ES I)**
Exposure of environmental systems to climate change, chemical environmental analysis, the impact of toxic substances, disturbance of feedback processes, assessment of cause-and-effect chains.

• **Environmental Remote Sensing and Modelling (ES II)**
Use of remote sensing systems for assessing and monitoring the environment focused on both the atmosphere/climate system and terrestrial ecosystems; integration of process models and spatial data analysis (GIS).

• **Environmental Conservation and Restoration Management (ES III)**
Management strategies for nature conservation as well as dumpsite reclamation and remediation. Consideration and evaluation of environmental impacts on economics and society, as well as possible solutions.

1. Environmental Monitoring and Pollution Assessment (ES I)

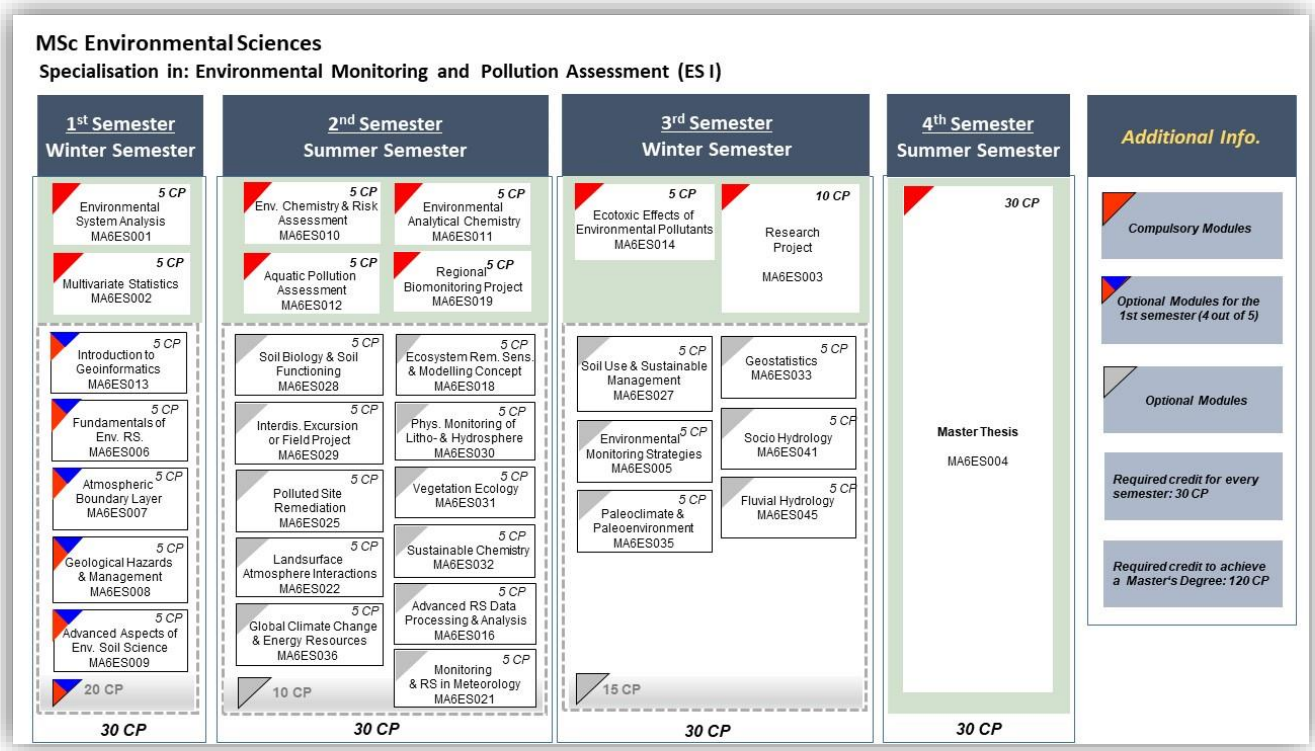

Table of courses in the Master of Science Degree Program Environmental Sciences Specialization in "Environmental Monitoring and Pollution Assessment" (ES I)

Semester	*Module Code*	*Module Name*	*CP*	*CP/Semester*
Winter	Compulsory Modules			
1st	*MA6ES001*	*Environmental System Analysis*	*5*	
1st	*MA6ES002*	*Multivariate Statistics*	*5*	
Optional Module (4 out of 5 modules)				
1st	*MA6ES013*	*Introduction to Geoinformatics*	*5*	
1st	*MA6ES006*	*Fundamentals of Environmental Remote Sensing*	*5*	
1st	*MA6ES007*	*Atmospheric Boundary Layer*	*5*	
1st	*MA6ES008*	*Geological Hazards and Management*	*5*	*30 CP*
1st	*MA6ES009*	*Advanced Aspects of Environmental Soil Science*	*5*	

Semester	Module Code	Module Name	CP	CP/Semester
Summer	Compulsory Modules			
2nd	MA6ES010	Environmental Chemistry and Risk Assessment	5	
2nd	MA6ES011	Environmental Analytical Chemistry	5	
2nd	MA6ES012	Aquatic Pollution Assessment	5	
2nd	MA6ES019	Regional Biomonitoring Project	5	
Optional Module (2 out of 11 modules)				
2nd	MA6ES028	Soil Biology and Functioning	5	
2nd	MA6ES016	Advanced Remote Sensing Data Processing and Analysis	5	
2nd	MA6ES029	Interdisciplinary Excursion or Field Project	5	
2nd	MA6ES030	Physical Monitoring of Litho- and Hydrosphere	5	
2nd	MA6ES025	Polluted Site Remediation	5	
2nd	MA6ES022	Land Surface Atmosphere Interactions	5	
2nd	MA6ES031	Vegetation Ecology	5	
2nd	MA6ES032	Sustainable Chemistry	5	
2nd	MA6ES036	Global Climate Change & Energy Resources	5	
2nd	MA6ES018	Ecosystem Remote Sensing & Modelling Concept (a & b)	5	
2nd	MA6ES021	Monitoring and Remote Sensing in Meteorology	5	30 CP

Semester	Module Code	Module Name	CP	CP/Semester
Winter	Compulsory Modules			
3rd	MA6ES003	Research Project	10	
3rd	MA6ES014	Ecotoxicological Effects of Environmental Pollutants	5	
Optional Module (3 out of 5 modules)				
3rd	MA6ES033	Geostatistik	5	
3rd	MA6ES027	Soil Use and Sustainable Management	5	
3rd	MA6ES035	Paleoclimate and Paleoenvironment	5	
3rd	MA6ES005	Environmental Monitoring Strategies	5	
3rd	MA6ES041	Socio Hydrology	5	30 CP
3rd	MA6ES045	Fluvial Hydrology	5	

Semester	Module Code	Module Name	CP	CP/Semester
Summer	Compulsory Modules			
4th	MA6ES004	Master Thesis	30	30 CP

2. *Environmental Remote Sensing and Modelling (ES II)*

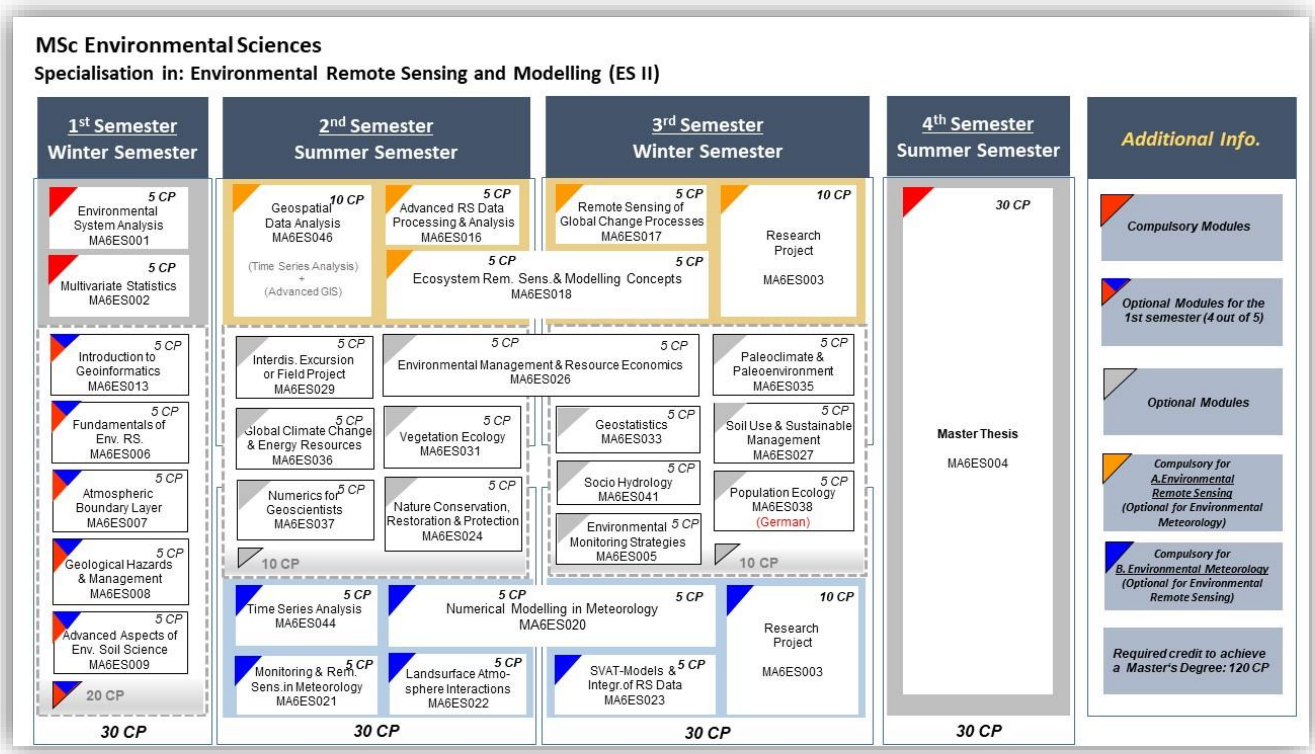

Table of courses in the Master of Science Degree Program Environmental Sciences Specialization in "Environmental Remote Sensing and Modelling" (ES II)

Semester	*Module Code*	*Module Name*	*CP*	*CP/Semester*
Winter	Compulsory Modules			
1st	*MA6ES001*	*Environmental System Analysis*	*5*	
1st	*MA6ES002*	*Multivariate Statistics*	*5*	
Optional Module (4 out of 5 modules)				
1st	*MA6ES013*	*Introduction to Geoinformatics*	*5*	
1st	*MA6ES006*	*Fundamentals of Environmental Remote Sensing*	*5*	
1st	*MA6ES007*	*Atmospheric Boundary Layer*	*5*	
1st	*MA6ES008*	*Geological Hazards, Risk Assessment and Management*	*5*	*30 CP*
1st	*MA6ES009*	*Advanced Aspects of Environmental Soil Science*	*5*	

Attention:
The compulsory modules offered for ES II group (A), are applicable as optional modules for group (B) and the compulsory modules for ES II group (B), are applicable as optional modules for group (A).

Semester	Module Code	Module Name	CP	CP/Semester
Summer	Compulsory Modules			
A. Environmental Remote Sensing				
2nd	MA6ES046	Geospatial Data Analysis: Advanced GIS (MA6ES047) & Time Series Analysis (MA6ES044)	10	
2nd	MA6ES016	Advanced Remote Sensing Data Processing and Analysis	5	
2nd + 3rd	MA6ES018	Ecosystem Remote Sensing and Modelling Concepts	5*	
B. Environmental Meteorology				
2nd	MA6ES044	Time Series Analysis	5	
2nd	MA6ES047	Geospatial Data Analysis: Advanced GIS	5	
2nd	MA6ES021	Monitoring and Remote Sensing in Meteorology	5	
2nd + 3rd	MA6ES020	Numerical Modelling in Meteorology	5*	
2nd	MA6ES022	Land Surface Atmosphere Interactions	5	
Optional Module (2 out of 6 modules)				
2nd	MA6ES031	Vegetation Ecology	5	
2nd + 3rd	MA6ES026	Environmental Management and Resource Economics	5*	
2nd	MA6ES029	Interdisciplinary Excursion or Field Project	5	
2nd	MA6ES024	Nature Conservation, Restoration and Protection	5	30 CP
2nd	MA6ES037	Numeric for Geoscientists	5	
2nd	MA6ES036	Global Climate Change & Energy Resources	5	

Semester	Module Code	Module Name	CP	CP/Semester
Winter	Compulsory Modules			
A. Environmental Remote Sensing				
3rd	MA6ES017	Remote Sensing of Global Change Processes	5	
3rd	MA6ES003	Research Project	10	
2nd + 3rd	MA6ES018	Ecosystem Remote Sensing and Modelling Concepts	5*	
B. Environmental Meteorology				
2nd + 3rd	MA6ES020	Numerical Modelling in Meteorology	5*	
3rd	MA6ES003	Research Project	10	
3rd	MA6ES023	SVAT Models and Integration of Remote Sensing Data	5	
Optional Module (2 out of 7 modules)				
3rd	MA6ES033	Geostatistics	5	
2nd + 3rd	MA6ES026	Environmental Management and Resource Economics	5*	
3rd	MA6ES038	Population Ecology (German)	5	
3rd	MA6ES005	Environmental Monitoring Strategies	5	
3rd	MA6ES035	Paleoclimate and Paleoenvironmental Changes	5	
3rd	MA6ES041	Socio Hydrology	5	
3rd	MA6ES027	Soil Use & Sustainable Management	5	30 CP

Semester	Module Code	Module Name	CP	CP/Semester
Summer	Compulsory Modules			
4th	MA6ES004	Master Thesis	30	30 CP

** The modules MA6ES018, MA6ES020 and MA6ES026: The topics are divided into two semesters. Each semester counts as 5 credits and in total the modules are worth 10CP.*

3. *Environmental Conservation and Restoration Management (ES III)*

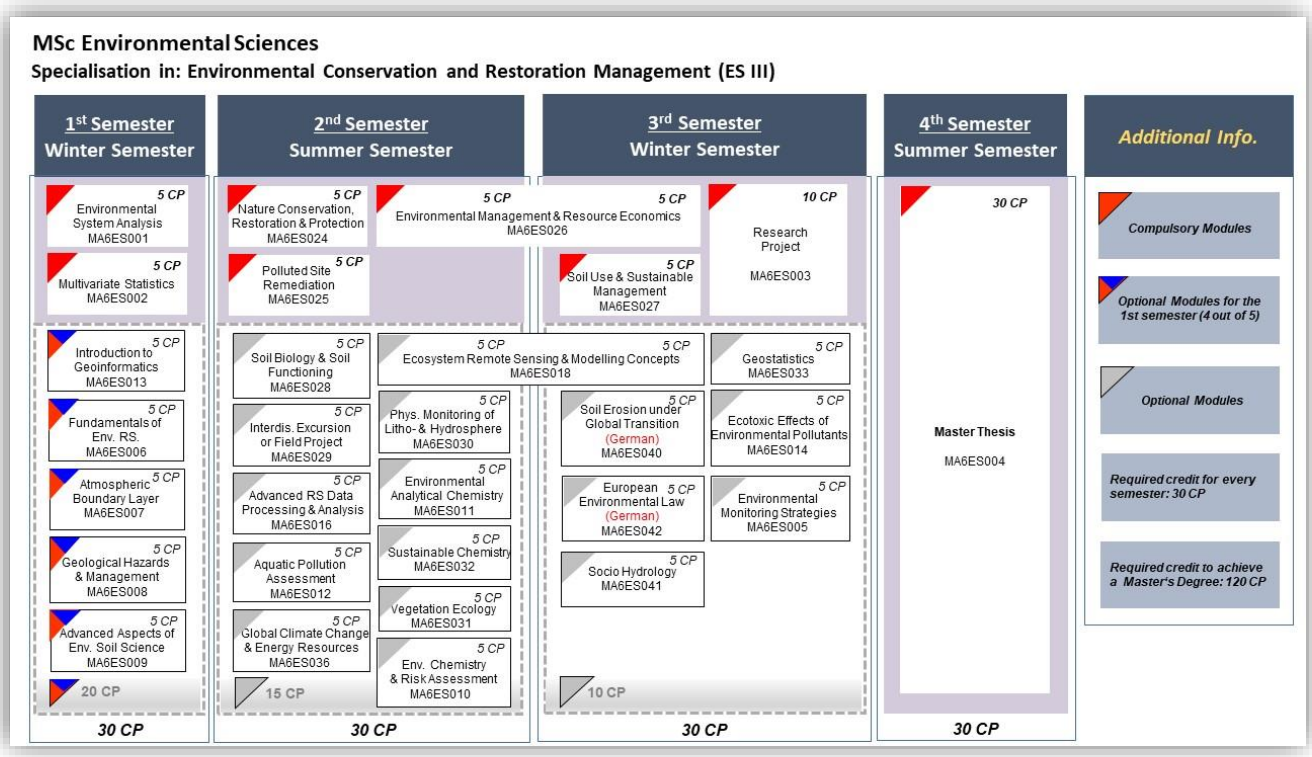

Table of courses in the Master of Science Degree Program Environmental Sciences Specialization in "Environmental Conservation and Restoration Management" (ES III)

Semester	*Module Code*	*Module Name*	*CP*	*CP/Semester*
Winter	Compulsory Modules			
1st	*MA6ES001*	*Environmental System Analysis*	*5*	
1st	*MA6ES002*	*Multivariate Statistics*	*5*	
Optional Module (4 out of 5 modules)				
1st	*MA6ES013*	*Introduction to Geoinformatics*	*5*	
1st	*MA6ES006*	*Fundamentals of Environmental Remote Sensing*	*5*	
1st	*MA6ES007*	*Atmospheric Boundary Layer*	*5*	
1st	*MA6ES008*	*Geological Hazards, Risk Assessment and Management*	*5*	*30 CP*
1st	*MA6ES009*	*Advanced Aspects of Environmental Soil Science*	*5*	

Semester	Module Code	Module Name	CP	CP/Semester
Summer	Compulsory Modules			
2nd	MA6ES024	Nature Conservation, Restoration and Protection	5	
2nd	MA6ES025	Polluted Site Remediation	5	
2nd + 3rd	MA6ES026	Environmental Management and Resource Economics	5*	
Optional Module (3 out of 11 modules)				
2nd	MA6ES031	Vegetation Ecology	5	
2nd	MA6ES032	Sustainable Chemistry	5	
2nd	MA6ES012	Aquatic Pollution Assessment	5	
2nd	MA6ES028	Soil Biology and Soil Functioning	5	
2nd	MA6ES016	Advanced Remote Sensing Data Processing and Analysis	5	
2nd + 3rd	MA6ES018	Ecosystem Remote Sensing and Modelling	5	
2nd	MA6ES011	Environmental Analytical Chemistry	5	
2nd	MA6ES010	Environmental Chemistry and Risk Assessment	5	
2nd	MA6ES030	Physical Monitoring of Litho- and Hydrosphere	5	
2nd	MA6ES029	Interdisciplinary Excursion or Field Project	5	
2nd	MA6ES036	Global Climate Change & Energy Resources	5	30 CP

Semester	Module Code	Module Name	CP	CP/Semester
Winter	Compulsory Modules			
2nd + 3rd	MA6ES026	Environmental Management and Resource Economic	5*	
3rd	MA6ES027	Soil Use and Sustainable Management	5	
3rd	MA6ES003	Research Project	10	
Optional Module (2 out of 7 modules)				
3rd	MA6ES033	Geostatistics	5	
3rd	MA6ES014	Ecotoxicological Effects of Environmental Pollutants	5	
3rd	MA6ES041	Socio Hydrology	5	
3rd	MA6ES005	Environmental Monitoring Strategies	5	
2nd + 3rd	MA6ES018	Ecosystem Remote Sensing and Modelling	5	
3rd	MA6ES042	European Environmental Law (German)	5	30 CP
3rd	MA6ES040	Soil Erosion under Global Change (German)	5	

Semester	Module Code	Module Name	CP	CP/Semester
Summer	Compulsory Modules			
4th	MA6ES004	Master Thesis	30	30 CP

** The module MA6ES026: The topics are divided into two semesters. Each semester counts as 5 credits and in total the module is worth 10CP.*

The First Semester in M.Sc. ES

The available modules for the first semester are offered as a general overview of the three specializations, in the Environmental Science master's programme. The modules are all same between three focal points and are available only for winter semester.
NOTE: The optional modules proposed for the first semester are not replaceable with the other elective modules provided for the next semesters.

Semester	***Module Code***	***Module Name***	***CP***	***CP/Semester***
Winter	Compulsory Modules			
1st	*MA6ES001*	*Environmental System Analysis*	*5*	
1st	*MA6ES002*	*Multivariate Statistics*	*5*	
Optional Module (4 out of 5 modules)				
1st	*MA6ES013*	*Introduction to Geoinformatics*	*5*	
1st	*MA6ES006*	*Fundamentals of Environmental Remote Sensing*	*5*	
1st	*MA6ES007*	*Atmospheric Boundary Layer*	*5*	
1st	*MA6ES008*	*Geological Hazards and Management*	*5*	*30 CP*
1st	*MA6ES009*	*Advanced Aspects of Environmental Soil Science*	*5*	

Compulsory Modules of the first Semester

Module "Environmental System Analysis"

Course Code: MA6ES001	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 1st (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Environmental Systems Analysis	2 SWH/30 h	30 h	25
	b) Environmental Systems Modelling	2 SWH/30 h	60 h	15
2	**Qualification Objectives** After the course, students are expected • to have improved knowledge of environmentally oriented decision-making, • to describe the general procedure of environmental systems analysis, • to be able to use different tools of environmental system analysis, • to be able to critically evaluate integrated analyses of complex environmental systems, • to develop and apply environmental simulation models.			
3	**Content** a) Principles of environmental systems analysis: • The nature of systems and the fundamentals of systems thinking, • Environmental systems: connections, cycles, and feedback loops, • Strategies for analyzing and using environmental system models, • Basic modeling concepts in environmental systems analysis, • Population development and boundaries of growth, • The meaning of catastrophes for natural systems, • Regional material transport, LCA, • Using simulation tools (e.g. STELLA) for system analysis, • Translation of "storylines" in model equations. b) Practical application of modeling scenarios.			
4	**Instruction Forms** a) Lectures and seminars in conjunction with an oral presentation b) Practical exercises			
5	**Examination Forms** Written examination (120 min)			
6	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
7	**Value of Mark in the Final Grade:** 5/120			
8	**Module Representative** Dr. R. Bierl, JProf. Dr. T. Schütz			
9	**Further Information** Literature: H. Bossel: Systems and Models – Complexity, Dynamics, Evolution, Sustainability. Books on Demand, Norderstedt, 2007 Deaton, M.L., Winebrake, J.J. (2000): Dynamic modelling of environmental systems. New York, Springer.			

Module "Multivariate Statistics"

Course Code: MA6ES002	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 1st (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture "Multivariate Statistics" b) Seminar "Multivariate Statistics"	**Contact Hours** 2 SWH/30 h 2 SWH/30 h	**Private Study** 45 h 45 h	**Group Size** 200 15
2	**Qualification Objectives** The overall aims of the module are to • gain basic knowledge in relevant multivariate methods for explorative data analysis, regression and classification, and pattern recognition • practice the application of multivariate methods with a statistical programming language (for example R) • acquire competence in critical and self-contained usage of statistical methods in research questions related to environmental sciences			
3	**Content** • Introduction to linear algebra • Variance analysis: ANOVA and MANOVA • Multiple correlation and regression analysis • Cluster analysis techniques: hierarchical cluster analysis and k-means clustering • Factor analysis and principal component analysis • Discriminant analysis • Pattern recognition: neuronal networks, kernel based regression and classification methods, Ensemble based statistical modelling			
4	**Instruction Forms** a) Lecture b) Exercise: Computer Lab / E-Learning			
5	**Examination Form** Written examination (120 min)			
6	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
7	**Value of Mark in the Final Grade:** 5/120			
8	**Module Representative** Prof. Dr. T. Udelhoven, Dr. Sascha Willmes			
9	**Further Information** Literature Field, A., Miles, J. and Field, Z., 2012. Discovering statistics using R. Sage publications.			

Optional Modules of the first Semester

Module "Introduction to Geoinformatics"

Course Code: MA6ES013	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 1st (Winter Semester)	**Duration:** 1 Semester

1	**Courses:** a) Exercise "Introduction into Geoinformatics" b) Exercise: E-Learning "Introduction into Geoinformatics"	**Contact Hours**: 2 SWH / 30h 1 SWH / 15h	**Private Study**: 45 h 60 h	**Group Size:** 15 15
2	**Qualification Objectives** • Understanding of the basic concepts, objectives, and principles of Geoinformatics, • Basic knowledge and practical experience in dealing with Geoinformation systems, • The capability of practical use of GIS methods in the acquisition, analysis, and visualization of Geodata.			
3	**Content** Introduction to geographic information systems - Spatial data models and concepts - Database concepts - Coordinate systems and projections Geodata processing and analysis - Geodata input and editing - Vector processing - Raster processing - Spatial data analysis Visualization of Geodata - Data visualization - Map layout			
4	**Instruction Forms** a) Exercise: Computer Lab b) Exercise: E-Learning			
5	**Examination Form** Written examination (60 min)			
6	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
7	**Value of Mark in the Final Grade:** 5/120			
8	**Module Representative** Prof. Dr. Thomas Udelhoven, Dr. Achim Röder, Dr. Johannes Stoffels			
9	**Further Information:** Literature Maguire, D.J., Batty, M. and Goodchild, M.F., 2005. GIS, Spatial Analysis, and Modeling. Esri Press. Jensen, J.R. and Jensen, R.R., 2012. Introductory Geographic Information Systems. Pearson Higher Ed. Heywood, DI, Cornelius, SC & Carver, SJ 2011, An Introduction to Geographical Information Systems. Fourth edn, Pearson Prentice Hall, London.			

Module "Fundamentals of Environmental Remote Sensing"

Course Code: MA6ES006	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 1st (Winter Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Lecture "Fundamentals of Environmental Remote Sensing"	2 SWH/30 h	45 h	200
	b) Exercise "Fundamentals of Environmental Remote Sensing"	2 SWH/30 h	45 h	15

2 Qualification Objectives

- Knowledge and hands-on experience of multi-scale remote sensing data,
- Expertise in the derivation of surface parameters from data sources with different spectral and radiometric properties,
- Understanding of interdisciplinary issues,
- Formulation, preparation, and presentation of research questions and interpretation strategies.

3 Content

Introduction to multi-scale remote sensing systems
- Specific sensor characteristics
- Object signatures, scaling effects
- Data archives

Radiometric processing of multi-spectral data
- Sensor calibration
- Empirical line correction
- Radiative transfer models

Analysis and interpretation strategies
- Procurement of long-term time series
- Derivation of qualitative surface characteristics
- Land use classification and land cover archives (MODIS, CORINE)
- Land use change detection based on time series (e.g. MODIS)
- Biophysical parameters
- Vegetation (e.g. cover, LAI, biomass) properties
- Vegetation indices and linear transformations (e.g. PCA, Tasseled Cap, Spectral Mixture Analysis)
- Soil (e.g. organic and inorganic carbon, mineral content)
- Indicators of productivity and disturbance
- Development of a processing and interpretation workflow
- Implementation of digital image processing concepts and specific analysis techniques in the frame of a case study

4 Instruction Forms

a) Lecture
b) Exercise: Computer Lab/ E-Learning

5 Examination Form

Written examination (60 min)

6 Condition for the Award of Credit Points: Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.

7 Value of Mark in the Final Grade: 5/120

8 Module Representative: Prof. Dr. Udelhoven, Dr. Achim Röder, Dr. Johannes Stoffels

9	**Further Information** Literature Jensen, John R., 2007, Remote Sensing of the Environment: An Earth Resource perspective, New York/Prentice Hall Jones, H.G. & Vaughn, R.A., 2010, Remote Sensing of Vegetation. Principles, Techniques, and Applications, Oxford/Oxford University Press. Lillesand, T.M., Kiefer, R.W., Chipman, J.W., 2008, Remote Sensing and Image Interpretation, New York/Wiley: New York Mather, P. & Koch, M., 2004, Computer Processing of Remotely-Sensed Images. An Introduction, Chichester/John Wiley & Sons Richards, J.A. & X. Jia, 2006, Remote Sensing. Digital Image Analysis, Berlin/Springer Verlag: Berlin Schowengerdt, R.A., 2006, Remote Sensing. Models and Methods for Image Processing, San Diego/Academic Press

Module "Atmospheric Boundary Layer"

Course Code: MA6ES007	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 1st (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture ABL b) Exercises ABL	**Contact Hours** 2 SWH/30h 2 SWH/30h	**Private Study** 45 h 45 h	**Group Size** 120 20
2	**Qualification Objectives** - Understanding the role of the atmospheric boundary layer (ABL), processes in the ABL and their interactions, - Knowledge of parameterization of exchange processes, - Independent, problem-oriented, scientifically founded, methodologically work.			
3	**Contents** This module is the basis for all modules, which deal with the soil-plant-atmosphere exchange, both for the modules with measurements of exchange processes and their modeling. In particular, the following topics are covered: • Structure of the atmospheric boundary layer, • Turbulent flux densities, • Surface energy balance, • Exchange processes and budgets in the ABL, • Hydrodynamic equations, • Laws and parameterizations.			
4	**Instruction Forms** a) Lecture b) Exercises			
5	**Examination Forms** Written examination (120 minutes)			
6	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
7	**Value of Mark in the Final Grade:** 5/120			
8	**Module Representative** Dr. C. Drüe, Meteorology Department			

Module "Geological Hazards, Risk Assessment and Management"

Course Code: MA6ES008	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 1st (Winter Semester)	**Duration:** 1 Semester

1	**Course** a) lecture b) seminar c) exercises	**Contact Hours** 2 SWS/30 h 1 SWS/15h 1 SWS/15 h	**Private Study** 15 h 30 h 30 h	**Group Size** 120 20 20
2	**Qualification Objectives** • Understanding and quantification of short-term geological processes (earthquake, volcanism, mass movements, tsunamis, etc.), • Prediction of geological hazards, • Risk Assessment, • Emergency Management and Mitigation, • Consequences of human activity on geological processes, • Effects of geological hazards on humans and ecosystems.			
3	**Contents** a) Introduction to geological disasters & hazard evaluation b) Geological hazards: 1. Volcanoes 2. Earthquakes & Tsunamis 3. Coastal Processes 4. Hurricanes & Tornadoes 5. River Floods 6. Mass Movements & Erosion 7. Global Climate Change c) Anthropogenic hazards: 1. Mining of Mineral & Energy Resources 2. Water Resources & Pollution 3. Agriculture & Soils 4. Brownfields			
4	**Instruction Forms** a) Lecture, b) Seminar, c) Exercises			
5	**Applicability of the Module** Optional Module for ES I, II, III			
6	**Examination Forms** Advanced examination effort: an oral presentation and exercise report. Final module examination: written examination (90 min).			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative** Prof. Dr. JF. Wagner			

Module "Advanced Aspects of Environmental Soil Science"

Course Code: MA6ES009	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 1st (Winter Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Lecture: "Environmental Soil Science" b) Practical course: "Advanced Methods in Soil Science"	2 SWH/30 h 2 SWH/30 h	40 h 50 h	120 20
2	**Qualification Objectives** Key qualifications: • In-depth understanding of interdisciplinary and multi-focus relations and interactions, • Application of system-oriented mindsets and methods, • Planning and organization of laboratory operational procedures; quality control, • Handling of scientific literature, respective data banks, and scientific English Expertise, • Adjustment of soil scientific basic knowledge among graduates from different bachelor programmes, • Communication and compilation of in-depth expert knowledge on specific aspects from soil chemistry, physics, and biology, • Acquisition of relevant analytical, recording, and modeling methods in theory and practice.			
3	**Content** • Mechanisms and kinetics of sorption, mobilization, transformation, and translocation of nutrients and pollutants in soil. • Modern functional concepts of and analytical methods for soil organic matter. • Soil organism communities and their interaction with biotic and abiotic factors. • Soil water balance at saturated and unsaturated conditions and impact on discharge within and on the soil. • Mechanic loading capacity, limits, and loadings of soils and measures to prevent soil from degradation through compaction. • Instruction to different analytical and recording methods to investigate processes and mechanisms within the above-mentioned fields of soil science. • Achievement of competence for field and laboratory investigation of relevant parameters from the above-mentioned fields of soil science.			
4	**Instruction Forms** a) Lecture (deepen basic knowledge in soil science with a focus on soil functions and threats). b) Practical course on special topics from soil chemistry, physics and biology.			
5	**Examination Forms** Oral examination (30 min)			
6	**Condition for the Award of Credit Points:** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
7	**Value of Mark in the Final Grade**: 5/120			
8	**Module Representative** Prof. Dr. S. Thiele-Bruhn, Dr. R. Schneider, Prof. Dr. C. Emmerling			
9	**Further Information** Literature: SCHEFFER/SCHACHTSCHABEL: Lehrbuch der Bodenkunde. Spektrum Akademischer Verlag. SPARKS D.: Environmental Soil Chemistry. Academic Press. HILLEL D. et al.: Encyclopedia of Soils in the Environment. Academic Press HARTGE K.H., HORN R.: Einführung in die Bodenphysik. Enke. BLUME H.-P. et al. (2011) Bodenkundliches Praktikum. 3rd ed., Spektrum Akademischer Verlag.			

Available Modules in the Master of Science Degree Program Environmental Sciences

Module "Environmental Chemistry and Risk Assessment"

Course Code: MA6ES010	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture 1: Environmental Fate and Reactions of Pollutants b) Seminar: Environmental Risk Assessment c) Laboratory research course	**Contact Hours** 2 SWH/30 h 2 SWH/30 h 2 SWH/30 h	**Private Study** 30 h 30 h	**Group Size** 125 125 12
2	**Qualification Objectives** The students should: • learn to understand environmental media and environmental compartments as chemical reactors, • apply and deepen the knowledge acquired in the BSc-UGW about the connection between molecular structure/functionality and reactivity of environmental chemicals, • be introduced to current research topics on environmental chemistry, • learn about priority and newly spreading pollutant classes, • develop an understanding of important abiotic substance transformation processes and be able to attribute them to fundamental (organic) chemical reaction mechanisms, • be able to evaluate the importance of these types of reactions for the various environmental compartments and pollutant classes, • be able to portray the influence of physical-chemical parameters on reaction conversion and reaction speed, • be able to understand and critically judge the derivation of limit values and other load indicator values, • be able to differentiate different "Environmental Risk Assessment" models and methods concerning their output premises and objectives.			
3	**Content** • Structural and physicochemical characteristics of priority and new emerging classes of environmental chemicals, • Important abiotic degradation mechanisms (hydrolysis, oxidation, reduction, radical reactions, substitution reactions, coupling reactions, photolysis, surface, and metal-ion-catalyzed reactions), • Correlation between the number and steric arrangement of structural units/functional groups and reactivity of molecules belonging to one congeneric substance group, • Importance of specific degradation mechanisms for different environmental compartments, • Influence of physiochemical environmental conditions on mechanism and rate of substance transformation, • Stabilization and sensibilization of environmental chemicals by sorptive bonding, • Interrelations between phase transfer and degradation processes, • Concepts and models of "Environmental Risk Assessments", • Risk concept and its application to behavior and effect of chemicals/environmental toxicants, • (Eco-) toxicological bases for environmental endangerment estimations and critical level/limit value settings, • Kinds of limit and other regulation and/or indication values, • Methods of limit value deduction, compromise the character of limit values, • The legal impact of limit values, action options in case of exceeding critical levels.			
4	**Examination Form** Written examination (90 min)			

5	**Instruction Forms** a) Lecture b) Seminar Laboratory research practical
6	**Condition for the Award of Credit Points** Passed final examination: written examination (90 min), and successful (qualified protocol) participation at the laboratory practical and seminar.
7	**Applicability of the Module:** Compulsory module for (ES I) and an optional Module for (ES III)
8	**Value of Mark in the Final Grade:** 5/120
9	**Module Representative** Prof. Dr. K. Fischer
10	**Further Information** SCHWARZENBACH, R.P., GSCHWEND, P.M., IMBODEN, D.M.: Environmental Organic Chemistry. New York, etc. (J. Wiley & Sons). Hodgson, A Textbook of Modern Toxicology 4th edition Wiley; ISBN-10: 047046206X, ISBN-13: 978-0470462065

Module "Environmental Analytical Chemistry"

Course Code: MA6ES011	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Environmental Monitoring and Trace Analysis b) Instrumental Analytical Techniques	**Contact Hours** 2 SWH/30 h 4 SWH/30 h	**Private Study** 30 h 60 h	**Group Size** 25 15
2	**Qualification Objectives** By the end of the course students can: • identify, examine and solve environmental analytical problems, • understand the basic theory and relevant parameters in environmental analytical chemistry, • select proper sample preparation methods for different media, • apply methods of instrumental analysis based on chromatography, spectrometry, and spectroscopy for target analysis of environmental pollutants in complex environmental matrices, • prepare reports based on experimental results and draw critical conclusions, • apply methods of analytical quality assurance and good laboratory practice.			
3	**Content** a) Environmental Monitoring and Trace Analysis • Introduction to the basic concepts of environmental analysis and monitoring, • Introduction to sampling, sample extraction, clean-up methods and analytical techniques for the analysis of liquid and solid samples, • Techniques for trace and ultra-trace analysis of nutrients and environmental pollutants: - Spectroscopic methods - Chromatography/mass spectrometry - Elemental analysis • Case-studies related to environmental pollutants, • In-situ measurement techniques and devices for field monitoring and automated analysis. b) The practical component of this module involves the application of analytical techniques to environmental samples done in practical laboratory exercises. • Introduction to the use of extraction techniques and methods for sample clean-up, • Introduction to the use of atomic absorption spectrometry, • Introduction to the use of liquid and gas chromatography with different detection devices, including mass spectrometry, • Introduction to analytical work with isotope-labeled compounds, • Introduction to imaging techniques.			
4	**Instruction Forms** a) Lectures and theoretical exercises. b) Case studies (practical laboratory exercises) and project work.			
5	**Examination Forms** Advanced examination effort: Report Oral examination (30 minutes)			
6	**Applicability of the Module** Compulsory module for (ES I) and an optional module for (ES III).			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
8	**Value of Mark in the Final Grade:** 5/120			

9	**Module Representative and Full-time Instructors** Dr. R. Bierl, Prof. Dr. S. Thiele-Bruhn
10	**Further Information** Literature: FIFIELD, F.W. & HAINES, P.J.(2000): Environmental Analytical Chemistry, 2nd ed., John Wiley & Sons KELLNER, R., MERMET, J.-M. ET AL. (2004) Analytical Chemistry - A Modern Approach to Analytical Science. Wiley-VCH, Weinheim PATNAIK, P. (2010) Handbook of Environmental Analysis. 2nd ed., CRC Press, Boca Raton, FL

Module "Aquatic Pollution Assessment"

Course Code: MA6ES012	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Aquatic ecology and impact of pollution b) Case studies in river catchments	2 SWH/30 h 2 SWH/30 h	60 h 30 h	15 15
2	**Qualification Objectives** The course intends to qualify the student for understanding the impact of pollution on freshwater ecosystems. It integrates different aspects of chemistry, physics, and biology determining freshwater ecosystems with an emphasis on human impacts and interactions with aquatic systems. After the course, the students will be able • to understand the main ecological processes occurring in freshwater ecosystems, • to describe water characteristics and properties of water quality, • to apply concepts of water quality and pollution processes in rivers and lakes, • to plan sampling programs and conduct laboratory experiments, • to communicate critically results of studies both orally and in written form.			
3	**Content** Lectures describe fundamental ecological processes and biotic communities in freshwater ecosystems as well as the impact of pollution: • Catchment characteristics • Organic matter dynamics • Biogeochemistry and nutrient cycling • Freshwater ecology: structure and dynamics of riparian zones, stream habitats, biofilms, hyporheic zone • Structure, function, and dynamics of the aquatic food webs • Anthropogenic influences, e.g. the ecological impacts of urban stormwater runoff quality, eutrophication, global warming • Water quality standards in a regional context • Water quality data evaluation • Invertebrates as indicators of pollution • Impacts of contamination and structural changes • Localization of sources of contamination The lab and field practice will consist of identification of algae and macroinvertebrates, basic ecological experiments, analytical techniques, and comparison of surveys of biological and chemical water quality at various stations.			
4	**Instruction Forms** a) Lectures and seminars in conjunction with oral presentation b) Lab and field course			
5	**Examination Forms:** Graded term paper			
6	**Applicability of the Module** Compulsory module for (ES I) and an optional Module for (ES III).			
7	**Condition for the Award of Credit Points:** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
8	**Value of Mark in the Final Grade**: 5/120			

9	**Module Representative** Dr. R. Bierl, JProf. Dr. T. Schütz
10	**Further Information** Literature: DODDS, WALTER K.(2002): Freshwater Ecology: Concepts and Environmental Applications. Academic Press.

Module "Regional Biomonitoring Project"

Course Code: MA6ES019	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Research concept and data analysis b) Field and laboratory course	**Contact Hours** 1 SWH/15h 3 SWH/45h	**Private Study** 50 h 40 h	**Group Size** 24 24
2	**Qualification Objectives** • Application of standardized passive and active Bio-monitors as sensitive or accumulation monitors, • Observation, sampling, and measurement of biological material (passive sampled or active exposed), • Development and evaluation of sensitive effect criteria and quality management and assurance of chemical analysis, • Practice with highly standardizes investigation methods and assessment of reproducibility, sensitivity, specify, validity and representatively of biomonitoring investigation concepts, • Interpolation of point-shaped measurements to the whole area investigated with an application of Geo-statistical methods, • Application of gas flux models to quantify fluxes of gaseous pollutants into leaves, • Development of critical loads and levels, • Knowledge and application of modern monitoring projects within the framework of UNECE ICP Vegetation and ICP- Forests.			
3	**Contents** • Exposition of bio-indicators for chosen pollutants (for instance ozone: Tobacco BEL W3, different sensitive clones of beans, clover, and poplar) on chosen localities in Trier region. • Exposure of active (standardized gras- & culy kale cultures) and passive accumulation monitors for air pollutants and particulate matter in the Trier region. • Application of quantitative chemical analytical methods for measuring heavy metals concentrations in plant exposed material (AAS), POPs or nitrogen accumulation in lichens and mosses. • Measuring different eco-physiological parameters for the characterization of effects from pollutants on plants (for instance leaf conductivity, pigment concentrations, and chlorophyll fluorescent. • Geo-statistics and aerial interpolation of point-shaped measurements including error maps. • Time series analysis of monitoring data. • Evaluation of results with aid of legal limits, chemical detection limits, and statistical methods. • Calculation and application of indices and gas fluxes to evaluate dose-effect responses from gaseous pollutants on organisms (for instance: AOT40, SOMO 35 and PODx).			
4	**Instruction Forms** a) seminar b) field and laboratory course			
5	**Examination Forms:** Final module examination: term paper			
6	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
7	**Applicability of the Module** Compulsory module for (ES I)			
8	**Value of Mark in the Final Grade**: 5/120			

9	**Module Representative** Geobotany Department
10	**Further Information** ARNDT U., NOBEL W. & SCHWEIZER B. 1987: Bioindikatoren: Möglichkeiten, Grenzen und neue Erkenntnisse. Ulmer, Stuttgart MARKERT B. [ED.] 1993: Plants as Biomonitors: Indicators for heavy metals in the terrestrial environment. VCH Weinheim. Manual for modelling and mapping critical loads & levels: http://icpvegetation.ceh.ac.uk/manuals/documents/Ch3revisedsummer2010final_221010_.pdf Moss survey protocol: http://icpvegetation.ceh.ac.uk/manuals/documents/UNECEHEAVYMETALSMOSSMANUAL2010POPsadaptedfinal_220 510_.pdf

Module "Ecotoxicological Effects of Environmental Pollutants"

Course Code: MA6ES014	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Principles of Molecular Environ-mental Toxicology	2 SWH/30 h	20 h	15
	b) Toxicant Effects in the Environment	1SWH/15 h	10 h	15
	c) Experiments on Selected Endpoints	1 SWH/15 h	60 h	15

2 Qualification Objectives

Key qualifications:

- In-depth understanding of interdisciplinary contexts and interactions,
- Application of system-oriented mindset and operation methods, enabling the students to analyze complex environmental problems, to develop and present approaches for solutions,
- A self-dependent, problem-oriented and targeted, scientifically based inquest, assessment and aggregation of scientific or technical information, in part done in groups,
- Presentation of results as written report and oral presentation,
- Self-dependent planning and organization of experiments and laboratory operations; data evaluation; quality assurance.

Professional competences:

- Gather and work out in-depth expert knowledge on specific topics of ecotoxicology in the intersection area of the disciplines toxicology/ecotoxicology, hydrology, and soil science.
- Basic knowledge in toxicology, modes of action, and principles of action (effect and adverse effect).
- Learn fundamental as well as legally required analysis and test methods in theory and practice.
- Integrate acquired expert knowledge on the fate and disposition of pollutants in different environmental compartments in the context of the aspect of effects.

3 Content

a) Toxicology/Ecotoxicology

- Relevant toxicological parameters: Transport through barriers, dose, introduction to structure-effect-problem, metabolism, classification of toxic effects, differences among species.

b) Hydrology & Soil Science

- Aquatic ecotoxicology: eco-toxicological risk potential of complex environmental samples (wastewater, seepage water, surface water), assessment of environmental samples with aquatic bio-test systems, ecological boundary conditions.
- Soil ecotoxicology: Effects on the level of organisms, populations, communities; determination of relevant endpoints, relevant boundary conditions, mixture toxicity, reactions of organisms, legal perspectives.

c) Toxicology/Ecotoxicology, Hydrology, Soil Science

- Experiments on the determination of the effects of selected pollutants on different endpoints.

4 Instruction Forms

a), b) Lecture, c) Laboratory Course (block course).

5 Examination Forms

Final module examination: Oral presentation (15 minutes).

6 Condition for the Award of Credit Points

Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam. Passed final examination: laboratory report and oral presentation.

7 Applicability of the Module

Compulsory module for (ES I) and an optional Module for (ES III).

8 Value of Mark in the Final Grade: 5/120

9	**Module Representative:** Prof. Dr. S. Thiele-Bruhn, Dr. R. Bierl
10	**Further Information** Literature: NAIDU R. (2008) Chemical Bioavailability In Terrestrial Environments. Elsevier. ALEXANDER M. (1999) Biodegradation and Bioremediation, 2nd Ed. Academic Press. NEWMAN, M.C., CLEMENTS W.H. (2008) Ecotoxicology – A comprehensive treatment. CRC Press, Boca Raton, FL. HOFFMAN, D.J. et al. (2003) Handbook of Ecotoxicology. 2nd ed. Lewis Publishers. VoHR, H.-W. (2010): Toxikologie, Bd. 1: Grundlagen der Toxikologie. ISBN 978-3-527-32319-

Module "Fluvial Hydrology"

Course Code: MA6ES045	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Particulate Transport in River Catchments b) Water Quality Modelling	2 SWH/30 h 2 SWH/30 h	45 h 45 h	25 15
2	**Qualification Objectives** The objective of this course is to give an overview of the analytical methods used in the development of water quality models, and the application of these models to stream and river systems. Special care is drawn to the transport of sediments and particle-bound substances in river catchments. Mathematical conceptualization and formulation of water quality constituent transport and fate mechanisms will be discussed. After the course, the students will be able • to understand the basic physical, chemical, biological and hydrological processes for sediment and water quality dynamics of streams, • to understand the principles of water quality modeling with basic experience of some water quality models, • to expand capabilities in teamwork, report writing, and presentation, • to communicate critically results of studies both orally and in written form.			
3	**Content** a) Particulate Transport in River Catchments • Runoff generation process and identification of particle sources • Natural tracer and runoff components • Erosion and suspended sediment transport • Physico-chemical properties of suspended sediments • Relationship between dissolved and suspended phase • Spatial and temporal dynamics of aquatic sediments • Transport and reactions of particle-bound contaminants in rivers b) Water Quality Modeling • Introduction to water quality modelling • Hydrologic and hydraulic principles relating to water quality modelling • Coupling of models of water quality and flow • Application of various water quality models • Eutrophication problem and nutrient modeling • Model calibration and verification			
4	**Instruction Forms** a) Lectures and seminars in conjunction with oral presentation b) Seminars and computer course			
5	**Examination Forms** Final module examination: oral examination (20 min.)			
6	**Applicability of the Module:** Optional module for (ES I).			
7	**Condition for the Award of Credit Points:** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam.			
8	**Value of Mark in the Final Grade:** 5/120			
9	**Module Representative and Full-Time Instructors** Dr. R. Bierl			
10	**Further Information** Literature: Chapra, S.C. (1997): Surface Water-Quality Modeling. New York, McGraw-Hill Allan, J.D. & Castillo, M.M. (2007): Stream Ecology: Structure and Function of Running Waters. Springer			

Module "Geospatial Data Analysis: Advanced GIS & Time Series Analysis"

Course Code: MA6ES046	**Frequency of Course Offer:** Annual
Credits: 10 CP	**Workload:** 300 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact hours**	**Private Study**	**Group Size**
	a) Lecture "Pattern Recognition in long-term global satellite archives"	2 SWH/30 h	30 h	200
	b) Exercise "Pattern Recognition in long-term global satellite archives"	2 SWH/30 h	60 h	15
	c) Exercise "Advanced Methods in GIS and Applications"	2 SWH/30 h	45 h	15
	d) Exercise: E-Learning "Advanced Methods in GIS and Applications"	1 SWH/15 h	60 h	15
2	**Qualification Objectives** a)+b) • Getting acquainted with global satellite archives, related data formats, and metadata, • Introduction in time-series analysis methods, concepts, and techniques, • Practical exercises in the analysis of Spatio-temporal patterns using the R and IDL/ENVI software environments, • Relating statistical results and global/regional environmental processes. c) • Fundamentals of geographical information processing and data management, • Problem-oriented integration of vector and raster data, • Knowledge and application of advanced geomatics methods.			
3	**Instruction Forms** a)+b) Introduction - Overview about major long-term global satellite data archives (e.g. MODIS, SPOT VGT, NOAA-AVHRR) - Statistical problems in dealing with auto correlated data - Introduction in the R system and relevant libraries for time-series analysis - Introduction of the IDL/ENVI software environment Time-series analysis - Introduction and definitions of time-series analysis methods and concepts - Homogeneity analysis of time-series: absolute and relative methods - The problem of temporal/spatial autocorrelation - Exponential smoothing - ARIMA-Models: model specification, estimation and validation - Trend analysis: parametric and non-parametric methods - Spectral and cross-spectral analysis - (Multivariate) regression of auto correlated data - Continuous and discrete wavelet analysis (CWA, DWA) Lining statistical temporal patterns with environmental processes - Practical examples using different regional/global long-term satellite archives c) Introduction to geo-data management - Thematic and topographic data sources - Remote sensing data sources - Mobile GIS applications Advanced analysis methods			

	- Cost surface models - Topographic analysis Automization of GIS workflows - Object-oriented graphical macro languages Development of GIS projects - Problem oriented integration of geo-data (raster and vector data) - GIS project management (soft skills) Presentation and map layout
4	**Instruction Forms** a) Lecture b) Exercise: Computer Lab c) Exercise: Computer Lab d) Exercise: E-Learning
5	**Examination Form** a)+b) Graded term paper (50% of final grade) c) Graded term paper (50% of final grade)
6	**Applicability of the Module** Compulsory for (ES II A. Remote Sensing)
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
8	**Value of Mark in the Final Grade**: 10/120
9	**Module Representative** Prof. Dr. T. Udelhoven, Dr. A. Röder, Dr. J. Stoffels
10	**Further Information** Recommended preparatory courses for this module are: - Introduction to Geoinformatics - Fundamentals of Environmental Remote Sensing - Multivariate Statistics - Literature a)+b) Box, G.E.P., Jenkins, G.M., Reinsel, G.C., Ljung G.M. (2016): Time Series Analysis: Forecasting and Control, 5th edition, Prentice Hall. Chatfield, C. and Xing, H., 2019. The analysis of time series: an introduction with R. CRC press. Hamilton, J.D. 1994. Time series analysis, Princeton University Press. Shumway, R.H. and Stoffer, D.S., 2017. Time series analysis and its applications: with R examples.Springer. Schlittgen, R., Streitberg, B. (2001). Zeitreihenanalyse, Oldenburg Verlag. c) Maguire, D.J., Batty, M. and Goodchild, M.F., 2005. GIS, Spatial Analysis, and Modeling, Esri Press. Wainwright, J. and Mulligan, M. eds., 2013. Environmental Modelling: Finding Simplicity in Complexity, John Wiley & Sons. Wilson, J. P., & Gallant, J. C. 2000. Terrain Analysis: Principles and Applications, John Wiley & Sons.

Module "Time Series Analysis"

Course Code: MA6ES044	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture "Pattern Recognition in long-term global satellite archives" b) Exercise "Pattern Recognition in long-term global satellite archives"	**Contact hours** 2 SWS/30 h 2 SWS/30 h	**Private Study** 30 h 60 h	**Group Size** 200 15
2	**Qualification Objectives** • Getting acquainted with global satellite archives, related data formats and metadata • Introduction in time-series analysis methods, concepts and techniques • Practical exercises in the analysis of spatio-temporal patterns using the R and IDL/ENVI software environments • Relating statistical results and global/regional environmental processes			
3	**Content:** **Introduction** - Overview about major long-term global satellite data archives (eg MODIS, SPOT VGT, NOAA-AVHRR), - Statistical problems in dealing with auto-correlated data, - Introduction in the R system and relevant libraries for time-series analysis, - Introduction of the IDL/ENVI software environment. **Time-series analysis** - Introduction and definitions of time-series analysis methods and concepts, - Homogeneity analysis of time-series: absolute and relative methods, - The problem of temporal/spatial autocorrelation, - Exponential smoothing, - ARIMA-Models: model specification, estimation, and validation, - Trend analysis: parametric and non-parametric methods, - Spectral and cross-spectral analysis, - (Multivariate) regression of auto-correlated data, - Continuous and discrete wavelet analysis (CWA, DWA). **Lining statistical temporal patterns with environmental processes** - Practical examples using different regional/global long-term satellite archives.			
4	**Instruction Forms:** a) Lecture, b) Exercise: Computer Lab			
5	**Examination Form** Graded term paper			
6	**Applicability of the Module** Compulsory module for focus ES II B (Environmental Remote Sensing and Modelling: Environmental Meteorology)			
7	**Condition for the Award of Credit Points:** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative and Full-Time Instructor:** Prof. Dr. T. Udelhoven			
10	Further Information Recommended preparatory courses for this module are: Fundamentals of Environmental Remote Sensing Multivariate Statistics			

	Literature Box, G.E.P., Jenkins, G.M., Reinsel, G.C., Ljung G.M. (2016): Time Series Analysis: Forecasting and Control, 5th edition, Prentice Hall. Chatfield, C. and Xing, H., 2019. The analysis of time series: an introduction with R. CRC press. Hamilton, J.D. 1994. Time series analysis, Princeton University Press. Shumway, R.H. and Stoffer, D.S., 2017. Time series analysis and its applications: with R examples. Springer. Schlittgen, R., Streitberg, B. (2001). Zeitreihenanalyse, Oldenburg Verlag.

Module "Geospatial Data Analysis: Advanced GIS"

Course Code: MA6ES047	**Frequency of course offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Exercise "Advanced Methods in GIS and Applications" b) Exercise E-Learning "Advanced Methods in GIS and Applications"	**Contact hours** 2 SWH/30 h 1 SWH/15 h	**Private Study** 45 h 60 h	**Group Size** 15 15
2	**Learning Outcomes/Qualification Objectives** • Fundamentals of geographical information processing and data management • Problem-oriented integration of vector and raster data • Knowledge and application of advanced geomatics methods			
3	**Content** Introduction to geo-data management - Thematic and topographic data sources - Remote sensing data sources Mobile GIS applications Advanced analysis methods - Cost surface models - Topographic analysis Automatization of GIS workflows - Object-oriented graphical macro languages Development of GIS projects - Problem oriented integration of geo-data (raster and vector data) - GIS project management (soft skills) - Presentation and map layout			
4	**Instruction Forms** a) Exercise: Computer Lab			
5	**Conditions for Participation**			
6	**Examination Form** Graded term paper			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Applicability of the Module** Optional module for focus ES II B (Environmental Remote Sensing and Modelling: Environmental Meteorology)			
9	**Value of Mark in the Final Grade** Without proportional weighting in final grade (5/120)			
10	**Module Representative and Full-Time Instructor:** Prof. Dr. T. Udelhoven, Dr. A. Röder, Dr. J. Stoffels			
11	**Further Information** Recommended preparatory courses for this module are: - Introduction to Geoinformatics			

	Literature: Maguire, D.J., Batty, M. and Goodchild, M.F., 2005. GIS, Spatial Analysis, and Modeling, Esri Press. Wainwright, J. and Mulligan, M. eds., 2013. Environmental Modelling: Finding Simplicity in Complexity, John Wiley & Sons. Wilson, J. P., & Gallant, J. C. 2000. Terrain Analysis: Principles and Applications, John Wiley & Sons.

Module "Advanced Remote Sensing Data Processing & Analysis"

Course Code: MA6ES016	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Exercise "Advanced Remote Sensing Data Processing and Analysis" b) Field exercise "Advanced Remote Sensing Data Processing and Analysis"	**Contact Hours** 3 SWH/45 h 1 SWH/15 h	**Private Study** 60 h 30 h	**Group Size** 15 20
2	**Qualification Objectives** • Expertise in radiative transfer modeling of hyperspectral imagery, • Skills in the derivation of surface properties from multi- and hyperspectral data, • Understanding of interdisciplinary issues, • Formulation, preparation, and presentation of scientific topics, • Competence in the +coordination of group work.			
3	**Content** a) Radiometric processing of multi- and hyperspectral imagery - Radiative transfer modelling - Water vapor estimation, sensor recalibration - Compression and transformation of hyperspectral data - Spectral Mixture Analysis - Principal Component Analysis - Partial Least Square-Regression - Minimum Noise Fraction Classification and interpretation strategies - Parametric and non-parametric methods (e.g. Maximum Likelihood, Support Vector Machines, Spectral Angle Mapper, Spectral Feature Fitting) - Empirical approaches (e.g. hierarchical or regression models) Multisensor approaches (algorithms und applications) - Sensor intercalibration - Data fusion b) Planning and execution of a hyperspectral field campaign - Field survey of reference data - Reflectance measurements - Atmospheric measurements			
4	**Instruction Forms:** a) Exercise: Computer Lab / E-Learning b) Field Exercise			
5	**Examination Form** Final module examination: Graded term paper			
6	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
7	**Value of Mark in the Final Grade**: 5/120			
8	**Applicability of the Module** Compulsory module for focus ES II A (Environmental Remote Sensing and Modelling: Environmental Remote Sensing) Optional Module for foci ES I, ES II B (Environmental Remote Sensing and Modelling: Environmental			

	Meteorology) and ES III
9	**Module Representative:** Prof. Dr. T. Udelhoven, Dr. A. Röder, Dr. R. Retzlaff
10	**Further Information** Recommended preparatory courses for this module are: - Introduction to Geoinformatics - Fundamentals of Environmental Remote Sensing Literature Schott, J.R. (2007): Remote Sensing - The Image Chain Approach, Oxford University Press/Oxford Richards, J.R. & Jia, X. (2006): Remote Sensing Digital Image Analysis, Springer/ Heidelberg Jensen, John R., 2007, Remote Sensing of The Environment: An Earth Resource Perspective, New York/Prentice Hall Liang, S. (2004): Quantitative Remote Sensing of Land Surfaces, Wiley/New York Thenkabail, P.S., Lyon, J.G., Huete, A. (2011): Hyperspectral Remote Sensing of Vegetation, Crc Press/New York

Module "Remote Sensing of Global Change Processes"

Course Code: MA6ES017	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Exercise "Remote Sensing of Global Change Processes"	2 SWH/30 h	75 h	15
	b) Seminar "Remote Sensing of Global Change Processes"	1 SWH/15 h	30 h	20

2 Qualification Objectives

- Understanding of global environmental processes and analytical approaches
- Conceptual knowledge and methodological expertise in applied environmental remote sensing and modelling techniques
- Skills in independent scientific treatise of specific research questions
- Competence in coordination of group-based field work and presentation techniques

3 Content

Global change processes
- Climate change and carbon sequestration
- Global vegetation and biomass
- Biodiversity
- Land use change
- Food security

Assessment of processes coupled social-ecological systems based on Remote Sensing
- Global processes
- Regional processes
- Landscape pattern analysis
- Metric indices and neutral models
- Spatially explicit indicators

Remote sensing contributions to conservation management
- REDD processes
- Desertification
- Biodiversity
- Metapopulation models and assimilation of remote sensing data
- Territorial behavior and movement patterns of animal populations
- Delineation of conservation areas
- Remote sensing applications in crisis management
- „Geohazards", empirical modelling of environmental pollution
- „Rapid Mapping", support to emergency services

4 Instruction Forms

a) Exercise: Computer Lab / E-Learning
b) Seminar

5 Examination Form

Graded term paper

6 Applicability of the Module

Compulsory for (ES II A. Remote Sensing) Optional Module for (ES II B. Environmental Meteorology).

7 Condition for the Award of Credit Points

Regular attendance at courses, successful completion of non-graded assessment-tasks (presentation, poster, homework), passing of module exam

8	**Value of Mark in the Final Grade**: 5/120
9	**Module Representative and Full-Time Instructor** Dr. A. Röder, Dr. J. Stoffels
10	**Further Information** Recommended preparatory courses for this module are: - Introduction to Geoinformatics - Fundamentals of Environmental Remote Sensing Literature: Chapin Iii, F., Kofinas, G., Folke, C. (2009): Principles of Natural Resources Stewardship: Resilience-Based Management in a Changing World, Springer. Chuvieco, E. (2007): Earth Observation of Global Change: The Role of Satellite Remote Sensing in Monitoring the Global Environment, Springer. Forman, R.T.T. & Wilson, E.O. (1995): Land Mosaics: The Ecology of Landscapes and Regions, Springer. Wiens, J. & Moss, M. (2005): Issues and Perspectives in Landscape Ecology, Cambridge University Press. Lambin, E.F. & Geist, H.J. (2006): Land Use and Land Cover Change: Local Processes and Global Impacts. Heidelberg/Springer. Maguire, D. J., Batty, M., & Goodchild, M. F. (2005): GIS, Spatial Analysis and Modeling. Redwood/Esri Press. MEA (2005): Ecosystems and Human Well-Being: General Synthesis. Island Press, Washington, DC. Mulligan, M., Wainwright, J. (2011): Environmental Modeling: Finding Simplicity in Complexity. Wiley. Shugart, H.H. & Woodward, F.I. (2011): Global Change and the Terrestrial Biosphere. Oxford/Wiley-Blackwell Purkis, S. & Klemas, V. (2011): Remote Sensing and Global Environmental Change. Oxford/Wiley-Blackwell

Module "Ecosystem Remote Sensing and Modelling Concepts"

Course Code: MA6ES018	**Frequency of Course Offer:** Annual
Credits: 5/10 CP	**Workload:** 150/300 h
Study Semester: 2nd & 3rd Semester	**Duration:** 2 Semesters

1	**Courses** a) Seminar "Ecosystem Remote Sensing and Modelling" b) Field exercise "Ecosystem Remote Sensing and Modelling" c) Exercise "Ecosystem Remote Sensing and Modelling"	**Contact Hours** 2 SWH/30 h 2 SWH/30 h 3 SWH/45 h	**Private Study** 45 h 45 h 105 h	**Group Size** 20 20 15
2	**Qualification Objectives** a)+b) • Understanding of interdisciplinary ecosystem assessment and resource inventories • Knowledge of advanced concepts in plant physiology and vegetation remote sensing • Hands-on experience in ground surveying techniques and experimental/analytical laboratory methods c) • Expertise in spatial analysis of point data and scaling issues • Expertise in ecosystem monitoring techniques using multi-temporal remote sensing data • Understanding of productivity models and assimilation of remote sensing-derived data a)+b)+c) Competence in coordination of group-based field work and presentation techniques			
3	**Content** a)+b) Specific topics in plant ecology and site characterization Interaction between leaf reflectance and plant physiology planning and execution of field survey campaigns - Scaling in remote sensing data - Inventory of site characteristics and biophysical variables (e.g. tree density, age, crown closure, species composition, LAI) Optical instruments and measurement concepts (LAI-2000, Hemiphotos, Laser scanning etc.) Laboratory experiments - Eco physiological measurements - Spectrometry c) Advanced data analysis - Long-term monitoring networks - Geo-statistical analysis - GIS-integration of field survey data Productivity and growth models (e.g. Biome-BGC, SILVA) - Concepts and implementation - Assimilation strategies for remote sensing data - Error estimation Estimation of biophysical plant- and site-parameters - Parameterization of empirical and physical-based reflectance models - Preparation of map products of plant- and site-related parameters - Image-based retrospective change detection and monitoring			
4	**Examination Form** Graded term paper			

5	**Instruction Forms** a) Seminar b) Field Course c) Exercise: Computer Lab
6	**Applicability of the Module** a)+b)+c) Compulsory module for focus ES II A (Environmental Remote Sensing and Modelling: Environmental Remote Sensing) (2 Semesters = 10 credits) Optional module for focus ES II B (Environmental Remote Sensing and Modelling: Environmental Meteorology) (2 Semesters = 10 credits) Optional module for focus ES III (Conservation and Restoration Management) (2 Semesters = 10 credits) a)+b) Optional module for focus ES I (Environmental Monitoring and Pollution Assessment) (Only 1 Semester = 5 credits)
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
8	**Value of Mark in the Final Grade**: ES II/ ESIII - Without proportional weighting in final grade (10/120) ES I - Without proportional weighting in final grade (5/120)
9	**Module Representative and Full-Time Instructor** Prof. Dr. T. Udelhoven, Dr. A. Röder, Dr. J. Stoffels
10	**Further Information** Recommended preparatory courses for this module are: Introduction to Geoinformatics Fundamentals of Environmental Remote Sensing Literature: Wulder, M.A. and Franklin, S.E. eds., 2012. Remote sensing of forest environments: concepts and case studies. Springer Science & Business Media. Rencz, A., S. Ustin, Eds. (2004): Remote Sensing for Natural Resource Management and Environmental Monitoring, Manual of Remote Sensing, John Wiley & Sons. Liang, S., 2004. Quantitative remote sensing of land surfaces. John Wiley & Sons.

Module "Numerical Modelling in Meteorology"

Course Code: MA6ES020	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 300 h
Study Semester: 2nd & 3rd Summer	**Duration:** 2 Semesters

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Dynamics (Lecture)	2 SWH/30 h	60 h	120
	b) Dynamics (Computer Course)	2 SWH/30 h	30 h	20
	c) Applications (Lecture)	2 SWH/30 h	30h	120
	d) Applications (Computer Course)	2 SWH/30 h	60 h	20
2	**Qualification Objectives** • Independent, problem-oriented and purposeful, scientifically founded, critical appraisal of methods; acquisition of presentation and teamwork abilities, • Application of numerical models; understanding of atmospheric processes.			
3	**Contents** This module deepens the knowledge acquired in the BSc on atmospheric dynamics and gives an introduction in practical work with a complex numerical model. **Dynamics** - Basics of the dynamics of the atmosphere (hydrodynamic equations, coordinate systems, scale analysis, hydrostatic balance, geostrophic balance, thermal wind). - Dynamics of mid-latitude cyclones (vorticity and divergence, vorticity equation, quasi-geostrophic approximation, quasi-geostrophic diagnostics, omega equation). - Dynamics of fronts (air mass theory, front types, and weather, field theory for fronts, frontogenesis). **Applications** - Overview of numerical models in weather and climate forecasting. - Numeric (basic equations and approximations, waves, discretization of differential equations, time step and advection methods). - Work with a complex numerical model (e.g. numerical weather forecast, sea ice model), application of evaluation and validation techniques.			
4	**Instruction Forms** a), c) Lecture, b), d) Exercises (computer course)			
5	**Examination Forms** Advanced examination effort: exercises Final module examination: Oral examination (30 minutes)			
6	**Applicability of the Module** Compulsory for ES II (B. Meteorology) and an Optional Module for ES II (A. Remote Sensing)			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 10/120			
9	**Module Representative and Full-Time Instructors** NN, Meteorology Department			

Module "Monitoring and Remote Sensing in Meteorology"

Course Code: MA6ES021	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Systems and Algorithms b) Practical Applications	**Contact Hours** 2 SWH/30h 2 SWH/30h	**Private Study** 30 h 60 h	**Group Size** 120 15
2	**Qualification Objectives** • Independent, problem-oriented and purposeful, scientifically founded, critical appraisal of methods, • Acquisition of teamwork and presentation skills, • Acquisition of knowledge about the physical bases of the meteorological remote sensing systems and procedures, • Ability to apply remote sensing data in the area of boundary layer meteorology and climate monitoring.			
3	**Contents** This module deals with different aspects of meteorological remote sensing. 1) Satellite-based meteorological remote sensing and climate monitoring Meteorological satellites in geostationary and near-polar orbits, an overview of monitoring systems, meteorological data products, remote sensing of the atmosphere, work with satellite data and determination of meteorological quantities, work with remote sensing data. 2) Ground-based meteorological remote sensing Ground-based systems (inter alia LIDAR, SODAR, RADAR, scintillometer), remote sensing of the atmosphere, work with remote sensing data.			
4	**Instruction Forms** a) Lecture, b) Exercises (computer course)			
5	**Examination Forms** Final module examination: Graded term paper			
6	**Applicability of the Module** Compulsory for ES II (B. Meteorology) and an Optional Module for ES II (A. Remote Sensing) Optional for ES I			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative and Full-Time Instructors** Dr. C. Drüe, Dr. S. Willmes			

Module "Land Surface-Atmosphere Interactions"

Course Code: MA6ES022	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Introduction to Land-Surface-Atmosphere Interactions b) Micro-meteorological and eco-physiological measurements	**Contact Hours** 2 SWH/30 h 4 SWH/60 h	**Private Study** 30 h 30 h	**Group Size** 120 20
2	**Qualification Objectives** - Independent, problem-oriented and purposeful, scientifically founded, critical appraisal of methods, - Acquisition of presentation abilities and teamwork, - Understanding of the interaction processes atmosphere-plant-soil, - Knowledge of modern measuring methods.			
3	**Contents** The emphasis of this module is on measurements of exchange processes of the system soil/plant/atmosphere with modern measuring methods. The theoretical basis will be laid through the lecture; field surveys and evaluations will be practiced through handling modern measuring instruments and the use of evaluation methods learned. Contents of the partial modules are: • Laws of the turbulent exchange in the Prandtl layer (atmosphere and plants), turbulent flux densities, computation of the components of the surface energy balance, stability measures, eco-physiological methods for the measurement of the gas exchange of plants, computation of conductivity, transpiration, and net photosynthesis, morphologically anatomical modifications and their effects on the gas change. Measuring methods of the water condition and derivable statements from this. Models on the gas change and water regime of plants and plant stocks. • Exercises with measurements at a common measuring point in the local area: Boundary layer measurements (e.g. energy balance components, CO_2 fluxes), measurements with a gas change porometer to determine the transpiration and photosynthesis activity on leaf level as a function of radiation, temperature, and humidity; measurements of the xylem sap flow and the conductivity of a plant individual as well as measurements of the total water potential of plants and plant parts with leaf and stem psychrometers.			
4	**Instruction Forms** a) Lecture b) Practical Exercises (block course)			
5	**Examination Forms** Final module examination: presentation (30 minutes)			
6	**Applicability of the Module** Compulsory for ES II (B. Meteorology) and an optional Module for ES II (A. Remote Sensing) and ES I			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative and Full-Time Instructors** Dr. C. Drüe, Prof. Dr. F. Thomas, NN. Meteorology Department, NN. Geobotanic Department			

Module "SVAT-Models and Integration of Remote Sensing Data"

Course Code: MA6ES023	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Remote Sensing of SVAT-Model Parameters b) Theory and Practical Use of SVAT Models	**Contact Hours** 2 SWH/30h 2 SWH/30h	**Private Study** 30 h 60 h	**Group Size** 15 15
2	**Qualification Objectives** • Acquisition of knowledge and methodological abilities for the integration of remote sensing data into space-oriented modelling approaches, • Acquisition of knowledge on the modeling of the atmosphere-soil-plant exchange.			
3	**Contents** This module shall enable students to obtain the theory and methods of remote sensing of surface properties and the interaction processes of the atmosphere-soil-plant exchange as well as practical work with a soil vegetation atmosphere transfer (SVAT) - model. Contents of the partial modules are: a) Possibilities of supplying quantitative variables for SVAT models through evaluation of multi-spectral remote sensing data (Landsat TM) and modelling of the following model inputs: energy balance quantities: albedo, global radiation, radiation balance, radiation temperature, emission coefficient, surface temperature; Land use variables: Land use class, leaf area index, vegetation coverage, water regime: ETA. b) Theoretical basis of a SVAT (Soil-Vegetation-Atmosphere-Transfer) models, parameterization of processes, practical work with a SVAT model, linking of SVAT model and remote sensing data.			
4	**Instruction Forms** a), b) Computer Course (Exercises)			
5	**Examination Forms** Advanced examination effort: report Final module examination: Oral presentation (20 minutes)			
6	**Applicability of the Module** Compulsory for ES II (B. Meteorology) and an optional Module for ES II (A. Remote Sensing)			
7	**Condition for the award of credit points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade:** 5/120			
9	**Module Representative and Full-Time Instructors** apl. Prof. Dr. M. Vohland, Dr. S. Willmes, NN. Meteorology Department			

Module "Nature Conservation, Restoration & Protection"

Course Code: MA6ES024	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Soil Protection Concepts b) Nature Conservation	2 SWH/30 h 2 SWH/30 h	45 h 45 h	20 20

2 Qualification Objectives

key qualifications:

- In-depth understanding of interdisciplinary contexts and interactions
- Application of system-oriented mindset and operation methods, enabling the students to analyze complex environmental problems, to develop and present approaches for solutions,
- A self-dependent, problem-oriented and targeted, scientifically based inquest, assessment and aggregation of (English) scientific or technical information, in part done in groups
- Presentation of results as written text and oral presentation Expertise:
- Gain theoretical knowledge on soil impacts, soil protection and remediation/restoration with a perspective on different and specific soil functions
- Learn examples for measures of soil remediation, recultivation, and amelioration
- Indicators of soil stress and contamination and aspects of soil protection planning
- Assess the endangerment of species and biotopes
- Know, apply and judge strategies of nature protection
- Develop plans for biotope management
- Contribute to aspects of landscape planning

3 Contents

A. Seminar Soil Protection Concepts

1. Soil Degradation
   - Acidification, salinization, contamination, imbalances of nutrients, humus degradation, water and wind erosion, soil compaction, sealing, removal of soil, emerging pollutants, decentral flood prevention, legal framework
2. Soil Remediation
   - Mechanical, chemical, biological and soil management methods, soil utilization and recycling
3. Soil amelioration and renaturation
4. Soil restoration and recultivation
5. Recycling of organic wastes

B: Seminar Nature Conservation

1. Endangerment of species and biotopes
2. Causes of endangerment and deterioration
3. Mapping of biotopes
4. Protection of species and biotopes
5. „Rote Listen", FFH appendix 2 list
6. Legal basics of nature conservation
7. Categories of protective areas
8. Biotope management plans of biotope maintenance (selected case studies)
9. Biotope connection, biotope networks
10. Nature conservation economics
11. Landscape planning and ecology

4 Instruction Forms

a) Seminar on current topics in soil conservation
b) Seminar on nature conservation

5	**Applicability of the Module** Compulsory for ES III and an optional Module for ES II (A and B)
6	**Examination Forms** Advanced examination effort: seminar presentation Final module examination: graded term papers in each seminar (50%, 50%)
7	**Condition for the Award of Credit points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
8	**Value of Mark in the Final Grade:** 5/120
9	**Module Representative and Full-Time Instructors** Prof. Dr. Thiele-Bruhn, apl. Prof. Dr. Emmerling, Dr. Schneider
10	**Further Information** BLUME ET AL.: Handbuch des Bodenschutzes, ecomed. ALEXANDER: Biodegradation and Bioremediation. Academic Press

Module "Polluted Site Remediation"

Course Code: MA6ES025	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture b) Seminar c) Field course	**Contact Hours** 2 SWH/30 h 1 SWH/15h 1 SWH/15 h	**Private Study** 15 h 30 h 30 h	**Group Size** 20 20 20
2	**Qualification Objectives** • Description and quantification of pollutant fluxes in the subsoil • Polluted Site characterization & Risk assessment • Criteria for choice of remediation technique (active and passive) and remediation targets • Land recycling			
3	**Content** • Geology for polluted sites • International and national policies and legislations • Chemistry for polluted sites • Site characterization • Risk assessment • Remediation techniques			
4	**Instruction Forms** a) Lecture, b) Seminar, c) Field course			
5	**Examination Forms** Advanced examination effort: oral seminar presentation and field exercise report Final module examination: Written examination (90 minutes)			
6	**Applicability of the Module** Compulsory for ES III and an optional Module for ES I			
7	**Conditions for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative and Full-Time Instructors** Prof. Dr. J.F. Wagner			
10	**Further Information** http://www.bmu.de http://www.epa.gov/superfund/ http://www.umweltbundesamt.de/			

Module "Environmental Management and Resource Economics"

Course Code: MA6ES026	**Frequency of Course Offer:** Annual
Credits: 10 CP	**Workload:** 300 h
Study Semester: 2nd & 3rd Semester	**Duration:** 2 Semesters

1	**Courses** a) Environmental Economics b) Resource Economics	**Contact Hours** 2 SWH/30 h 2 SWH/30 h	**Private Study** 120 h 120 h	**Group Size** unlimited 25
2	**Qualification Objectives** Key qualifications: • Understanding of the economic structure of environmental problems • Ability to handle environmental policy issues scientifically and to discuss instruments • Ability to work out economic aspects in interdisciplinary environmental projects Expertise: • Implementation of cost-benefit analysis in the environmental field • Application of game theory on the strategic interaction between actors in the environmental field • Determining the economically optimal use of environmental policy instruments • Identifying sub-optimal use of resources in a market economy • The formulation, specification and implementation of efficiency and sustainability concepts			
3	**Content** <u>Environmental problems as market failure</u> - A social dilemma for public goods and common-pool resources - Property rights, transaction costs, and Coase negotiated solutions <u>Environmental policy instruments</u> - Regulatory approaches - Taxes and eco-taxes - Tradable emission allowances, Hybrid Systems - Voluntary agreements <u>Valuation of environmental goods</u> - Evaluation quotas (CVM) - The transport cost approach, hedonic pricing methods, and other approaches <u>Resources analysis</u> - Determination of price and quantity of paths of natural resources (Hoteling model) - Strong and weak sustainability - A business-like and economically efficient use of resources <u>Integrated Assessment Models</u> - Integration of model components from different disciplines in a single evaluation approach - Integrated models of global climate change - Global policies, cooperation, and conflict in the use of resources			
4	**Instruction Forms** a) Lecture b) Seminar			
5	**Examination Forms** Final module examination: Written examination (60 Min), graded term paper and presentation (Seminar)			
6	**Applicability of the Module** Compulsory for ES III and an optional Module for ES II (A and B)			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade:** 5/120			

9	**Module Representative and Full-Time Instructors** Prof. Dr. G. Müller-Fürstenberger
10	**Further Information** Literature: STEPHAN G. & M. AHLHEIM (1996). Ökonomische Ökologie. Springer, Berlin u.a. TIETENBERG, T. (2006). Environmental and Natural Resource Economics, 7th ed.. Pearson Addison Wesley, Boston et al. KAHN, R. (2005). The Economic Approach to Environmental & Natural Resources, 3rd ed. Thomson South-Western, Mason

Module "Soil use and Sustainable Management"

Course Code: MA6ES027	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Soil Use in Agriculture (Lecture) b) Forest Site Assessment (Seminar) c) Waste Management (Seminar)	**Contact Hours** 2 SWS/30h 1 SWS/15h 1 SWS/15h	**Private Study** 50 h 20 h 20 h	**Group Size** no limitation 15 15
2	**Qualification objectives** a) Introduction in Agronomy and Crop Science and the interaction with soil b) Assessment of forest sites and sustainable use of forests c) Introduction in waste management and application of bio-wastes in agriculture, visitations, presentation, and discussion			
3	**Content** A. *Lecture: Agricultural Land-use* Introduction & History of Agriculture Recent Situation and Trends (Germany & Europe) Agricultural Systems (incl. Crop Rotation) Agricultural Management towards Sustainability Soil Tillage Application of Organic Wastes in Agriculture Growth and Yield Factors Plant Nutrition & Fertilization Agricultural Crops (Grain) Agricultural Crops (Remaining) Renewable Resources & Energy Crops Plant Protection, Plant Breeding & GMOs B. *Seminar: Forest Site Assessment* 1. Demands of forest trees 2. Forest management 3. Forest Monitoring 4. Visitation of a forest measurement station C. *Seminar:* *Waste Management* Visitation of a Sewage Sludge Plant Visitation of a Compost Plant Visitation of a Biogas Plant Presentations concerning the application of bio-wastes in agriculture			
4	**Instruction Forms:** a) Lecture b)Seminar c)Seminar with field trips			
5	**Examination Form** Advanced examination effort: accepted homework and oral presentation (15 minutes) Final module examination**:** Written examination (90 minutes)			
6	**Applicability of the Module** Compulsory for ES III and an optional Module for ES II (A and B) and ES I			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade:** 5/120			
9	**Module Representative and Full-Time Instructor:** apl. Prof. Dr. C. Emmerling; apl. Prof. Dr. G. Schüler			
10	**Further Information** LECTURE NOTES: Land-use in Agriculture LAEGREID ET AL.: Agriculture, Fertilzers and the Environment. CABI			

Module "Research Project"

Course Code: MA6ES003	**Frequency of Course Offer:** Every Semester
Credits: 10 CP	**Workload:** 300 h
Study Semester: 3rd (Summer & Winter)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Advanced Aspects in Environmental Sciences	1 SWH/15 h	75 h	20
	b) Research methods in Environmental Sciences	3 SWH/45 h	165 h	20
2	**Qualification Objectives** • The students will be expected to conduct small research projects (first of all literature research) under guidance and practice to work self-dependent in project teams, • Students should become familiar with recent topics in environmental research, current methodology, experimental design, and data analysis, • Students should improve their competence in literature research, scientific documentation, and the presentation of scientific results.			
3	**Contents** • The project topics are mainly related to the current environmental research of the participating departments, • The research topics may contain a field and/or laboratory component or include modeling aspects.			
4	**Instruction Forms** a) Seminar b) Practical exercise			
5	**Examination forms** Advanced examination effort: oral presentation (30 min). Final module examination: graded term paper and presentation (30 min).			
6	**Condition for the Award of Credit Points** Passed final examination: term paper and oral presentation			
7	**Value of Mark in the Final Grade:** 10/120			
8	**Module Representative and Full-Time Instructors** Module representative Prof. Dr. S. Thiele-Bruhn and all lecturers of MSc Environmental Sciences. Lecturers of related disciplines may be accepted on request.			

Module "Master Thesis"

Course Code: MA6ES004	**Frequency of Course Offer:** Every Semester
Credits: 30 CP	**Workload:** 900 h
Study Semester: 4th (Summer & Winter)	**Duration:** 1 Semester

1	**Courses** a) Master Thesis b) Master Colloquium	**Contact Hours** 4 SWH/60 h 2 SWH/10 h	**Private Study** 810 h	**Group Size**
2	**Qualification objectives** Aptitude for independent handling of a scientific question of basic research or applied research of specialization in the environmental Geo-scientific subjects; Mastery of appropriate methods of determination, processing, assessment, and visualization of relevant data; competence for interpretation and critical discussion of developing results taking into account the current status of science and requirements to put scientific knowledge into practice; ability to present scientific work and significant results.			
3	**Content** Independent work on a scientific question under supervision; review of scientific background and state of the art; identification and use of a versatile set of methods (under technical guidance) for testing research hypotheses; assessment, interpretation and critical discussion of results in the context of existing, published knowledge; presentation of significant results.			
4	**Instruction Forms** Formulation of independent scientific work based on studies in the area, experimental fieldwork, laboratory or guided project work; presentation of the results in a colloquium.			
5	**Examination Forms** Graded written scientific study (4/5 of the module mark) Graded oral presentation (presentation of the study in a seminar or colloquium, 20 min. presentation, 10 min. discussion) (1/5 of module mark)			
6	**Condition for the Award of Credit Points** Passed master thesis and presentation			
7	**Value of Mark in the Final Grade:** 30/120			
8	**Module Representative and Full-Time Instructors** Supervisor of the Master study; Lecturers in the environmental sciences subjects.			

Optional Modules

Module "Soil Biology and Soil Functioning"

Course Code: MA6ES028	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Biology & Ecology of Soil Organisms (Lecture) b) Applied Soil Biology	**Contact Hours** 2 SWH/30 h 2 SWH/30 h	**Private Study** 45 h 45 h	**Group Size** No limitation 15
2	**Qualification objectives** • In-depth understanding of soil biological functions and interactions • Application of system-oriented mindsets and methods • Planning and organization of laboratory operational procedures • Handling of scientific literature and scientific English			
3	**Content** • Soil as a habitat for soil organisms • Diversity of life in the soil • Organism interactions and soil processes • Microbial activity and nutrient availability • Linkages between soil biological communities and plants • Trophic interactions and soil biological communities • Methods for sampling, enumeration, and investigation of soil biological communities • Methods for applied soil microbiology, and biochemistry • Soil organisms related to land use, tillage, crop rotation and soil properties • Soil organisms as bio-indicators • Soil organisms and Applied Biotechnology			
4	**Instruction Forms:** a) Lecture b) Field and laboratory course			
5	**Applicability of the Module** Optional module for ES I and ES III			
6	**Examination Form** Graded Term Paper			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative and Full-Time Instructor** apl. Prof. Dr. C. Emmerling			
10	**Further Information** BARDGETT ET AL.: Biological Diversity and Functions in Soil. Cambridge Univ. Press. RITZ ET AL.: Beyond the Biomass. John Wiley & Sons. BENCKISER ET AL.: Fauna in Soil Ecosystems. Marcell Dekker. BENCKISER & SCHNELL: Biodiversity in Agricultural Production Systems. Taylor & Francis			

Module "Interdisciplinary Excursion or Field Project"

Course Code: MA6ES029	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Seminar b) 10-day Field Trip	2 SWH/30 h 5,3 SWH/80 h	40	24 24
2	**Qualification objectives** **Key qualifications:** • In-depth understanding of interdisciplinary contexts and interactions • A self-dependent, problem-oriented and targeted, scientifically based inquest, assessment and aggregation of (English) scientific or technical information, in part done in groups • Presentation of results as written text and oral presentation **Expertise:** • Understand the characteristic physical-geographic and socio-economic factors as well as their relevance for the geo-ecology (climate, geomorphology, geology, soil science, vegetation, land use, landscape history, anthropogenic activities etc.) • Analyze the pollution, impacts and degradation of a geographic region and gather the possibilities and limits of a usage management and protection measures, respectively • Examples for the (successful) implementation of procedural methods for a sustainable usage of nature services and for the guidance of diverse interests of usage • Analyze the potentials for development and endangerment, respectively, of a landscape unit • Elaborate an excursion/field project protocol • Improve the abilities to write up a report on a considerable topic in a precise, concise and structured manner • Improve the oral presentation technique and also the ability to discuss scientific aspects			
3	**Content** • An in-depth presentation of a region out of the German low mountain range in the frame of an excursion or in-depth scientific work on an environmental problem in the frame of a field project with special regard to the boundary conditions for the utilization and/or valorization of a region • Self-dependent elaboration of a seminar paper on specific aspects of the excursion area or field project			
4	**Instruction Forms** a) Seminar b) Excursion or field trip (field project with measurements/investigations)			
5	**Applicability of the Module** Optional module for (ES I), (ES II), and (ES III)			
6	**Examination Forms** Advanced examination effort: seminar presentation Final module examination: graded term paper (excursion protocol and/or project protocol)			
7	**Condition for the award of credit points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module representative and full-time instructors** Module representative: ap. Prof. Dr. W. Werner and Lecturers of the faculty Geography and Geosciences (FB VI)			

Module "Physical monitoring of lithosphere and hydrosphere"

Course Code: MA6ES030	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact hours**	**Private Study**	**Group Size**
	a) Lectures on basics and introduction	1 SWS/15 h	15 h	120
	b) Practical course on geophysical systems, data processing and presentation	2 SWS/30 h	30 h	24
	c) Tutorial-based seminar on selected topics	2 SWS/30 h	30 h	24

2 Qualification objectives

Soft skills:

- Planning, elaboration, and discussion of a geophysical monitoring program and its interdisciplinary aspects in a research team
- Competency for critical comments and discussions in the context of complex and controversy discussed scientific topics
- The ability of elaboration and discussion of complex scientific processes in working groups, which are alternated guided by the participants

Expertise:

- Knowledge of physical properties of soils, sediments, rocks, waste deposits, and water columns in oceans and lakes. Furthermore, the reasons for changes in these physical properties should become clear.
- Overview of methods which can be used to monitor the geophysical properties of the underground: e.g. ground penetration radar (GPR), multi-beam, parametric echo sounding, gravity, geoelectrical and magnetic measurements, conductivity-temperature-depth (CTD) analyzers
- Knowledge and applications of distinct monitoring systems: e.g. thermohaline structure of oceans as a key factor for ocean circulations, sediment structures and their implications for drilling or building projects, changes in the groundwater level, archeological investigations, structure and water distribution in waste deposits.
- Capacity to interpret GPR, echo and seismic diffractograms and CTD profiles
- Georeferenciation, 3D and ArcGIS-based visualization of geophysical properties
- Calibration and comparison of geophysical data with related sampling or core drilling
- Competency concerning a critical review on the progress in new techniques concerning geophysical monitoring of lithosphere and hydrosphere
- Evaluation of selected methods and their implications based on data calculation, interpolation, calibration as well as ArcGIS- based volume and mass calculations

3 Content

a) Lectures:

Introduction concerning geophysical properties of soft rocks, sediments, waste deposits as well as lacustrine and marine water columns. Presentation of selected methods to visualize the geophysical properties including eoelectric, geomagnetic, geoacoustics, gravimetrical methods and Ground Penetrating Radar.

b) Practical training with selected methods and techniques:

georeferenciacion, graphic presentation, calibration, evaluation and interpretation of geophysical records, including especially parametric echo sounding, ground-penetrating radar, CTD measurements of water columns and magnetic susceptibility of sediment records.

c) Seminar:

Critical evaluation and presentation (in small working groups) of selected newly published methods and the general progress in these methods

4	**Instruction Forms** a) Lecture b) Practical course c) Seminar with presentations
5	**Applicability of the Module** Optional module for ES I and ES III
6	**Examination Form** Advanced examination effort: oral seminar presentation, accepted reports Final module examination: Written examination (90 minutes)
7	**Conditions for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
8	**Value of Mark in the Final Grade**: 5/120
9	**Module representative and full time instructors** Dr. Oscar Baeza Urrea
10	**Further Information** Butler, D.K. (e.d.) (2005): Near-surface geophysics. 732 p., Society of Exploration Geophysic. Fowler, C.M.R. (2004): The Solid Earth: An Introduction to Global Geophysics. 704 p., Cambride University Press. ISBN-10: 0521893070 Idziak, A.F. and Dubiel, R. (2011): Geophysics in Mining and Environmental Protection. 150 p., Springer, ISBN: 3642190960. Jones, E.J.W. (1999): Marine Geophysics. 474 p., Wiley, ISBN-10: 0471986941. Kaufman, A. and Hansen, R.O. (2007): Principles of the Gravitational Method, Volume 41 (Methods in Geochemistry and Geophysics). 258 p., Elsevier. Lowrie, W. (2009): Fundamentals of Geophysics. 381 p., (2nd ed.) Cambridge University Press. ISBN-10: 0521675960. Spichak, V. (2006): Electromagnetic Sounding of the Earth's Interior, Volume 40 (Methods in Geochemistry and Geophysics). 404 p., Elsevier. Waltham T. et al. (2005): Sinkholes and Subsidence (Springer Praxis Books / Geophysical Sciences). 413 p., Springer.

Module "Vegetation Ecology"

Course Code: MA6ES031	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Research concept and data analysis b) Field and Laboratory Course	1 SWH/15h 3 SWH/45h	50 h 40 h	24 24
2	**Qualification Objectives** Students become acquainted with synecological research Identification and interpretation between the presence of species or the development of plant associations and specificity of ecological factors like water and nutrient supply microclimate conditions and radiation (Ecological Indicator Concept (ELLENBERG) physiological potency and ecological existence). Knowledge of plant species, classification of ecological factors in the field (humus form, soil profile, water, and nutrient supply, microclimatic conditions of vegetation) Aspects of plant population ecology (Dissemination, germination, safe site concept (nurse plants), inter- and intraspecific competition) Knowledge and interpretation of indicators to classify matter and energy budget of ecosystems (Ellenberg's indicator values, Grime's C-S-R-strategies) Knowledge of research and data analysis concepts to investigate correlations between the presence of species and abiotic and biotic ecological factors as well as a critical evaluation of these results (multivariate statistical methods).			
3	**Contents** Identification and classification of plant associations and their site factors in the field with aid of index and differential species and with aid of indicator values as well as with characteristic values of water and nutrient budget of the soil: Application of methods for documentation of species composition (Vegetation releve) and soil and description of the soil profile, soil classification (with aid of 'Bodenkundliche Kartieranleitung' inclusive humus forms and field capacity) as well as measurement and documentation of different site gradients. • Light gradients on forest edges, water gradients on soils with different hydromorphic characteristics, nitrogen supply gradients in extensive and intensive managed grass- and farmland • Effects on species composition of different intensive land use concerning C-S-R-Strategies of plants (for example extensive and intensive managed grass- and farmland, attributes of eutrophication of plant communities by N- Deposition and/or liming • Correlations between soil acidification and presence/absence of plant species or the development of plant associations and soil types, humus forms and buffer ranges of soils. • Measurement of pH, cation exchange capacity, C/N-ratio, phosphor concentrations, nitrogen mineralization, nutrient concentrations and nutrient ratios in plant organs • Biological Interactions between organisms (competition, predation, commensalism, symbiosis) and experimental approaches for their investigation • Statistical data analysis: logistic correlations between presence of species and differentiation of site factors, similarity, and correspondence between site factors and species composition (correspondence analysis, ordinations, cluster- and discriminant analysis).			
4	**Instruction Forms** a) Seminar, b) Field and laboratory course			
5	**Applicability of the Module** Optional module for ES I, ES II, and ES III			
6	**Examination Forms** Final module examination: Graded term paper			

7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
8	**Value of Mark in the Final Grade**: 5/120
9	**Module Representative and Full-Time Instructors** NN. Geobotanic Department
10	**Further Information** ELLENBERG H, LEUSCHNER C. 2010: Vegetation Mitteleuropas mit den Alpen in ökologischer, dynamischer und historischer Sicht. Ulmer Verlag, 6. Auflage ELLENBERG H., WEBER H.E., DÜLL R., WIRTH V. & W. WERNER 2001: Zeigerwerte von Pflanzen in Mitteleuropa Goltze Verlag, Göttingen 3. Aufl. GRIME J.P. 2001: Plant Strategies, Vegetation Processes, and Ecosystem Properties. (2nd edition) Wiley DIERSCHKE H. 1994: Pflanzensoziologie Ulmer Verlag. AG BODENKUNDE 2005: Bodenkundliche Kartieranleitung 5. Hannover. SCHEFFER/SCHACHTSCHABEL 2010: Lehrbuch der Bodenkunde, Enke Verlag.

Module "Sustainable Chemistry"

Course Code: MA6ES032	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Lecture: Principles of Sustainable Chemistry	2 SWH/30 h	45 h	125
	b) Practical: Chemical Exploitation of Renewable Resources	1 SWH/15 h	15 h	30
	c) Laboratory Exercises	2 SWH/30 h	15 h	12
2	**Qualification Objectives** The students should: • be able to understand the fundamentals, historical roots and ethical objective of the sustainability concept • be able to review and apply environmental sustainability and measuring categories • be in a position to apply sustainability criteria to material and energy cycles, to products and processes • arrive at an idea of the possible contribution of chemistry to the achievement of sustainable development, • to know the chemical exploitation potential of renewable raw materials and biomass residual materials.			
3	**Content** •Basic principles of sustainability, historical background, ethical concept, central values •Milestones of sustainable development, sustainability and measuring categories, minimizing and optimizing requirements •Energy and material use from the sustainability point of view •Evaluation procedures for chemical products and processes, life cycle analysis •A new design of chemical syntheses: a claim of the "Green Chemistry" •12 point program of the "Green Chemistry" •Renewable raw materials and biomass residual materials as alternative starting materials for chemical processes and syntheses •Concept of the "Green bio-refinery" •Systematic of the utilizable biological materials and their sources •Transformation of the biological raw materials to industrial chemicals and end products •Application possibilities in environmental protection technology •Chemical analytical methods for determining value substance concentrations •Basic laboratory tests to extract chemical raw materials from biomass			
4	**Instruction Forms** a) Lecture, b) practical course, c) laboratory exercise or research internship (block event or one day/specific day distributed throughout the semester).			
5	**Applicability of the Module** Optional Module for ES I and ES III			
6	**Examination Forms** Final module examination: graded term paper			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			

8	**Value of Mark in the Final Grade**: 5/120
9	**Module Representative and Full-Time Instructor** Module representative: Prof. Dr. Dr. K. Fischer, other lecturer: Dr. A. Meyer.
10	**Further Information**: Course books: Anastas, P.T., Warner, J.C. (1998): Green Chemistry – Theory and Practice. Oxford (University Press). Anastas, P.T., Heine, L.G., Williamson, T.C. [Eds.] (2000): Green Chemical Syntheses and Processes. ACS Symp. Ser. 767. Washington, D.C. (ACS).

Module "Paleoclimate and Paleoenvironment"

Course Code: MA6ES035	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**courses**	**Contact Hours**	**Private Study**	**Group Size**
	a) Lectures on geological time scales, age determinations, climate archives	1 SWH/15 h	15 h	120
	b) Practical course on climate archives, data processing and presentation	2 SWH/30h	30 h	24
	c) Seminar	2 SWH/30 h	30 h	24

2 Qualification objectives

Soft skills:

- Learning of planning, elaboration and discussion of a scientific work program in a research team
- Competency for critical comments and discussions in the context of complex and discussed scientific topics
- Ability of elaboration and discussion of complex scientific processes in working groups, which are alternated guided by the participants

Expertise:

- Knowledge of changes in the global geochemical cycles (e.eg. carbon, sulfur, phosphate, nitrogen silica) including calculation of mass transport and accumulation
- Understanding the complex interaction of geochemical cycles at different regional and geological time scales
- Knowledge of geological time scale and age determination methods
- Competency for critical discussion of major paleoclimate controlling factors
- Overview and critical view of paleoclimate and paleo environmental archives as well as selected environmental and climate proxies
- Knowledge on access of international paleoclimate data bases, data comparison and data presentation forms
- Critical evaluation of the importance of newly published (International Journals) high-resolution paleoclimate reconstructions worldwide and their interhemispheric linkages.

3 Content

a) Lectures:

Geological time scale and age determination methods (e.g. K/Ar, Th/U, ^{14}C, ^{10}Be, paleo magnetism, fission track, luminescence methods)
Global and regional geochemical cycles (C, N, P, S, Si) with reservoirs, residence and transfer times as well as enrichment and depletion processes
Major controlling factors on paleoclimate
Paleoclimate and paleo-environmental archives (e.g. tree rings, ice cores, stalagmites, peat and soils, lacustrine and marine sediments), and selected environmental and climate proxies (geochemical and isotopic, mineralogical and paleontological proxies)

b) Practical training with selected climate archives and proxies:

Tree rings: Computer-aided analysis to create tree ring chronologies
Stalagmites: annual laminations in thin sections; Processing, evaluation, time series analyses and interpretation of geochemical (Mg, Ca, U, Sr, Fe, Mn, Y) and isotopic data (O-, C- and Sr- isotopes)
Lake sediments: Investigation of warved lake sediments in thin sections (optical micro-scope; warve structures and counting) and electron scatter microscope (minerogenic and biogenic warve components).

	Marine sediments: core logging and sampling; geochemical, mineralogical, micro-structural and paleontological investigations Tutorial-based and computer-aided elaboration, comparison with paleoclimate data base (http://wdc.cricyt.edu.ar/paleo/recons.html) and presentation of results in small working groups c) Seminar: Critical evaluation and presentation (in small working groups) of selected newly published high resolution paleoclimate reconstructions and interhemispheric linkages New aspects of global geochemical cycles (methan, gas hydrates, ecological impacts)
4	**Instruction Forms** a) Lecture b) Practical course c) Seminar with presentations
5	**Applicability of the Module** Optional Module for ES I and ES II (A and B)
6	**Examination Form** Advanced examination effort: oral seminar presentation, accepted reports Final module examination: Written examination (90 minutes)
7	**Conditions for the award of credit points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
8	**Value of Mark in the Final Grade**: 5/120
9	**Module representative and full time instructors** Björn Klaes
10	**Further Information** Alverson, K.D., Bradley, R.S., Pederson, T.F. (2003): Paleoclimate, global change and the future. 235 p., Springer Cronin, T.M. (2009): Paleoclimates: Understanding Climate Change Past and Present. 448 p.; Bradley, R.S. (1999): Paleoclimatology: reconstructing climates of the Quaternary. 614 p., Elsevier, Fischer, G. and Wefer, G. (1999): Use of proxies in paleoceanography. 727 p.,

Module "Global Climate Change and Energy Resources"

Course Code: MA6ES036	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture/Seminar b) Seminar	**Contact Hours** 2 SWH/30 h 2 SWH/30 h	**Private Study** 60 h 60 h	**Group Size** No limitation No limitation
2	**Qualification objectives** • Examine and analyze the sociopolitical, economic and environmental dimensions of energy production and consequences of energy use • Identify and scrutinize the role of the actors, institutions, structures and regulations that govern energy systems at multiple spatial scales. • Develop a critical understanding of how choices about energy development reflect power imbalances and generate social, environmental, political and economic consequences that are unevenly distributed across time, space and social groups • Identify, examine and discuss critical perspectives on energy transitions and the emergence of resistance movements to dominant energy/environmental policies and discourses			
3	**Content** - Global Climate Change and energy production - Changing societal metabolism of energy - Modernity and Energy - Energy Infrastructures - The politics of energy – Geopolitics - The political economy of fossil fuels and renewables - Uneven Energy Geographies (uneven energy consumption and unequal CO_2 emissions; Carbon colonialism) - Energy and Development: Energy in/security, extractivism and Post-extractivism, Environmental and climate justice - Energy Governance: Global climate politics, Geographies of energy transitions, low carbon initiatives, Resistance movements and the call for alternative energy futures a) Lecture/Seminar: Energy Geographies and the Governance of Energy b) Seminar: regional and thematic case studies			
4	**Instruction Forms** Lecture/Seminar, including oral presentations by students and field trip			
5	**Applicability of the Module** Optional Module for ES I, ES II, and ES III			
6	**Examination Forms** Term Paper (~7-8 pages, 2500-3000 words without attachments)			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade:** 5/120			
9	**Module Representative and Full-Time Instructors** Prof. Dr. A. Bruns			

Module "Environmental Monitoring Strategies"

Course Code: MA6ES005	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Monitoring in ecological research b) Advanced environ-mental monitoring	**Contact Hours** 2 SWH/30 h 2 SWH/30 h	**Private Study** 30 h 60 h	**Group Size** 15 15
2	**Qualification Objectives** The overall aims of the module are: • to provide a grounding in ecological research techniques both in the field and laboratory • to explain and evaluate the terminology, theoretical principles and practical limitations of air, water and soil pollution monitoring and control systems • to explain monitoring/control techniques and strategies for air, water and soil pollutants • to assess the roles of local, national and international agencies with respect to the management of air, water and soil quality. • to provide transferable skills in team work and individual skills in data collection and data analysis			
3	**Content** • Long-term monitoring in ecosystems • Air pollution monitoring • Contaminant-control process monitoring • Biosensors, bioanalytical and biomonitoring systems • Tools and strategies for river ecology evaluation Integrated approaches: environmental parameters that are relevant for the structure and functioning of the ecosystem			
4	**Instruction Forms** a) Lectures and seminars in conjunction with oral presentation b) Seminar			
5	**Examination Forms** Advanced examination effort: term paper Final module examination: oral examination (20 minutes)			
6	**Applicability of the Module** Optional Module for ES I, ES II, and ES III			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative and Full-Time Instructors** Module representative Dr. R. Bierl, and Prof. Dr. W. Werner			

Module "Socio Hydrology"

Course Code: MA6ES041	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture/Seminar b) Seminar	**Contact hours** 2 SWH/30 h 2 SWH/30 h	**Private Study** 30h 60h	**Group Size** No limitation No limitation
2	**Learning Outcomes/Qualification Objectives** The students are expected to: - develop an understanding of the complex relations between society and nature (water) - theorize socio-nature, understand the production of socio-nature - understand the political ecology of environmental change - have knowledge on analytical frameworks to study socio-nature dynamics: for example the concept of societal metabolism and the hydro-social cycle - understand that resources are contested - engage with water governance in order to critically question whose decision-making shape socio-natures and who gains and who loses - understand how science and policy interconnect The theoretical and conceptual basis for this module is rooted in political ecology. <u>The Module is divided into two parts:</u> 1 – Theorizing societal relations to nature with a focus on water 2 – Case Studies: Hydro-social systems			
3	**Content** <u>Political Ecology - Hydro-Social Research</u> - Human relations with Nature - Modernity and Capitalism - Development and Growth – exploitative World - Limits, boundaries and inequality - International Responses and Local Resistance - Methods and Approaches in Political Ecology (Theorizing Key Concepts such as Power and Scale; Cities and Nature; North and South) - Environmental Justice - Dealing with Knowledge - Politics of Environmental Science - Progressive Changes – how and where to begin? <u>Case Studies on Hydro-Social Systems</u> Deepening of lecture content with selected literature and development of skills for analyzing hydro-social systems. Topics include: water infrastructures as hybrids between nature and culture, land and water grabbing, the water-energy nexus and other topical issues around recent water debates - Understanding Water: The paradigm of modern water - Hydrology or hydro-social studies or social hydrology? Studying Water - Water Infrastructures – technical systems as mediator between society and nature - Ethical, religious and cultural meaning of water - Water Conflicts; Commodification and Privatization of Water; Water Grabbing - Water regulation and Governance - (Transboundary/Integrated) Water (Resources) Management			

	Global Water Governance and the Water SDGs
4	**Instruction Forms** Lecture/Seminar, including oral presentations by students.
5	**Applicability of the Module** Optional Module for ES I, ES II, and ES III
6	**Examination Form** Oral examination or Term Paper (10 pages, ~5.000 words without attachments).
7	**Conditions for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam
8	**Value of Mark in the Final Grade:** 5/120
9	**Module Representative and Full-Time Instructors** Prof. Dr. Antje Bruns, Team members of Governance and Sustainability Lab

Module "Numerical Methods for Geoscientists"

Course Code: MA6ES037	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 2nd (Summer Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture b) Course	**Contact hours** 2 SWS/30 h 1 SWS/15 h	**Private Study** 150	**Group Size** Unlimited 20
2	**Qualification Objectives** • Learning the basic concepts of numerical analysis • Understanding and applying numerical methods			
3	**Content** a/b) − Brief introduction to linear algebra and matrix operations − Eigenvalues: theory and algorithms − Direct methods for solving linear systems − Iterative methods for solving linear systems − Least squares solutions of linear systems (interpolation and curve fitting) − Singular Value Decomposition (SVD): theory and applications (e.g., truncated SVD and the principle component analysis (PCA)) − Elements of nonlinear numerical analysis (e.g., solving nonlinear systems with Newton's method)			
4	**Instruction Forms** a) Lecture b) Course			
5	**Applicability of the Module** Optional Module for ES II (A and B)			
6	**Examination Form** Final module examination: Written examination (120 min)			
7	**Conditions for the Award of Credit Points** Prerequisites for admission to the written examination will be announced during lecture. Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Module Representative and Full-Time instructors** Dr. Christian Vollmann; Mathematik, FB IV			

Module "Geostatistics"

Course Code: MA6ES033	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Lecture "Geostatistics" b) Exercise "Geostatistics"	**Contact hours** 2 SWH/30 h 2 SWH/30 h	**Private Study** 45 h 45 h	**Group Size** 200 15
2	**Qualification objectives** • Introduction in spatial point patterns and geo statistical methods, concepts and techniques • Practical exercises in the analysis of spatial patterns using the R and GIS software environments • Competences in the critical assessment of different geo statistical methods and approaches			
3	**Instruction Forms:** Introduction - Statistical and geostatistical concepts - Introduction in the R system and relevant geo statistical libraries Spatial point patterns - Analysis of spatial point patterns: independence/randomness and interaction, Poisson processes - Statistical tests for the assessment of spatial point patterns - Concepts for statistical modelling and simulation of spatial point patterns - Monte-Carlo simulations Geo statistical interpolation - Variogram analysis - Spatial trend analysis - Regionalization: Kriging and its variants; cokriging - Model validation - Geostatistical examples			
4	**Instruction Forms** a) Lecture b) Exercise: Computer Lab			
5	**Applicability of the Module** Optional Module for ES I, ES II, and ES III			
6	**Examination Form** Portfolio			
7	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
8	**Value of Mark in the Final Grade**: 5/120			
9	**Applicability of the Module** Optional module for all foci MSc. Environmental Science (recommended for focus ES 2 Environmental Remote Sensing and Modelling)			
10	**Module Representative and Full-Time Instructor** Prof. Dr. T. Udelhoven			

11	**Further Information** Recommended preparatory courses for this module are: - Introduction to Geoinformatics - Multivariate Statistics Literature: Bivand, R.S., Pebesma, E.J., Gomez-Rubio, V. and Pebesma, E.J., 2008. Applied spatial data analysis with R (Vol. 747248717). Springer, New York. Baddeley, A., Bárány, I. and Schneider, R., 2007. Spatial Point Processes and their Applications. In: Weil W. (eds) Stochastic Geometry. Lecture Notes in Mathematics, vol 1892. Springer, Berlin, Heidelberg

Optional Module in German

Module "Population Ecology (Populationsökologie)"

Course Code: MA6ES038	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** a) Populationsökologie (Lecture) Populationsökologie (Practical course)	**Contact hours** 2 SWS/30 h 0.5 SWS/7.5 h	**Private Study** 60 h 52.5 h	**Group Size** No limitation 24
2	**Qualification Objectives** a/b) • Vertiefte theoretische und praktische Kenntnisse in der Populationsökologie, sowie Kenntnisse ihrer Anwendung in Ökologie, Phylogenie, Biogeographie und Naturschutz • Verständnis der Dynamik natürlicher Systeme durch Prozessmodellierung; Verständnis der mathematischen Formalisierung von Populationsprozessen.			
3	Instruction Forms: a/b) • Populationsökologie und Konkurrenz (geschlossene und offene Populationen, Populationswachstum, Dichteregulation, Prädation und Populationsdynamik,, Räuber-Beute-Beziehungen, Parasitismus, Mutualismus, Symbiose, Populationsschwankungen, intra- und interspezifische Konkurrenz, r/K-Strategien, Dispersion und Migration, Tierwanderungen,) • Metapopulationstheorie, • Lifetables, Lebenszyklusstrategien. • Modellierung von Populationsprozessen mittels Simulationssoftware.			
4	**Instruction Forms** a) Vorlesung b) Übung			
5	**Examination Form** Klausur (60 min)			
6	**Language** Offered only in German			
7	**Applicability of the Module** Optional Module for ES II (A and B)			
8	**Condition for the Award of Credit Points** Regelmäßige Teilnahme, Bestehen der Studienleistungen, Bestehen der Prüfungsleistung			
10	**Value of Mark in the Final Grade**: 5/120			
11	**Module Representative and Full-Time Instructor** Prof. Dr. T. Schmitt (Modulbeauftragter); Prof. Dr. M. Veith			
12	**Further Information** Townsend, C. R. Begon, M. & Harper, J. L. Ökologie. 2nd ed. (Springer, Berlin, Heidelberg, 2009).ISBN-3540958967 Hastings, A. Population biology. Concepts and models (Springer, New York, 1997). ISBN-0-387-94853-8			

Module "European Environmental Law"

Course Code: MA6ES042	**Frequency of Course Offer:** Every Semester
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses** Lecture	**Contact Hours** 4 SWS/60 h	**Private Study** 90 h	**Group Size** No limitation
2	**Qualification Objectives** • Advanced expertise in environmental law with specific focus on European Environmental Law			
3	**Content** **Lecture "European Environmental Law"** a. The legal system in the European Union b. The legal system of environmental law in the European Union c. Comparison of European and German legal systems d. European Law of emission control e. European Waste Legislation f. European Nature Protection Law g. European Laws pertaining to Water and Waterways h. European Soil protection Charta			
4	**Instruction Forms:** Lecture Tutorial			
5	**Language** Offered only in German			
6	**Applicability of the Module** Optional Module for ES III			
7	**Examination Form** Final module examination: Written examination (120 minutes)			
8	**Condition for the Award of Credit Points** Regular attendance at courses, successful completion of non-graded assessment-tasks, passing of module exam			
9	**Value of Mark in the Final Grade**: 5/120			
10	**Module Representative and Full-Time Instructor** Module Representative: N.N. (Dekanat) Instructor Dr. Spitzlei (Lehrbeauftragter)			

Module "Bodenerosion unter Globalem Wandel"

Course Code: MA6ES040	**Frequency of Course Offer:** Annual
Credits: 5 CP	**Workload:** 150 h
Study Semester: 3rd (Winter Semester)	**Duration:** 1 Semester

1	**Courses**	**Contact Hours**	**Private study**	**Group Size**
	a) VL: Bodenerosion unter Globalem Wandel b) HS: Forschungsbezogene Fragestellungen zur aktuellen Geomorphodynamik in subhumiden bis semiariden Gebieten	2 SWS/30 h 2 SWS/30 h	30 h 60 h	30 Maximum 15

2 Qualification Objectives

- Vertieftes Verständnis für fächer- und themenübergreifende Zusammenhänge u. Wechselwirkungen
- Selbstständiges, problemorientiertes und zielgerichtetes, wissenschaftlich fundiertes, methodenkritisches Arbeiten
- Mündliche und schriftliche Präsentation eines anspruchsvollen wissenschaftlichen Themas Fachkompetenzen:
- Bodenerosion als weltweites Problem kennen lernen
- Verschiedene theoretische Konzepte zum Suspensionsfrachtverlust auf Globaler Ebene kennen lernen und die Probleme auf dieser Maßstabsebene erkennen.
- Prozessen, Einflussfaktoren und Ursachen der Bodenerosion kennen lernen
- räumliche Verbreitungsmuster der Bodenerosion auf größeren Maßstabsebenen (regional bis lokal) erkennen können • Schwierigkeiten bei der Bewertung des Schweregrades von Bodenerosion auf unterschiedlichen Maßstabsebenen erkennen und Lösungsmöglichkeiten diskutieren
- Szenarios der Bodenerosionsentwicklung unter sich verändernden Umweltbedingungen (Klima-, Landnutzungswandel) entwickeln und bewerten lernen
- Verfahren der Erosionsvermeidung kennen und bewerten lernen
- Mündliche und schriftliche Präsentation eines anspruchsvollen wissenschaftlichen Themas

3 Content

a) Als Einführungsveranstaltung in den Studiengang kommt dem Modul Bodenerosion unter Globalem Wandel eine zentrale Stellung innerhalb des Studienganges zu. Sowohl prozessuale und kausale Interdependenzen als auch die gesellschaftliche Relevanz dieses weltweiten Problemfeldes in seiner spezifischen räumlichen Differenzierung werden im Rahmen einer Vorlesung vorgestellt bzw. erarbeitet. Zu den Inhalten gehören folgende Einheiten:

• Bodenerosion im weltweiten Vergleich, Globaler Wandel (Klima- und Landnutzungswandel), Definitionen von Bodenerosion, Prozesse und Formen der Bodenerosion, Bodenerosion als historisches Phänomen

• Faktoren der Bodenerosion wie Erosivität des Niederschlages, Erodibilität des Bodens etc..

• Erfassungsmethoden wie qualitative, semiquantitative und quantitative Verfahren sowie experimentelle Messverfahren.

• Methodische Probleme einzelner Erfassungsmethoden.

• Bodenerosionsmodelle wie empirische Modelle ("Blackbox"-Modelle), prozessorientierte, physikalisch basierte Modelle, z. B. EUROSEM (European Soil Erosion Modell), CREAMS (Chemicals, Runoff and Erosion from Agriculture Management System), WEPP (Water Erosion Prediction Project), Produktivitäts-Modelle (EPIC, Erosion Productivity Impact Calculator), Erosion 2D und Erosion 3D

• Kombination aus Testflächenkartierungen und Fernerkundungsdaten, Rasterklassifikation und V/G-Komplex, Erosionsprognosemodelle.

• Bodenschutzmaßnahmen, wie z.B. Konzept vom 'Tolerierbaren Bodenabtrag.

• Erosionskontrolle (Technische Maßnahmen, sozio-ökonomische und politische Rahmenbedingungen, neue Konzepte für die Bodenerosionsforschung)

b) Im Hauptseminar: Vertiefung ausgewählter Themen aus a) unter besonderer Berücksichtigung aktueller Ergebnisse aus laufenden Forschungsprojekten in semihumiden bis semiariden Gebieten.

4	**Instruction Forms** a) Vorlesung; b) Hauptseminar (15): mit Vortrag und schriftlicher Ausarbeitun
5	**Language** Offered only in German
6	**Examination Form** Schriftliche Hausarbeit
7	**Condition for the Award of Credit Points** Regular participation, lecture and at least sufficiently graded written homework
8	**Applicability of the Module** Optional Module for ES III
9	**Value of Mark in the Final Grade:** 5/120
10	**Module Representative and Full-Time Instructor** Prof. J.B. Ries und wiss. Mitarbeiter
11	**Further Information** The Module will be teached in German language Das Modul wird in deutscher Sprache gehalten Grundlagenliteratur: Richter 1998, Lal 2000, Ries 2000, Morgan 2002, Hudson 2004, Ries 2019, Dikau et al. 2019 und entsprechende Zeitschriftenartikel aus Geomorphologie, Catena, ZFG, MDBG.