



## *Module Handbook*

International Elite Graduate Programme

# **Global Change Ecology (M.Sc.)**

Elite Network Bavaria (ENB)

Current Version from 22 June 2022



UNIVERSITÄT  
BAYREUTH



# 1 Goals and Organisation of the Degree Programme

The Elite Graduate Degree Programme „Global Change Ecology“ addresses the most important and far-reaching environmental issues of the 21st century: Global change of the climate and ecosystem characteristics (mass balance, biodiversity). The study of human reaction and the development of adaptation strategies are also included. Effects of the interaction with other globally relevant developments such as regionally specific land use changes and loss of biodiversity that can intensify the negative effects of global change are also a vital part of course content.

The interdisciplinary and entirely new problems of Global Change demand innovative and highly efficient approaches in research and teaching. For this reason, competencies at the University of Bayreuth as well as in the Bavarian research community, along with business, public administration and international organisations are pooled together in the programme.

Changes in climate, transformation in land-use and population pressure all brings about drastic changes in the behaviour of ecological systems, making it increasingly difficult to judge. Due to the complex interaction between social and ecological processes, fields in natural science are supplemented by disciplines in social science.

There is apprehension about negative consequences on goods and services in ecological systems (e.g. drinking water, food, pharmaceutical resources, carbon storage). Economic, social and political risks are emerging and uncertainty is growing. Research and training needs are evident in process-oriented problem analysis, effective ecological risk management as well as in the development of optimised management strategies. These issues are of global significance for the sustainable development of societies.

The goal of this programme is to educate and train students to work in science and the environment, in politics and in business as highly qualified experts and decision makers. With a well-founded scientific background and expertise knowledge, such individuals must be able to analyse complex issues, recognize new problems, and work out and adopt solid solutions.

Specialised training of qualified scientists in new fields of research is continually gaining importance. The current global developments in the environmental sector are becoming more relevant both in science as well as in the economy. Our graduates are extraordinarily well qualified for careers in research, in advisory or consulting capacities or as leaders in science, politics, public administration and business.

The integrative exchange with research groups and guest lecturers as well as communication with foreign partners in an international consortium of institutions encourages increasing sensitivity for the research approaches that are under debate in the international arena. Students are specifically prepared to work in an international environment through inclusion in the programme of internationally operating businesses and research institutes. Places of work can be found in many fields: as policy advisors, in financial consulting, dealing with environmental policy, managing environmental change and risks, in Global Change research as well as in management of scientific institutions (research centres, public agencies and organisations).

Possible employers can be international organisations (e.g. EU, NGOs), national agencies (government ministries, federal agencies, state offices), departments of sustainability, consulting businesses, insurance companies, universities and large research centres.

Outstanding graduates with above average knowledge and skills who are able to deal with the practical application of global environmental problems are needed for leading managerial positions. The basis of this work requires well-founded training in natural science, but also a background in social science disciplines. By directly involving students in current research projects, they will be encouraged to use personal experience to help them understand the relevant processes within the framework of Global Change. There are no ready-made solutions to the problems needing to be tackled. Single individuals, no matter how extraordinary, cannot accomplish anything on their own. Furthermore, the temporary and spatial consequences must be taken into consideration reaching far beyond an individual's own personal range of experience. For this reason, characteristics such as creativity, flexibility, team spirit and sense of responsibility are particularly encouraged in this programme as they will be indispensable in later fields of work.

The programme Global Change Ecology places great value on an exchange of scientific knowledge with the professional world and with society in general. To ensure practical application of scientific knowledge, close contact is guaranteed between the university programme with an alliance of non-university partners working on similar subject matter (particularly with research centres). Students interested in the programme should combine extraordinary intellectual skills with a pronounced sense of responsibility and high motivation. Their development is actively fostered throughout the studies. Special courses and intensive, individual support differentiates the Elite degree programme from conventional programmes. Direct communication with the instructors is offered and is encouraged between all students; international students are given special attention and are integrated into the programme.

The Elite Programme starts where the first academic degree (normally B.Sc.) leaves off. Applicants to the programme must fulfil above-average requirements. The programme is open to excellent, high-achieving and hard-working students from Germany and abroad. Major subject areas in the first degree can be: Biology, Geography, Geo-Ecology, Forestry, Agricultural Science, Hydrology, Limnology, Meteorology, Environmental Physics, Environmental Computer Science, Engineering Ecology, Landscape Ecology, Environmental Economics, Environmental Law and related disciplines. Applicants go through a selective admission process. Criteria for admission include submitting previous degrees and certificates and a personal written application statement. During candidate interviews, personal qualifications, willingness to work hard and motivation will be evaluated.

## 2 General Information, Forms of Teaching and Knowledge Transfer

The Elite Programme places enormous demands on each student's achievement potential and willingness to work hard.

*Lectures (Vorlesungen, V)* present a coherent description of the central topics in each respective Module. Lectures can also take place at partner universities.

During Seminars (*Seminaren, S*) current research topics are covered by term papers, homework assignments, presentations and discussions. Classes that take place in another location and which in individual cases might be necessary for optimally taking advantage of specific resources will be linked to participating universities through an e-learning portal. Both asynchronous courses (E-Seminars and Discussion Forums with continual communication between teachers and students) as well as synchronous classes will be offered.

*Tutorials (Übungen, Ü)* take place in small groups and serve to deepen methodology and to teach technical knowledge through block courses with fieldwork (measurements, experiments, data evaluation). They enable students to deal intensively with methods, current issues and problems. These courses strive to form a heterogeneous structure in all group teams in order to take advantage of the different background experience of each individual student and to encourage discussion. Modelling exercises teach the students to use simulations and forecasts.

Research oriented *Science Schools* (Summer/Winter Schools, Module S) play an important part in the teaching concept as they offer students the opportunity to practice and deepen their specialised knowledge by dealing intensively with a specific topic. Furthermore, they encourage the exchange and contact with international students as well as allowing participants to become familiar with comparable institutions in different locations.

External Internships (*Internships, Module I*) that each last for six weeks enable participants to gain practical experience in research and administration, in businesses and in international organisations. Internships take place in institutions dealing with issues included in the Master Programme. The elite feature of the programme is conveyed by, among other aspects, the direct and regular conversations between instructors and students as well as in the weekly meetings that take place on a regular basis. This means that individual interests can be particularly encouraged and supported. All courses are offered annually. Examinations and performance assessments take place during the course.

Student workload is listed for each course in the number of credit points. One credit point (CP) is equivalent to 30 hours of work. For on-site classroom attendance, a one-hour class corresponds to 0.5-CP (1 SWS x 15 weeks = 15 hours). Credit points are given for contingent necessary preparation and follow-up work; depending on amount of time necessary, credit points are also given for exam preparation.

## 3 Programme Design

### 3.1 Structure of Study Programme and Courses

The Programme of Study is designed so that students can complete all requirements in four semesters and it encompasses a total of 120-credit points. This includes the Master Thesis in the fourth semester with 30-credit points.

University instruction is organised in Modules, each one is normally worth 5-credit points. Generally, 30-credit points are to be achieved each semester. The Modules are arranged in groups of Modules that all have a similar specialised focus. It is possible to choose courses within each Module group. In the Free Choice Module (F), students can select any 5-credit point course they would like to take. Credit points are also given for external Science Schools (Module S) and Internships (Module I). Course content must, however, be coordinated with the programme and agreed upon in advance in order for credit to be given.

All Module names as well as the titles for Module areas are in English.

In the first semester, relevant issues and approaches as well as the state of research in general will be taught in a transdisciplinary overview Module (O) in relationship with „Global Change Ecology“. The concept of the programme will be introduced in this class and the state of special knowledge that the students might have will also be determined.

The three central Module Areas (A Environmental Change, B Ecological Change, C Societal Change) will be offered parallel to this, out of which at least one Module in each semester must be chosen. (Fig. 1) Starting in the second semester an individual field of specialised interest (Specialization) will arise out of the selection of two further Modules from the course offerings from each particular Module Area. In the third semester a further Module or single classes encompassing a total of 5-credit points can be chosen freely. These courses can be taken from the field of specialised interest, but this is not necessary.

Additionally, students must take method-oriented courses (Module M) during the first two semesters to round out their knowledge. At this point any possible shortcomings can be compensated for and individual interests can be developed. It is possible to read in the course descriptions about the individual Module parts (see below) where previous knowledge in methods is required. This can be gained in method-oriented courses of different extents. In all, 10-credit points must be earned in this area.

The names of the Module Areas and the courses are presented in English in the Module Handbook, just as the courses are taught in English in the Elite Programme itself.

The structure as a whole helps students to take responsibility for planning out their course of studies. Within the Modules there are no options to choose from (exceptions: Module F and M). However, under certain conditions student can select modules from the Module Areas and in this way are able to individually design their course of study.

Students are also helped in designing their own course of study by a Free Choice Module (Module F) as well as with courses in methods for their focus of specialised interest (Module M) and through the choice offered by Summer and Winter Schools (Science Schools, Module S) and career-oriented internships (Internships, Module I).

|            |                            |                         |                          |                        |                           |                            |
|------------|----------------------------|-------------------------|--------------------------|------------------------|---------------------------|----------------------------|
| Semester 1 | Global Change Ecology<br>O | „Environm. Change“<br>A | „Ecological Change“<br>B | „Societal Change“<br>C | Methods<br>M              | Internship or School I / S |
| Semester 2 | Focus<br>A / B / C         | „Environm. Change“<br>A | „Ecological Change“<br>B | „Societal Change“<br>C | Methods<br>M              | Internship or School I / S |
| Semester 3 | Focus<br>A / B / C         | „Environm. Change“<br>A | „Ecological Change“<br>B | „Societal Change“<br>C | Individ. Free Choice<br>F | Internship or School I / S |
| Semester 4 | <b>Master Thesis</b>       |                         |                          |                        |                           |                            |
| LP         | 5                          | 10                      | 15                       | 20                     | 25                        | 30                         |

The Master Thesis (Master Thesis) is to be done in one of the Module Areas. It should, however, demonstrate multidisciplinary features. Normally, it is undertaken as a study within a research project; however, it is also possible to work on external projects, e.g. with a partner in business, an agency or government department or in a large research centre.

„Master of Science (M.Sc.)“ is awarded upon completion of the programme.

### 3.2 Structure and Course Schedule of Programme

The implications of Global Change will be dealt with, starting from global social and ecological developments as well as with an understanding of biotic systems. In the first semester, an interdisciplinary Module will be offered that covers the philosophy of the programme and is also an introduction to the topics (**Overview**, Module O).

Due to the differences in educational background and specialised interests of the students in the programme, the teaching process is intentionally designed to be as flexible as possible. The vertical orientation of the structure (Fig. 1.2) guarantees a wide programme spectrum appropriate to the topics of the programme. At the same time, however, it allows room for individual advancement (specialization) of the students through their choice of Modules in one (or two) Module Areas to supplement the required three Modules.

All three main Module Areas: **Environmental Change** (A), **Ecological Change** (B) and **Societal Change** (C) are continually offered up to the final thesis. This ensures intensive training in all areas and in this way links the different qualities of Global

Change as a basic component of the programme structure. Three Modules are to be chosen from the course offerings in these Module groups.

Through individualised choice of advanced study, an individualised shaping of the programme is both possible and desired. As specialisation in one of the areas appears sensible, a particular direction or Module area can be chosen to focus on from A, B or C (two Modules can be selected from the course offerings in these Module Areas as well from the transdisciplinary selection in Module Area (F).

Additionally, free chose of courses offered in Module F leads to advanced study of the selection of **Methods** courses in Module M, **Internships** (Practical, Module I) and Science **Schools** (Module S). A Performance Assessment is required in these courses but they are ungraded. (See Fig. 2)

|            |                            |                         |                          |                        |                           |                            |
|------------|----------------------------|-------------------------|--------------------------|------------------------|---------------------------|----------------------------|
| Semester 1 | Global Change Ecology<br>O | „Environm. Change“<br>A | „Ecological Change“<br>B | „Societal Change“<br>C | Methods<br>M              | Internship or School I / S |
| Semester 2 | Focus<br>A / B / C         | „Environm. Change“<br>A | „Ecological Change“<br>B | „Societal Change“<br>C | Methods<br>M              | Internship or School I / S |
| Semester 3 | Focus<br>A / B / C         | „Environm. Change“<br>A | „Ecological Change“<br>B | „Societal Change“<br>C | Individ. Free Choice<br>F | Internship or School I / S |
| Semester 4 | <b>Master Thesis</b>       |                         |                          |                        |                           |                            |
| LP         | 5                          | 10                      | 15                       | 20                     | 25                        | 30                         |

Fig. 2: Areas marked in red are graded Modules (85 of a total of 120-credit points). The end grade is composed of Module grades based on their respective number of credit points and the grade on the Master Thesis. The Module Global Change Ecology Overview (O), Methods (M), Free Choice (F), Internships (I) and Science Schools (S) each have a non-graded Performance Assessment; any possible grades are not part of the total grade.

The course selection of Methods courses (Module M) allows students to learn specific techniques (e.g. R, Statistics, GIS) that are necessary to understand certain other Modules. A flexible selection of Methods courses to round out what students are learning is particularly necessary due to the heterogeneity of students' previous knowledge. The requirements in each Module are described in this Module Handbook. The Examination Committee may accept additional methods-oriented courses.

Suggestions for individual **Free Choice Electives in Module (F)** may be given, but no requirements will be stated. Additional specially oriented courses or languages can be taken. Research oriented small projects can be implemented within Module F. This serves as practice in cooperating on research projects as well as transdisciplinary cooperation with external partners in the community or country, in business or politics. Multidisciplinary specific Modules, listed in this Module Handbook under F, can be chosen as individually selective Modules and for Module specialisation (A/B/C). A total of 15-credit points are to be earned from Internships (Module I) and Science Schools (Module S). Logistic problems in providing internship places or in the organisation of the Schools are avoided through the flexible manner in which courses are offered. The emphasis in each of these areas, those of Internships or Science Schools, may not exceed 10-credit points.

The Fourth Semester is entirely devoted to the Master Thesis. Didactic goals are the independent execution of an analysis of complex interrelations with a trans-disciplinary approach; discussion of global problem areas; transfer of knowledge to current key environmental issues; use of modern methods and approaches; use of current reference material and research sources.

## 4 Course Content

### 4.1 Module Area O „Global Change Ecology Overview“

This Module Area gives an overview of the background motivation for the programme as well as the target objectives. The structure concept of the programme and the course sequence are also described and special characteristics of the German university system, of particular interest for foreign students, will be covered. The students also learn about the organisation of the programme itself, the Coordinating Office and the University of Bayreuth with its research specialties, central institutions and research centres. Tours of the laboratories, the Ecological-Botanical Garden and the campus of the University of Bayreuth introduce students to the science facilities.

Finally, current global research developments are covered and the research community dealing with global change is discussed. The most recent developments in the current state of knowledge concerning global change are introduced. An overview of the statements of IPCC reports and other international studies helps students gain insight into the issues. This information is relevant for several different courses in the Global Change Ecology programme.

Pertinent textbooks, studies, as well as important publications are introduced (e.g. Global Change Biology, Global Environmental Change, Nature Climate Change, Global and Planetary Change) and references to appropriate websites and links are given. The development of the political landscape concerning the issues, international lectures, conferences and initiatives are also briefly outlined. Students can contribute their own knowledge as well.

The philosophy of the programme is discussed and special features of the programme are described. Students are given the opportunity to talk about their personal motivation for having chosen this programme and to discuss with instructors about their attitudes toward research and teaching. The goal is to exactly identify expectations and what the programme offers for an accurate match of both. Individual interests should be identified early so that, if possible the courses can be designed with this in mind.

Programme Extent:

Only one Module with 5-credit points is offered in the first semester. This course is obligatory for all students.

## O Global Change Ecology Overview

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Biogeography, University of Bayreuth (UBT)   |           |
| Structural Content         | Biogeography, UBT;<br>Ecological Services, UBT;<br>Soil Physics, UBT   |           |
| Learning Objectives        | This module covers the conception approach of the Master Programme. Participating disciplines and instructors are introduced. Logistical and organisational details are discussed. Students are also able to share and exchange their individual experience and knowledge.   |           |
| Course Content             | First, an overview of the information about current and expected global development is given. Not only climate change but also land-use changes and the loss of biodiversity is included. In the advanced seminar, current research results are presented and analysed.  |           |
| Teaching Style             | <p>This module lasts for one semester and must be taken in the first semester as it sets the basis for the entire programme. The course consists of a one-hour lecture and a one-hour seminar. Additionally, a regularly scheduled weekly meeting is offered to discuss current study issues and for group mentoring. Two daylong excursions about landscape ecology supplement the module.</p> <p>V Global Change Ecology (1 SWS, 1 CP)<br/> S Progress in Global Change Research (1 SWS, 2 CP)<br/> S Regularly Scheduled Meetings (1 SWS, 1 CP)<br/> Two Excursions (1 SWS, 1 CP)</p> |           |
| Course Entry Requirements  | No Special Course Entry Requirements   |           |
| Performance Assessment     | Contribution (ungraded)  |           |
| Work Load                  | Active Participation in 4 Class Sessions:  | 60 Hours  |
|                            | Written Report and Lecture   | 30 Hours  |
|                            | Preparation and Follow-Up:   | 30 Hours  |
|                            | Regularly Scheduled Meetings:  | 15 Hours  |
|                            | Two Excursions (one in the 1 <sup>st</sup> , one in the 2 <sup>nd</sup> semester):   | 15 Hours  |
|                            | Total:   | 150 Hours |
| Credit Points              | 5 CP   |           |
| Scope of Time              | Two Semesters (1 <sup>st</sup> and 2 <sup>nd</sup> semester)   |           |
| When Offered               | Winter semester  |           |
| Target Group               | Global Change Ecology  |           |
| Reference to Other Modules | The basics for the entire programme are taught.  |           |

## 4.2 Module Area A „Environmental Change“

Information on the processes in Global Change is covered in this Module Area. The emphasis is on abiotic processes, which includes physical and chemical mechanisms in relationship with global environmental changes. Physical and chemical specific aquatic and terrestrial ecological systems are identified. The dynamics of Global Change are handled in great detail whereby different spatial scales are examined. The speed of development in relationship to the affected objects as well as the role of single individual extreme events is also taken into consideration.

On the landscape level, recent climatic data and historic developments are identified. The relationship to global climate systems is presented. Control data of global developments is discussed, along with climate driving forces and land-use changes as decisive factors in material and biotic change. Of particular interest are over-use and degradation, erosion and desertification. Finally, the relationship between environmental change and change in bio-chemical action is taught.

Overview of Modules (each worth 5-credit points):

- A1 Climate Change
- A2 Ecological Climatology
- A3 Extreme Events and Natural Hazards
- A4 Changes in Aquatic Ecosystems
- A5 Changes in Agroecosystems
- A6 Biogeochemical Fluxes
- A7 Rhizosphere Biogeochemistry
- A8 Biodiversity in the Tropics
- A9 Mathematical Modeling for Climate and Environment
- A10 Land Use Change and Microclimate

Total Extent of Module:

At least, 15-credit points. These can be expanded among the specialised area of interest. A graded Performance Assessment is required in each of the selected Modules.

## A1 Climate Change

|                            |   |
|----------------------------|---|
| Responsible for the Module | Physical Geography, University of Augsburg  |
| Structural Content         | Physical Geography, University of Augsburg;   |
| Learning Objectives        | The aim of this module is to teach fundamental knowledge about current climate development.   |
| Course Content             | Basic principles of the climate system; naturally-occurring climate variability, climate change in the past; reconstruction of past climate; natural forcing-factors, circulation dynamics; human impact on the climate system; global warming; Greenhouse effect; land use change; aerosols; ozone depletion; global circulation models; forecasts; scenarios; fundamentals of energy and mass balance; modelling; sensitive parameters of global change |
| Teaching Style             | V Natural Climate and Human Impacts on Climate (2 SWS; 2 CP)<br>S Climate Variability and Change: Natural and Man-Made (2 SWS; 3 CP)  |
| Prerequisites              | None  |
| Performance Assessment     | Oral exam (graded) and Contribution (ungraded)  |
| Workload                   | Active participation in 2 courses: 60 hours<br>Preparation and follow-up: 60 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 150 hours   |
| Credit Points              | 5 CP  |
| Scope of Time              | One semester (Recommended: 1 <sup>st</sup> Global Change Ecology semester)  |
| Semester Offered           | Winter semester   |
| Target Group               | Global Change Ecology   |
| Reference to Other Modules | This is the basis Module for Module Area A  |

## A2 Ecological Climatology

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Climatology, UBT   |           |
| Structural Content         | Climatology, UBT; Atmospheric Chemistry, UBT   |           |
| Learning Objectives        | <p>Climate Ecology is the interface between Ecology, Micrometeorology and Climatology as an interdisciplinary formation to understand the function of terrestrial ecosystems within the climate system. This course integrates the disciplinary areas of Meteorology, Hydrology, Soil Science, Plant Physiology, etc. to understand the physical, chemical and biological processes relevant to climate with which landscape and atmosphere are connected, and which can mutually influence both systems.</p> <p>In this module students should develop a problem and process-oriented understanding with a variety of scale levels about the interaction between Pedosphere, Biosphere and Atmosphere. Furthermore, students learn to collect and analyze terrain data.</p> |           |
| Course Content             | <p>The seminar deals with climate-relevant material and energy flows in the soil-vegetation-atmosphere system on different scale levels. In particular, the interrelation between single compartments of ecosystems and their ecological relevance on climate will be dealt with.</p> <p>The course looks at examples of the parameters of climate data collection for terrain and analysis and modelling with particular attention given to scale transitions.</p>  |           |
| Teaching Style             | <p>S Ecological Climatology (2 SWS; 3 CP)</p> <p>Ü Ecological Climatology: Measurements and Analyses (2 SWS; 2 CP).</p>  |           |
| Prerequisites              | <p>Module C2 Ecosystem Services (recommended)</p> <p>Knowledge in programming language R</p>   |           |
| Performance Assessment     | <p>Seminar: written report (graded) and presentation (ungraded).<br/>Exercise: written report (ungraded)</p>   |           |
| Workload                   | Active participation in 2 courses:   | 60 hours  |
|                            | Preparation and follow-up:   | 30 hours  |
|                            | Assessment component determined by instructor:   | 60 hours  |
|                            | Total:   | 150 hours |
| Credit Points              | 5 CP   |           |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)   |           |
| Semester Offered           | Summer semester  |           |
| Target Group               | Global Change Ecology, Physical Geography, Geoecology  |           |
| Reference to Other Modules | <p>A1 Climate Change</p> <p>A4 Changes in Aquatic Ecosystems</p> <p>A5 Changes in Agroecosystems</p>   |           |

## A3 Extreme Events and Natural Hazards

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Disturbance Ecology, UBT   |           |
| Structural Content         | Disturbance Ecology, UBT;<br>Physical Geography, University of Augsburg;   |           |
| Learning Objectives        | Aim of this module is to teach about occurrence and impact of natural risks and extreme events in ecology. Reoccurring events are included as well as single disasters; those with stabilizing effects and those with catastrophic consequences and regime shift. The impact of climatic, biotic and geomorphological events on biodiversity, ecology, provision of services, and cultural landscapes is covered. The learning objective is the ability to deal with in-depth theories and methods of Disturbance Ecology and to research extreme events. Fundamentals for a scientific study of interdisciplinary disaster research and risk management will be developed.  |           |
| Course Content             | Climate and land-use change are leading to global changes in disturbance regimes and to an increase in the frequency and magnitude of extreme events. In this module, we deal with, geomorphological hazards, abrupt climate change and extreme weather events like heat waves, drought, intense rainfall, tropical cyclones and extra-tropical severe storms. Furthermore, avalanches, mass movement, large fires, insect calamities, pandemics, volcano eruptions and floods will be covered. The ecological consequences of possible future extreme events such as a lack of cold winter and occurrence of late frosts in the northern hemisphere will be addressed. Developing and presenting a scientific expert presentation trains students in analyzing and understanding the progress in current scientific literature on extreme events. . |           |
| Teaching Style             | V/Ü Natural Risks and Hazards (2 SWS; 3 CP)<br>S Extreme Events (2 SWS; 2 CP)  |           |
| Prerequisites              | A1 Climate Change  |           |
| Performance Assessment     | Contribution (ungraded) and seminar presentation during lecture including extended abstract (graded)   |           |
| Workload                   | Active participation in 2 courses:   | 60 hours  |
|                            | Preparation and follow-up:   | 60 hours  |
|                            | Assessment component determined by instructor:   | 30 hours  |
|                            | Total:   | 150 hours |
| Credit Points              | 5 CP   |           |
| Scope of Time              | Two semesters (Recommended: 1 <sup>st</sup> and 2 <sup>nd</sup> Global Change Ecology semester)  |           |
| Semester Offered           | Winter semester (V/Ü)<br>Summer semester (S)   |           |
| Target Group               | Global Change Ecology, Environmental Geography, Biodiversity and Ecology, Geoecology   |           |
| Reference to Other Modules | A1 Climate Change<br>B3 Disturbance Ecology (and further B-Modules)  |           |

## A4 Changes in Aquatic Ecosystems

|                                    |   |                                    |          |                            |          |                               |          |        |           |
|------------------------------------|---|------------------------------------|----------|----------------------------|----------|-------------------------------|----------|--------|-----------|
| Responsible for the Module         | Hydrology, UBT  |                                    |          |                            |          |                               |          |        |           |
| Structural Content                 | Hydrology, UBT  |                                    |          |                            |          |                               |          |        |           |
| Learning Objectives                | The objective of this module is to gain a thorough understanding of natural processes of water flow and storage in and between the various compartments of the environment and to learn about various impacts on global water resources.  |                                    |          |                            |          |                               |          |        |           |
| Course Content                     | <p>The module is divided into a lecture/exercise about fundamental hydrological processes and a seminar with interactive content .</p> <p>The focus of the lecture are the hydrological cycle and the water balance equation. Processes of water movement through the compartments of the atmosphere, biosphere and geosphere and their interactions are discussed in detail. Furthermore, aspects of chemical and ecological water quality and strategies for protecting surface- and groundwater are presented.</p> <p>In the seminar, we discuss current risks for and impacts on water resources in a global context. Students select a topic and present the results of their literature review to their fellow students, with the aim to stimulate a critical discussion also of potential mitigation strategies. The student presentations may be complemented by presentations of external experts.</p> |                                    |          |                            |          |                               |          |        |           |
| Teaching Style                     | <p>V Hydrological Concepts (2 SWS; 3 CP)</p> <p>S/Ü Water resources in a quickly changing world – impacts and challenges (2 SWS, 2 CP)</p>  |                                    |          |                            |          |                               |          |        |           |
| Prerequisites                      | None  |                                    |          |                            |          |                               |          |        |           |
| Performance Assessment             | Written exam (graded) and seminar presentation (ungraded)   |                                    |          |                            |          |                               |          |        |           |
| Workload                           | <table><tr><td>Active participation in 2 courses:</td><td>60 hours</td></tr><tr><td>Preparation and follow-up:</td><td>45 hours</td></tr><tr><td>Written exam and presentation</td><td>45 hours</td></tr><tr><td>Total:</td><td>150 hours</td></tr></table>   | Active participation in 2 courses: | 60 hours | Preparation and follow-up: | 45 hours | Written exam and presentation | 45 hours | Total: | 150 hours |
| Active participation in 2 courses: | 60 hours  |                                    |          |                            |          |                               |          |        |           |
| Preparation and follow-up:         | 45 hours  |                                    |          |                            |          |                               |          |        |           |
| Written exam and presentation      | 45 hours  |                                    |          |                            |          |                               |          |        |           |
| Total:                             | 150 hours   |                                    |          |                            |          |                               |          |        |           |
| Credit Points                      | 5 CP  |                                    |          |                            |          |                               |          |        |           |
| Scope of Time                      | Two semesters (Recommended: 1 <sup>st</sup> and 2 <sup>nd</sup> Global Change Ecology semester)   |                                    |          |                            |          |                               |          |        |           |
| Semester Offered                   | Winter semester (V)<br>Summer semester (S/Ü)  |                                    |          |                            |          |                               |          |        |           |
| Target Group                       | Global Change Ecology, Geoecology   |                                    |          |                            |          |                               |          |        |           |
| Reference to Other Modules         | A1 Climate Change<br>A2 Ecological Climatology<br>A5 Changes in Agroecosystems  |                                    |          |                            |          |                               |          |        |           |

## A5 Changes in Agroecosystems

|                            |  |
|----------------------------|--|
| Responsible for the Module | Agroecology UBT  |
| Structural Content         | Agroecology UBT, Soil Physics UBT  |
| Learning Objectives        | The module goal is to learn fundamental knowledge about regional and global developments in agroecosystems.  |
| Course Content             | Concepts of agroecosystems research; Ecological mechanisms and processes that are influenced by global change; Drought; Principles of soil and plant water relationships; Implication of drought for agriculture worldwide; Human impact on water balances and resources on different scales; Hydrologic and biogeochemical interactions |
| Teaching Style             | V Soil and Plant Hydrology (2 SWS; 2 CP)<br>S Global Change and Agroecosystems (2 SWS; 3 CP)   |
| Prerequisites              | None   |
| Performance Assessment     | Written exam (graded) and seminar presentation (ungraded)  |
| Workload                   | Active participation in 2 courses: 60 hours<br>Preparation and follow-up: 60 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 150 hours  |
| Credit Points              | 5 CP   |
| Scope of Time              | One semester (Recommended: 1st Global Change Ecology semester)   |
| Semester Offered           | Winter Semester  |
| Target Group               | Global Change Ecology  |
| Reference to Other Modules | A1 Climate Change<br>A7 Rhizosphere Biogeochemistry  |

## A6 Biogeochemical Fluxes

|  |   |                                   |           |  |          |        |           |
|--|---|-----------------------------------|-----------|--|----------|--------|-----------|
| Responsible for the Module                     | Micrometeorology, UBT   |                                   |           |  |          |        |           |
| Structural Content                             | Micrometeorology, UBT;<br>Atmospheric Chemistry, UBT;<br>Soil Physics, UBT;   |                                   |           |  |          |        |           |
| Learning Objectives                            | The module aim is the advanced study about ecological matter and energy flows. Central starting point is the hydrological cycle in the air-water-soil-plant continuum.  |                                   |           |  |          |        |           |
| Course Content                                 | <p>Measuring methods for bio-geochemical flows in the atmosphere, plants and soil: Profile of state variables, techniques to measure fluxes including Eddy-covariance and gradient approaches, radiation, sap flow, gas exchange, soil chambers, and lysimeter.</p> <p>Models of bio-geochemical flows: approaches like Penman Monteith, SVAT models, plant models, soil models, statistic approaches, surface averaging, remote sensing, top-down and bottom-up approaches.</p> <p>Field campaigns with measurements in a forest or agricultural eco-system, data analysis, modules of experimental data and model approaches.</p> |                                   |           |  |          |        |           |
| Teaching Style                                 | Lectures, exercises, lab experiments, field experiments (4 SWS; 5 CP, in small groups)  |                                   |           |  |          |        |           |
| Prerequisites                                  | Knowledge of Modules A1 to A3   |                                   |           |  |          |        |           |
| Performance Assessment                         | Written elaboration (take-home examinations) (Micrometeo. Atm. Chem., Plant Ecol.) (graded); presenting results of the field experiment (Soil Physics, Micrometeo) as seminar presentation (ungraded) and written elaboration (report) (graded)   |                                   |           |  |          |        |           |
| Workload                                       | <table> <tr> <td>Active participation in 1 course:</td> <td>120 hours</td> </tr> <tr> <td>Assessment component determined by instructor:</td> <td>30 hours</td> </tr> <tr> <td>Total:</td> <td>150 hours</td> </tr> </table>  | Active participation in 1 course: | 120 hours | Assessment component determined by instructor: | 30 hours | Total: | 150 hours |
| Active participation in 1 course:              | 120 hours   |                                   |           |  |          |        |           |
| Assessment component determined by instructor: | 30 hours  |                                   |           |  |          |        |           |
| Total:   | 150 hours   |                                   |           |  |          |        |           |
| Credit Points                                  | 5 CP  |                                   |           |  |          |        |           |
| Scope of Time                                  | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)  |                                   |           |  |          |        |           |
| Semester Offered                               | Summer semester   |                                   |           |  |          |        |           |
| Target Group                                   | Global Change Ecology   |                                   |           |  |          |        |           |
| Reference to Other Modules                     | <p>Modules A1 to A3</p> <p>A5 Changes in Agroecosystems</p>   |                                   |           |  |          |        |           |

## A7 Rhizosphere Biogeochemistry

|  |  |                                    |          |                            |          |  |          |        |           |
|--|--|------------------------------------|----------|----------------------------|----------|--|----------|--------|-----------|
| Responsible for the Module                     | Agroecology UBT  |                                    |          |                            |          |  |          |        |           |
| Structural Content                             | Agroecology UBT, Soil Physics UBT  |                                    |          |                            |          |  |          |        |           |
| Learning Objectives                            | The module goal is to learn fundamental biogeochemical and physical processes taking place at the root-soil interface and their larger scale implications  |                                    |          |                            |          |  |          |        |           |
| Course Content                                 | <p>The rhizosphere is one of the most dynamic interfaces in terrestrial ecosystems and certainly the most important zone in terms of defining the quality and quantity of our crops.</p> <p>Interactions in the rhizosphere between living organisms (roots and microorganisms), solids (minerals and organic matter), liquids (water with dissolved nutrients) and gaseous phases are pivotal in controlling ecosystem dynamics, functions and the services they provide.</p> |                                    |          |                            |          |  |          |        |           |
| Teaching Style                                 | <p>V Rhizosphere Biogeochemistry and Biophysics (2 SWS; 3 CP)</p> <p>S Emerging topics in Rhizosphere Research (2 SWS; 2 CP)</p>   |                                    |          |                            |          |  |          |        |           |
| Prerequisites                                  | None   |                                    |          |                            |          |  |          |        |           |
| Performance Assessment                         | Oral exam (graded) and seminar presentation (ungraded)   |                                    |          |                            |          |  |          |        |           |
| Workload                                       | <table><tr><td>Active participation in 2 courses:</td><td>60 hours</td></tr><tr><td>Preparation and follow-up:</td><td>60 hours</td></tr><tr><td>Assessment component determined by instructor:</td><td>30 hours</td></tr><tr><td>Total:</td><td>150 hours</td></tr></table>   | Active participation in 2 courses: | 60 hours | Preparation and follow-up: | 60 hours | Assessment component determined by instructor: | 30 hours | Total: | 150 hours |
| Active participation in 2 courses:             | 60 hours   |                                    |          |                            |          |  |          |        |           |
| Preparation and follow-up:                     | 60 hours   |                                    |          |                            |          |  |          |        |           |
| Assessment component determined by instructor: | 30 hours   |                                    |          |                            |          |  |          |        |           |
| Total:   | 150 hours  |                                    |          |                            |          |  |          |        |           |
| Credit Points                                  | 5 CP   |                                    |          |                            |          |  |          |        |           |
| Scope of Time                                  | One semester (Recommended: 1st Global Change Ecology semester)   |                                    |          |                            |          |  |          |        |           |
| Semester Offered                               | Winter Semester  |                                    |          |                            |          |  |          |        |           |
| Target Group                                   | Global Change Ecology  |                                    |          |                            |          |  |          |        |           |
| Reference to Other Modules                     | A5 Changes in Agroecosystems   |                                    |          |                            |          |  |          |        |           |

## A8 Biodiversity in the Tropics

|  |  |          |
|--|--|----------|
| Responsible for the Module             | Functional and Tropical Plant Ecology, UBT   |          |
| Structural Content Learning Objectives | Functional and Tropical Plant Ecology, UBT   |          |
| Learning Objectives                    | Module aim is to gain a sound overview of tropical ecology and in particular of research on biodiversity in the tropics. Students learn on the basis of examples different approaches to advance and test an ecological hypothesis. Critically reading and assessing scientific literature, as well as scientific presentation are practiced.  |          |
| Course Content                         | First, the module provides an introductory overview of tropical ecology. On the basis of tropical forests which represents one of the most diverse ecosystems on Earth, we deal with theories and today's state of knowledge on mechanisms of the origin and maintenance of diversity, processes determining the spatial and temporal distribution of diversity, the functions of diversity, impacts of climate change and land use and strategies for protection. In doing so we include genetic, chemical, functional and species diversity as well as different taxonomic groups. |          |
| Teaching Style                         | Lecture and seminar (4 SWS, 5 CP)  |          |
| Prerequisites                          | Recommended: Foundations of animal ecology, plant ecology and evolution.<br>Basic statistical knowledge is required, R knowledge is advantageous.  |          |
| Performance Assessment                 | One overall module examination (graded) consisting of two seminar presentations (graded, each 50%)   |          |
| Work Load                              | Active participation in the courses:   | 60 Std.  |
|  | Preparation and follow-up:   | 30 Std.  |
|  | Literature work, and elaboration of own contributions  | 60 Std.  |
|  | Total:   | 150 Std. |
| Credit Points                          | 5 CP   |          |
| Scope of Time                          | One semester   |          |
| Semester Offered                       | Winter semester  |          |
| Target Group                           | Global Change Ecology, Biodiversity and Ecology, Molecular Ecology   |          |
| Reference to Other Modules             | M23 Dynamic Ecosystem Modeling<br>B1 Biogeography and Macroecology<br>B2 Biodiversity and Ecosystem Functioning  |          |

## A9 Mathematical Modeling for Climate and Environment

|  |   |                                 |          |                            |          |  |          |        |           |
|--|---|---------------------------------|----------|----------------------------|----------|--|----------|--------|-----------|
| Responsible for the Module                     | Scientific Computing, UBT   |                                 |          |                            |          |  |          |        |           |
| Structural Content                             | Scientific Computing, UBT   |                                 |          |                            |          |  |          |        |           |
| Learning Objectives                            | <p>Knowledge of important physical principles and their representation in mathematical models for main types of climate and environmental models</p> <p>Ability to identify the key interactions between different compartments of a climate model and to express them in mathematical form</p>                                   |                                 |          |                            |          |  |          |        |           |
| Course Content                                 | <p>Physical principles, mathematical models, and selected numerical methods in climate and environmental sciences</p> <p>Earth system: Main components, driving forces, scales, feedbacks</p> <p>Hierarchy of climate models, regional and global focus</p> <p>Environmental modeling: Main applications and problem settings</p> |                                 |          |                            |          |  |          |        |           |
| Teaching Style                                 | V Mathematical Modeling for Climate and Environment (4 SWS; 5 CP)   |                                 |          |                            |          |  |          |        |           |
| Prerequisites                                  | M22 Mathematical Modeling for Climate and Environment (exercise)  |                                 |          |                            |          |  |          |        |           |
| Performance Assessment                         | Oral examination (graded)   |                                 |          |                            |          |  |          |        |           |
| Workload                                       | <table> <tr> <td>Active participation in course:</td> <td>60 hours</td> </tr> <tr> <td>Preparation and follow-up:</td> <td>30 hours</td> </tr> <tr> <td>Assessment component determined by instructor:</td> <td>60 hours</td> </tr> <tr> <td>Total:</td> <td>150 hours</td> </tr> </table>  | Active participation in course: | 60 hours | Preparation and follow-up: | 30 hours | Assessment component determined by instructor: | 60 hours | Total: | 150 hours |
| Active participation in course:                | 60 hours  |                                 |          |                            |          |  |          |        |           |
| Preparation and follow-up:                     | 30 hours  |                                 |          |                            |          |  |          |        |           |
| Assessment component determined by instructor: | 60 hours  |                                 |          |                            |          |  |          |        |           |
| Total:   | 150 hours   |                                 |          |                            |          |  |          |        |           |
| Credit Points                                  | 5 CP  |                                 |          |                            |          |  |          |        |           |
| Scope of Time                                  | One semester (Recommended: 3 <sup>rd</sup> Global Change Ecology semester)  |                                 |          |                            |          |  |          |        |           |
| Semester Offered                               | Summer semester (V)   |                                 |          |                            |          |  |          |        |           |
| Target Group                                   | Global Change Ecology, Scientific Computing   |                                 |          |                            |          |  |          |        |           |
| Reference to Other Modules                     | M22 Mathematical Modeling for Climate and Environment (exercise)  |                                 |          |                            |          |  |          |        |           |

## A10 Land Use Change and Microclimate

|                            |  |
|----------------------------|--|
| Responsible for the Module | Micrometeorology, UBT  |
| Structural Content         | Micrometeorology, UBT<br>Atmospheric Chemistry, UBT  |
| Learning Objectives        | The learning outcome of this class is to comprehend the fundamental interactions between anthropogenic land use and land cover changes and the cycling of heat, water, carbon and reactive gas species at the land surface, to collect and analyze field observations, and to apply this knowledge across contrasting land uses and covers.  |
| Course Content             | Land use and land cover (LULC) change from local to global scales is an important aspect of global change and acts as both a responder to social-economic demands and as a driver of societal development. At the heart of this feedback processes is the biogeochemical cycling of heat, water, carbon, and reactive species creating specific microclimates between the land surface and the near-surface air, both of which comprise the 'critical zone' containing almost all terrestrial life including human activities. The microclimate and thus the state of the critical zone is important for identifying sustainable solutions in a rapidly changing world impacted by urbanization, agricultural expansion, afforestation, and desertification. Students will first develop a conceptual problem- and process-oriented understanding of how LULC changes impact the microclimatic cycling of heat, water, carbon, and other trace gases in a classroom setting. Next, they will apply their skills by designing, conducting, analyzing, and interpreting field measurements of heat, water, and radiative fluxes across the soil-air-plant continuum across contrasting land use types (grassland, urban land cover) to understand the urban heat island and agricultural cool islands. Methods include commonly applied micrometeorological experimental techniques and models including the Bowen-ratio, Penman-Monteith evapotranspiration, and Soil-Vegetation-Atmosphere Transfer (SVAT) models. |
| Teaching Style             | V/S Land Use Change and Microclimate (2 SWS)<br>S/Ü Microclimatic field experiment across land uses (1 SWS)  |
| Prerequisites              | None   |
| Performance Assessment     | One overall module examination (graded) consisting of written homework assignments (pass/fail), oral seminar presentation (pass/fail) and written report (graded)  |
| Workload                   | Active participation in 2 courses: 60 hours<br>Preparation and follow-up incl. problem sets: 30 hours<br>Field activities 20 hours<br>Presentation and report writing 40 hours<br>Total: 150 hours   |
| Credit Points              | 5 CP   |
| Scope of Time              | One semester (Recommended: 2nd Global Change Ecology semester)   |
| Semester Offered           | Summer semester (V/Ü/S)  |

|                            |  |
|----------------------------|--|
| Target Group               | Global Change Ecology, Geoecology, Environmental Geography   |
| Reference to Other Modules | A1 Climate Change<br>A2 Ecological Climatology<br>A5 Changes in Agroecosystems<br>A9 Mathematical Modelling for Climate and Environment<br>M2 Statistical Data Analysis with R |

### 4.3 Module Area B „Ecological Change“

Here, the ecological effects of Global Change are addressed. Courses focus on the responses of organisms and ecological systems to changes in environmental conditions and to human influence, to changes in the energetic and material framework as well as to changing natural disturbance regimes. The impact of changing climate and land-use as well as the influence of growing global connectivity on species and biodiversity is discussed. Functional consequences are identified. The significance of new, more efficient vectors for expansion of organisms will be dealt with as well as the role of invasive species in creating novel systems.

The loss of biodiversity is connected to considerable functional consequences and can intensify the effect of other drivers such as climate change. Changes in land-use are a prominent driving force behind the loss of biodiversity.

Climate Change goes way beyond short-term impact on structural content and functionality of ecological systems. That is why it is important to assess the resilience of ecosystems in order to mitigate and adapt to rapid changes. Among other processes, organismic processes determine the sequestration, storage and release of carbon.

Along with a background in biology, knowledge in methods of modelling and geostatistics is expected. There is an opportunity to gain experience in data acquisition in the field and in experiments.

Overview of Modules (each worth 5-credit points):

- B1 Biogeography and Macroecology
- B2 Biodiversity and Ecosystem Functioning
- B3 Disturbance Ecology
- B4 Spatial Ecology
- B5 Global Change Impacts on Species Distributions
- B6 Soil Carbon and Global Change
- B7 Remote Sensing in Landscape Ecology
- B8 Dynamic Vegetation Ecology
- B9 Paleoecology and Paleobiology

Total Extent of Course:

At least 15 credit points. These can be expanded among the area of specialised interest. A graded Performance Assessment is required in each of the selected Modules.

## B1 Biogeography and Macroecology

|                            |  |
|----------------------------|--|
| Responsible for the Module | Biogeography, UBT  |
| Structural Content         | Biogeography, UBT  |
| Learning Objectives        | <p>Module aim is to teach about development and distribution of the variety of life on earth. Students learn about the spatial features of organisms and biotic communities on different spatial scales. The role of biodiversity for a functioning ecosystem will be discussed along with global change and its impact.</p> <p>The lecture deals with the evolution of variety on earth, prior major extinctions, the significance of the variety of ecosystem functions and current trends.</p> <p>In the seminar „Progress in Biogeography“, current developments in Biogeography will be dealt with. Students gain practice in working with literature data banks and online-journals. Putting together and presenting a presentation trains students in the production of survey articles based on current scientific primary literature.</p> |
| Course Content             | <p>Through global climate change, material flow, land-use and the linking between habitats will greatly impact the biodiversity on earth that has had millions of years to develop. Local, regional and global losses are the result. Possible consequences will be worked out in the course.</p> <p>Biogeography is undergoing great change, as more and more questions about the complex relationships on a global scale are being asked. We will deal intensively with current methods of development.</p>  |
| Teaching Style             | V Development and Change of Biodiversity (2 SWS, 3 CP)<br>S Progress in Biogeography (2 SWS, 2 CP)   |
| Prerequisites              | None   |
| Performance Assessment     | Seminar presentation (ungraded) and written exam of the lecture (graded)   |
| Work Load                  | Active participation in 2 courses: 60 hours<br>Preparation and follow-up: 40 hours<br>Preparation of the presentation: 20 hours<br>Preparation for the written exam: 30 hours<br>Total: 150 hours  |
| Credit Points              | 5 CP   |
| Scope of Time              | One semester (Recommended: 1st Global Change Ecology semester)   |
| Semester Offered           | Winter semester  |
| Target Group               | Global Change Ecology, Environmental Geography, Biodiversity and Ecology, Geoecology   |
| Reference to Other Modules | none   |

## B2 Biodiversity and Ecosystem Functioning

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Disturbance Ecology, UBT   |           |
| Structural Content         | Disturbance Ecology, UBT; Biogeography, UBT;   |           |
| Learning Objectives        | <p>The learning outcome of the module Experimental Ecology is to reach an overview over recent experimental approaches in community ecology. In particular, globally coordinated, geographically distributed experiments such as HerbDivNet, BioDEPTH, EVENT, SUSALPS, DroughtNet or NutrientNet have proven to be very stimulating for understanding design and analysis of standardized experiments and testing ecological theory. Goal of this module is an in-depth look at the relationship between biodiversity and ecological functioning, understanding the scientific approaches and findings on impacts of climate change and land use change on ecosystem services. This course will be composed of several elements including theoretical instruction on experimental design and analysis, participation in ongoing field campaigns as well as collecting and analyzing own data. At the conclusion of this module, students will have a thorough understanding of experimental ecology.</p> |           |
| Course Content             | <p>General concepts of experimental ecology will be introduced initially using ongoing field experiments as model ecosystems. Here, the focus of interest are effects of global change drivers on biodiversity and ecosystem functions. Guided by instructors, students will develop their own hypothesis within an ongoing research activity, collect and evaluate their own data. In doing so, students will learn about the potential and limitation of experimental approaches. Thus, students will become familiar with different methods of collecting and evaluating data in experimental ecology</p>   |           |
| Teaching Style             | Ü Experimental Ecology<br>(4 SWS, 5 CP, in small groups)   |           |
| Prerequisites              | Knowledge based on Module B1 or B3, basic knowledge in R is strongly advised, advanced knowledge very welcome.   |           |
| Performance Assessment     | Written elaboration: scientific report (graded) and data evaluation (manuscript form)  |           |
| Workload                   | Active participation in 1 course:  | 120 hours |
|                            | Assessment component determined by instructor:   | 30 hours  |
|                            | Total:   | 150 hours |
| Credit Points              | 5 CP   |           |
| Scope of Time              | One semester (Recommended: 2nd or 4th Global Change Ecology semester)  |           |
| Semester Offered           | Summer semester  |           |
| Target Group               | Global Change Ecology  |           |
| Reference to Other Modules | Based on B1 Biogeography and Macroecology or B3 Disturbance Ecology  |           |

## B3 Disturbance Ecology

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Disturbance Ecology, UBT   |           |
| Structural Content         | Disturbance Ecology, UBT;  |           |
| Learning Objectives        | <p>At the conclusion of this module, students will comprehend how ecosystems in all biomes are affected by natural and anthropogenic disturbance regimes, which create their own dynamics and spatio-temporal phenomena. This knowledge will enable participants to understand effects of disturbances and extreme events on biodiversity and ecosystem functions, regeneration dynamics, and mechanisms of stability such as functional resilience. The learning outcome of the seminar is to reach an overview over recent scientific literature covering disturbance ecology and puls dynamics increasingly interacting with climate change and land-use change. This understanding will enable students to evaluate system behavior, to contribute to developing adaptation strategies and to tackle current research frontiers in disturbance ecology. At the conclusion of this module, students will comprehend how ecosystems in all biomes are affected by natural and anthropogenic disturbance regimes, which create their own dynamics and spatio-temporal phenomena. This knowledge will enable participants to understand effects of disturbances and extreme events on biodiversity and ecosystem functions, regeneration dynamics, and mechanisms of stability such as functional resilience. The learning outcome of the seminar is to reach an overview over recent scientific literature covering disturbance ecology and puls dynamics increasingly interacting with climate change and land-use change. This understanding will enable students to evaluate system behavior, to contribute to developing adaptation strategies and to tackle current research frontiers in disturbance ecology.</p> |           |
| Course Content             | <p>Theory, methodology and application of disturbance ecology and pulse dynamics as well as the relationship between disturbance, vegetation dynamics and ecosystem functions are taught in the lecture "Disturbance Ecology". Current research frontiers in disturbance ecology, resilience and sustainability science are presented and discussed in the seminar "Resilience". The significance of understanding disturbance ecology for ecosystem restoration and sustainable land-use planning is also addressed. Temporal variability of ecosystems, their rhythms and recurrent events are discussed with respect to future global changes to assess the dynamics of ecological systems.</p>   |           |
| Teaching Style             | <p>V Disturbance Ecology (2 SWS, 2 CP)<br/> S/Ü Stability, Resilience and Inertia (2 SWS, 3 CP)</p>  |           |
| Prerequisites              | None   |           |
| Performance Assessment     | Seminar presentation (graded) and written exam of the lecture (ungraded)   |           |
| Workload                   | Active participation in 2 courses:   | 60 hours  |
|                            | Preparation and follow-up:   | 60 hours  |
|                            | Seminar presentation:  | 30 hours  |
|                            | Total:   | 150 hours |

|                            |   |
|----------------------------|---|
| Credit Points              | 5 CP  |
| Scope of Time              | One semester  |
| Semester Offered           | Winter semester   |
| Target Group               | Global Change Ecology, Environmental Geography, Biodiversity and Ecology, Geoecology. |
| Reference to Other Modules | A3 Extreme Events and Natural Hazards<br>B2 Biodiversity and Ecosystem Functioning    |

## B4 Spatial Ecology

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Biogeography, UBT  |           |
| Structural Content         | Biogeography, UBT  |           |
| Learning Objectives        | <p>Spatial processes play an important role in ecology, e.g. for the persistence of single populations, expansion of invasive species or preservation of species diversity.</p> <p>During this module, students should develop a problem-oriented understanding for the essential spatial processes like expansion and they should also develop skills to apply and develop dynamic models.</p>                  |           |
| Course Content             | <p>The Seminar „Spatial Ecology“ works with examples of ecological spatial phenomena (e.g. source-sink dynamics, metapopulations, invasions, coexistence).</p> <p>The exercise „Modelling of Spatial Ecological Processes“ covers numerical simulations of spatial processes (e.g. cellular automaton models, species distribution models). The relevant modelling approaches will be applied and discussed.</p> |           |
| Teaching Style             | <p>S Spatial Ecology (2 SWS; 2 CP)</p> <p>Ü Modelling of Spatial Ecological Processes (2 SWS, 3 CP)</p>  |           |
| Prerequisites              | <p>Knowledge in programming language R (obligatory)</p> <p>Basic knowledge about ecological processes and models (obligatory)</p> <p>M4 Foundations of Biogeographical Modelling (recommended)</p>   |           |
| Performance Assessment     | <p>Seminar presentation (ungraded) and written elaboration (report) (graded)</p>   |           |
| Workload                   | Active participation in 2 courses:   | 60 hours  |
|                            | Preparation and follow-up:   | 30 hours  |
|                            | Assessment component determined by instructor:   | 60 hours  |
|                            | Total:   | 150 hours |
| Credit Points              | 5 CP   |           |
| Scope of Time              | One semester (Recommended: 3 <sup>rd</sup> Global Change Ecology semester)   |           |
| Semester Offered           | Winter semester  |           |
| Target Group               | Global Change Ecology  |           |
| Reference to Other Modules | <p>B1 Biogeography and Macroecology</p> <p>B2 Biodiversity and Ecosystem Functioning</p> <p>M4 Foundations of Biogeographical Modeling</p> <p>M23 Dynamic Ecosystem Modeling</p>   |           |

## B5 Global Change Impacts on Species Distributions

|                            |  |
|----------------------------|--|
| Responsible for the Module | Biogeography, UBT  |
| Structural Content         | Biogeography, UBT  |
| Learning Objectives        | Ability to analyze changes in the distribution of species (displacement, extinction, invasion), dependent upon environmental conditions, particularly land cover.  |
| Course Content             | Land cover classification, land cover change (e.g. deforestation), texture, species distribution modelling, displacements, extinction and invasion processes, anthropogenic influences on species distributions. |
| Teaching Style             | V Global Change Impacts on Species Distributions (2 SWS; 2 CP)<br>Ü Global Change Impacts on Species Distributions (2 SWS; 3 CP)   |
| Prerequisites              | Knowledge in programming language R<br>M2 Statistical Data Analysis with R<br>M5 Remote Sensing  |
| Performance Assessment     | Exercise: Written elaboration (report) (graded)<br>Lecture: Contribution (ungraded)  |
| Workload                   | Active participation in 2 courses: 60 hours<br>Preparation and follow-up: 30 hours<br>Assessment component determined by instructor: 60 hours<br>Total: 150 hours  |
| Credit Points              | 5 CP   |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)   |
| Semester Offered           | Summer semester  |
| Target Group               | Global Change Ecology  |
| Reference to Other Modules | M5 Remote Sensing<br>B4 Spatial Ecology<br>B7 Remote Sensing in Landscape Ecology  |

## B6 Soil Carbon and Global Change

|  |  |                                    |          |                            |          |  |          |        |           |
|--|--|------------------------------------|----------|----------------------------|----------|--|----------|--------|-----------|
| Responsible for the Module                     | Soil Ecology, UBT  |                                    |          |                            |          |  |          |        |           |
| Structural Content                             | Soil Ecology, UBT  |                                    |          |                            |          |  |          |        |           |
| Learning Objectives                            | Knowledge of carbon reserves in the soil of different biomes, influence factors on soil carbon levels and soil carbon reserves and greenhouse gas emissions. Impact on reserves by global climate changes as well as land-use. Technique of carbon inventory in soil, characterization of soil organic matter.   |                                    |          |                            |          |  |          |        |           |
| Course Content                                 | <p>Lecture: Carbon reserves in the soil, mechanisms of carbon stabilisation in soil, influence of climate and land-use change. Characteristics of soil organic matter, the role of dissolved organic carbon compounds and greenhouse gas emissions.</p> <p>Seminar: Current questions of carbon turnover in soil and manipulation by human beings: variety of topics.</p> <p>Tutorial: Carbon storage in different soil. Determining carbon levels in different soil. Extraction of water-soluble fractions. Qualitative features of organic substances.</p> |                                    |          |                            |          |  |          |        |           |
| Teaching Style                                 | <p>V Soil Organic Matter and Greenhouse Gases – part II (2 SWS, 2 CP),</p> <p>S Soil Carbon and Global Change (1 SWS, 1 CP)</p> <p>Ü Soil Carbon and Global Change (1 SWS, 2 CP)</p>   |                                    |          |                            |          |  |          |        |           |
| Prerequisites                                  | Basic knowledge of soil science  |                                    |          |                            |          |  |          |        |           |
| Performance Assessment                         | <p>Lecture: Written exam (graded)</p> <p>Seminar: Seminar presentation (ungraded)</p> <p>Exercise: Written elaboration (report) (ungraded)</p>   |                                    |          |                            |          |  |          |        |           |
| Workload                                       | <table><tr><td>Active participation in 3 courses:</td><td>60 hours</td></tr><tr><td>Preparation and follow-up:</td><td>50 hours</td></tr><tr><td>Assessment component determined by instructor:</td><td>40 hours</td></tr><tr><td>Total:</td><td>150 hours</td></tr></table>   | Active participation in 3 courses: | 60 hours | Preparation and follow-up: | 50 hours | Assessment component determined by instructor: | 40 hours | Total: | 150 hours |
| Active participation in 3 courses:             | 60 hours   |                                    |          |                            |          |  |          |        |           |
| Preparation and follow-up:                     | 50 hours   |                                    |          |                            |          |  |          |        |           |
| Assessment component determined by instructor: | 40 hours   |                                    |          |                            |          |  |          |        |           |
| Total:   | 150 hours  |                                    |          |                            |          |  |          |        |           |
| Credit Points                                  | 5 CP   |                                    |          |                            |          |  |          |        |           |
| Scope of Time                                  | One semester (Recommended: 2nd Global Change Ecology semester)   |                                    |          |                            |          |  |          |        |           |
| Semester Offered                               | Summer semester  |                                    |          |                            |          |  |          |        |           |
| Target Group                                   | Global Change Ecology  |                                    |          |                            |          |  |          |        |           |
| Reference to Other Modules                     | A5 Changes in Agroecosystems   |                                    |          |                            |          |  |          |        |           |

## B7 Remote Sensing in Landscape Ecology

|                            |   |           |
|----------------------------|---|-----------|
| Responsible for the Module | Biogeography, UBT   |           |
| Structural Content         | Biogeography, UBT   |           |
| Learning Objectives        | Possibilities of continual surface data collection through remote sensing for biodiversity research are taught. An important objective is to inform about the different ways of closing spatial gaps in field data collection by using remote sensing data. A suitable sampling design comes along with in-situ field data collection as well as processing steps in the evaluation of different data sets (field and remote sensing data). The latter includes statistical procedures and spatial models.  |           |
| Course Content             | Results of biological assessments and records from applied sciences such as forestry, nature conservation, agriculture in the field (Basal area, forest successional stages, species, drought impact, tree mortality etc.) are linked with remote sensing data (hyperspectral data, results from remotely sensed field data and products such as FAO land cover classification system LCCS or Global Land Cover - Sentinel 2; LAI records and hemispheric measuring). With selected examples, the potential and limitations of using aircraft- and satellite-based missions for the collection of biodiversity patterns will be shown. Processing steps like dimension reduction, index calculation as well as spatial filters and measures to determine heterogeneity of habitats and ecosystems will be taught. |           |
| Teaching Style             | Ü In-situ Field Data Recording(2 SWS, 2 CP)<br>Ü Remote Sensing Data Analysis (graded written report) (2 SWS, 3 CP)   |           |
| Prerequisites              | Skills in R, GIS;<br>M5 Remote Sensing  |           |
| Performance Assessment     | Written elaboration: Data protocol (ungraded) und written report (graded)   |           |
| Workload                   | Active Participation in field data recording:   | 60 hours  |
|                            | Active Participation in remote sensing data analyses  | 40 hours  |
|                            | Preparation and follow-up:  | 20 hours  |
|                            | written report:   | 30 hours  |
|                            | Total:  | 150 hours |
| Credit Points              | 5 CP  |           |
| Scope of Time              | One semester (Recommended: 2nd/3rdGlobal Change Ecology semester)   |           |
| Semester Offered           | Summer semester   |           |
| Target Group               | Global Change Ecology   |           |
| Reference to Other Modules | B2 Biodiversity and Ecosystem Functioning   |           |

## B8 Dynamic Vegetation Ecology

|                            |   |
|----------------------------|---|
| Responsible for the Module | Plant Ecology, UBT  |
| Structural Content         | Plant Ecology, UBT  |
| Learning Objectives        | The module's aim is to teach students about the drivers that influence earth's vegetation distribution as well as to communicate the role of terrestrial vegetation in earth's ecosystems. Students who successfully participate in this course will be able to critically assess and interpret dynamic vegetation models (DGVMs).  |
| Course Content             | <p>The Lecture focuses on the most important ecological processes regarding terrestrial vegetation. The lecture stresses that understanding vegetation dynamics and distribution requires knowledge of biophysical laws and knowledge of the evolutionary history of individual ecosystems. Major topics include photosynthesis, respiration, allocation, birth, death, fire, herbivory and ecosystem assembly.</p> <p>In the seminar we review and discuss seminal contributions to vegetation ecology and use this knowledge to articulate research priorities for plant ecology in the context of global change.</p> |
| Teaching Style             | V Dynamic Vegetation Ecology (2 SWS. 2 CP)<br>S Foundations of Dynamic Vegetation Ecology (2 SWS. 3CP)  |
| Prerequisites              | None  |
| Performance Assessment     | Written elaboration (report) (graded) and seminar presentation(s) (ungraded)  |
| Work Load                  | Active participation in 2 courses: 60 hours<br>Preparation and follow-up: 60 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 150 hours   |
| Credit Points              | 5 CP  |
| Scope of Time              | One semester (Recommended: 2nd Global Change Ecology semester)  |
| Semester Offered           | Summer semester   |
| Target Group               | Global Change Ecology, Environmental Geography, Biodiversity and Ecology, Geoecology, Physical Geography. Limited number of participants.   |
| Reference to Other Modules | M20 Methods in Dynamic Vegetation Ecology<br>M23 Dynamic Ecosystem Modeling   |

## B9 Paleocology and Paleobiology

|                            |   |
|----------------------------|---|
| Responsible for the Module | Sport Ecology, UBT  |
| Structural Content         | Sport Ecology, UBT  |
| Learning Objectives        | Upon completion of the module Paleobiology and Paleocology, students understand the potentials and limitations of fossils as a research object. They are able to address important research questions and current debates in Quantitative Paleobiology and Paleocology and illustrate them with practical examples. They can analyse paleontological data with modern quantitative methods using existing scripts and name the most important challenges in taking the fossil record as a basis for analyses.   |
| Course Content             | The module imparts the use of fossils as research objects (e.g. taphonomy, fossil diagenesis, states of preservation, analytical methods) and the meaning of paleobiological and paleoecological analyses for understanding recent ecosystems. Students collaboratively acquire an insight into research questions of paleontology and learn quantitative methods for the analysis of fossil databases ( <a href="http://www.paleobiodb.org">www.paleobiodb.org</a> ) with the help of the programming language R ( <a href="http://www.r-project.org">www.r-project.org</a> ). |
| Teaching Style             | <ol style="list-style-type: none"><li>1. Paläobiologie und Paläoökologie (Paleobiology and Paleocology), Hauptseminar (seminar), 2 SWS</li><li>2. Analyse paläontologischer Daten (Analysis of Paleontological Data), Kleingruppenübung (exercise), 2 SWS</li></ol>   |
| Prerequisites              | A basic ecological understanding as well as skills in statistical modelling and in the application of the programming language R are expected.  |
| Performance Assessment     | Written elaboration (report) or seminar presentation or written exam or oral exam (announcement at the outset of module) (graded)   |
| Work Load                  | active participation in courses, 60 hours<br>preparation and follow-up and 60 hours<br>exam preparation 30 hours<br>Total: 150 hours  |
| Credit Points              | 5 CP  |
| Semester Offered           | The module will generally be held in the summer term and possibly in English.   |
| Target Group               |   |
| Reference to Other Modules |   |

## 4.4 Module Area C „Societal Change“

Global environmental changes have on one hand, anthropogenic causes and on the other, society at large bears the consequences of climate change and changes in ecological systems. Module Area C discusses the global interplay between social and ecological changes. The social-economic reasons for global climate and land-use change and their ecological consequences for ecosystem functionality, regional climate and biodiversity are covered in this Module. On this basis, the economic consequences of ecological changes are studied, in particular, the changing availability of natural resources (e.g. drinking water) and of ecosystem services (e.g. food production, providing substances for pharmaceutical use, erosion protection, carbon sequestration or of landscape aesthetical value).

To better understand the driving forces behind global environmental change, the fundamentals of the functioning of global economic systems as well as formal and informal political systems are covered. Social strategies in dealing with global syndromes (special adaptation to global change) and the available instruments used in markets and politics to influence global change are discussed. Module Area Methods (M) additionally covers practical use of accounting tools (e.g. eco-balance) that keep the social actors informed about the environmental consequences of their decisions and which they use as a basis for decision-making. This Module Area focuses on quality and quantity of methods of social research and economics as well as the spatial and temporal modelling of socio-ecological systems.

Module Overview (each worth 5 credit points):

- C1 Climate Policies and Economics
- C2 Ecosystem Services
- C3 Global Economy
- C4 Global Policy and Governance
- C5 Socio-Economic and Political Dimensions of Global Change
- C6 Sport Ecology
- C7 Land Use Policies, Markets and Ecosystems
- C8 Biodiversity, Climate Change and Health

Total Extent of Course:

At least 15-credit points. These can be expanded among the area of specialised interest. A graded Performance Assessment is required in each of the selected Modules.

## C1 Climate Policies and Economics

|  |  |                                    |          |                            |          |  |          |        |           |
|--|--|------------------------------------|----------|----------------------------|----------|--|----------|--------|-----------|
| Responsible for the Module                     | Ecological Services, UBT   |                                    |          |                            |          |  |          |        |           |
| Structural Content                             | Teaching assignments   |                                    |          |                            |          |  |          |        |           |
| Learning Objectives                            | <p>After attending the lecture (i), students are familiar with various instruments for achieving climate policy goals, (ii) can analyze them in terms of efficiency, distribution effect and uncertainties, and (iii) are able to critically discuss the advantages and disadvantages of real-world political instruments along economic criteria.</p> <p>The course will introduce key concepts such as the “tragedy of the commons” and “collective action problems”, and discuss key academic developments in the understanding of the management of global commons. The course will ensure that the students develop a firm grasp of the fundamental dynamic of climate change negotiations while introducing the main legal instruments that form the backbone of the climate regime. Students will be able to critically assess how the Paris Agreement can mobilize action.</p>   |                                    |          |                            |          |  |          |        |           |
| Course Content                                 | <p>In the first part of the lecture, economic criteria for determining efficient and fair climate policy goals are developed. Then climate policy instruments are dealt with (e.g. regulatory policy; CO2 tax; emissions trading) and instrument selection is discussed with imperfect information. In interactive phases, economic concepts are deepened along with current case studies, such as the German coal phase-out, national CO2 pricing (climate package) or European emissions trading (EU ETS).</p> <p>In the second part of the module, an introduction into the climate regime (United Nations Framework Convention on Climate Change, Kyoto Protocol, Paris Agreement) in the context of international environmental governance will be given. This will be discussed against the backdrop of geopolitical developments.</p> <p>Global environmental commons, Introduction into the International Climate Regime, discuss the role of state and non-state actors, Case Studies, Critical Assessment and Concluding Discussion.</p> |                                    |          |                            |          |  |          |        |           |
| Teaching Style                                 | <p>V/S Climate Policy and Instruments (2 SWS, 2 CP)</p> <p>V/S Climate Diplomacy (2 SWS, 3 CP)</p>   |                                    |          |                            |          |  |          |        |           |
| Prerequisites                                  | None   |                                    |          |                            |          |  |          |        |           |
| Performance Assessment                         | Contribution (ungraded) and written elaboration (report) (graded)  |                                    |          |                            |          |  |          |        |           |
| Workload                                       | <table border="0"> <tr> <td>Active participation in 2 courses:</td> <td>60 hours</td> </tr> <tr> <td>Preparation and follow-up:</td> <td>30 hours</td> </tr> <tr> <td>Assessment component determined by instructor:</td> <td>60 hours</td> </tr> <tr> <td>Total:</td> <td>150 hours</td> </tr> </table>   | Active participation in 2 courses: | 60 hours | Preparation and follow-up: | 30 hours | Assessment component determined by instructor: | 60 hours | Total: | 150 hours |
| Active participation in 2 courses:             | 60 hours   |                                    |          |                            |          |  |          |        |           |
| Preparation and follow-up:                     | 30 hours   |                                    |          |                            |          |  |          |        |           |
| Assessment component determined by instructor: | 60 hours   |                                    |          |                            |          |  |          |        |           |
| Total:   | 150 hours  |                                    |          |                            |          |  |          |        |           |
| Credit Points                                  | 5 CP   |                                    |          |                            |          |  |          |        |           |
| Scope of Time                                  | One semester (Recommended: 1st semester)   |                                    |          |                            |          |  |          |        |           |
| Semester Offered                               | Winter semester  |                                    |          |                            |          |  |          |        |           |
| Target Group                                   | Global Change Ecology  |                                    |          |                            |          |  |          |        |           |
| Reference to Other Modules                     | A2 Ecological Climatology  |                                    |          |                            |          |  |          |        |           |

C2 Ecosystem Services

C3 Global Economy

## C2 Ecosystem Services

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Ecological Services, UBT   |           |
| Structural Content         | Ecological Services, UBT   |           |
| Learning Objectives        | Global change in climate, land use, markets and politics has a major impact on the performance of ecosystems. The aim of this module is to examine in greater depth the ecosystem services relevant to societies (food production, erosion regulation, drinking water purification, risk protection, etc) and their relationship to biodiversity.  |           |
| Course Content             | <p>The lecture „Ecosystem Services” gives an overview of ecosystem services in regional and global human-environmental systems. Contents include the definition and classification of ecosystem services, their relationship to biodiversity and the role of global change. Furthermore, the physical quantification and socio-economic evaluation, the supply and demand by social actors as well as the management of the performance of the ecosystem by market-related policy instruments are dealt with.</p> <p>The seminar deepens lecture topics with current examples from research.</p> |           |
| Teaching Style             | <p>V Ecosystem Services (2 SWS, 2 CP)</p> <p>S Current Research in Ecosystem Services (2 SWS, 3 CP)</p>  |           |
| Prerequisites              | None   |           |
| Performance Assessment     | <p>Lecture: Written exam (graded)</p> <p>Seminar: Contribution (ungraded)</p>  |           |
| Workload                   | Active participation in 2 courses:   | 60 hours  |
|                            | Preparation and follow-up:   | 30 hours  |
|                            | Assessment component determined by instructor:   | 60 hours  |
|                            | Total:   | 150 hours |
| Credit Points              | 5 CP   |           |
| Scope of Time              | One semester   |           |
| Semester Offered           | Winter semester  |           |
| Target Group               | Global Change Ecology  |           |
| Reference to Other Modules | <p>A5 Changes in Agroecosystems</p> <p>B2 Biodiversity and Ecosystem Functioning</p> <p>C3 Global Economy</p> <p>C7 Land Use Policies, Markets and Ecosystems</p>  |           |

## C3 Global Economy

|                            |   |
|----------------------------|---|
| Responsible for the Module | Ecological Services, UBT  |
| Structural Content         | Ecological Services, UBT;<br>VWL VI: Empiric Economic Research, UBT   |
| Learning Objectives        | <p>The increasing demand for goods and services as well as the globalization of markets has far-reaching economic, ecological and social effects. On the one hand, developing countries could benefit economically from increased export of raw materials (e.g. biofuels) or through direct investment from industrial nations (e.g. in the agricultural sector), on the other hand, ecosystems could be sustainably damaged due to low environmental standards in developing countries.</p> <p>The aim of this module is to understand the flows of goods and services in global financial and raw materials markets and their economic and ecological effects, and to critically examine environmental policy instruments.</p>  |
| Course Content             | <p>The lecture teaches the basics of the function and actors as well as environmental innovations in the global financial sector. The lecture also provides an introduction to environmental economic theories and policies in an international context. This knowledge enables students to critically examine the influence of globalization in the area of goods and finance on the environment and ecosystems.</p> <p>The seminar discusses what effects global trade, particularly of raw materials, induces due to the use of terrestrial and marine ecosystems. In order to reduce negative effects, environmental policy measures such as environmental standards play a special role. However, national environmental policies and different environmental policy standards between trading partners can also distort competition. Global market changes, environmental impacts and policy measures are critically reflected.</p> |
| Teaching Style             | V Globalization of Economies and the Environment (2 SWS, 2 CP)<br>S Globalization of Economies and the Environment (2 SWS, 3 CP)  |
| Prerequisites              | None  |
| Performance Assessment     | <p>Lecture: Contribution (plenary discussion (including written questions) (ungraded)</p> <p>Seminar: Seminar presentation (graded) and written elaboration (report) (graded), each 50%.</p> <p>The overall grade for the seminar is only awarded when both parts have been passed and graded.</p>  |
| Workload                   | Active participation in 2 courses: 60 hours<br>Preparation and follow-up: 30 hours<br>Assessment component determined by instructor: 60 hours<br>Total: 150 hours   |
| Credit Points              | 5 CP  |
| Scope of Time              | One semester  |
| Semester Offered           | Summer semester   |

Target Group

Global Change Ecology

Reference to Other Modules

C2 Ecosystem Services

## C4 Global Policy and Governance

|                            |   |           |
|----------------------------|---|-----------|
| Responsible for the Module | Ecological Services, UBT  |           |
| Structural Content         | Teaching assignments  |           |
| Learning Objectives        | The aim of the module is to lead students into the economic and political dimensions of global change. Global environmental change confronts societies with problems (e.g. loss of biodiversity, desertification, climate change or soil erosion) that can create considerable costs for society at large. Political solutions are needed to deal with conflicting interests. Environmental governance encompasses a variety of different approaches of social regulation from international treaties across borders to informal networks or market-based competition.  |           |
| Course Content             | <p>The seminar “Economics of Global Environmental Change” addresses important studies on the topics with a focus on climate change (e.g. the Stern Review), loss of biodiversity (e.g. The Economics of Ecosystems and Biodiversity TEEB), or land degradation (e.g. The Economics of Land Degradation ELD). Apart from their significance for politics and research, the focus is on the methodological and economic assessments and economic instruments of environmental policy.</p> <p>The seminar “Global Change Policy, Contracts and Administrative Strategies” provides an introduction to international political processes in the Convention on Biological Diversity (CBD) and the Intergovernmental Platform on Biodiversity &amp; Ecosystem Services (IPBES).</p> |           |
| Teaching Style             | <p>S Economics of Global Environmental Change C4a (2 SWS, 2 CP)</p> <p>S Global Change Policy, Contracts and Administrative Strategies (CBD and IPBES) C4b (2 SWS, 3 CP)</p>  |           |
| Prerequisites              | No special prerequisites  |           |
| Performance Assessment     | <p>Seminar C4a: Contribution (ungraded)</p> <p>Seminar C4b: Seminar presentation (graded)</p>   |           |
| Workload                   | Active participation in 2 courses:  | 60 hours  |
|                            | Preparation and follow-up:  | 30 hours  |
|                            | Assessment component determined by instructor:  | 60 hours  |
|                            | Total:  | 150 hours |
| Credit Points              | 5 CP  |           |
| Scope of Time              | One semester  |           |
| Semester Offered           | Summer semester   |           |
| Target Group               | Global Change Ecology   |           |
| Reference to Other Modules | <p>C3 Global Economy</p> <p>C5 Socio-economic and Political Dimensions of Global Change</p> <p>M14 International Environmental Law</p>  |           |

## C5 Socio-Economic and Political Dimensions of Global Change

|                            |  |           |
|----------------------------|--|-----------|
| Responsible for the Module | Social and Population Geography, UBT   |           |
| Structural Content         | Social and Population Geography, UBT   |           |
| Learning Objectives        | <p>The Anthropocene refers to a new geo-chronological era on Earth in which humans made the most significant impacts on geology, biological processes and ecosystems, not least anthropogenic climate change. The module aims to address foundations and concepts to understand possible causes and impacts of global change, as well as the quality of adaptation measures in various social contexts. Global and environmental change demands a variety of transformation, avoidance, and adaptive strategies that are at the centre of debates in the social sciences; in this connection, system-immanent reflections on neo-liberal economies that can be considered the drivers of global environmental change is also encouraged. The students are exposed to a cross-section of politico-economic and politico-ecological approaches based on relevant studies on global environmental change from the social sciences; they also learn social approaches and approaches from social theory to examine social transition and adaptation.</p> |           |
| Course Content             | <p>The seminar “Socio-Economic and Political Dimensions of Global Change” analyses society-environment interrelationships from the perspective of political ecology. Areas of tension are access to natural resources, the distribution of environmental risks, or defining environmental rights and duties. Environmental conflicts often include various spatial and social scale levels, from the local neighbourhood to international relations. In addition, fundamental processes of transformation in the Global South that are not only related to climate and environmental change are also addressed. Moreover, an analysis requires interacting with various dimensions of global change in the context of geographical development research, considering specific social, economic, political, and cultural contexts, and their inherent power structures. Comparing current case studies from the Global South and the Global North helps illustrate the unjust socialization of global change.</p>                                     |           |
| Teaching Style             | S “Socio-Economic and Political Dimensions of Global Change” (2 SWS, 5 CP)   |           |
| Prerequisites              | None   |           |
| Performance Assessment     | Written elaboration (report) (graded), The module grade is only awarded when the written elaboration has been graded and the Contribution has been passed.   |           |
| Workload                   | Active participation in 1 course:  | 60 hours  |
|                            | Preparation and follow-up:   | 30 hours  |
|                            | Assessment component determined by instructor:   | 60 hours  |
|                            | Total:   | 150 hours |
| Credit Points              | 5 CP   |           |
| Scope of Time              | One semester   |           |
| Semester Offered           | Winter semester  |           |
| Target Group               | Global Change Ecology, Human Geography   |           |

Reference to Other Modules    C1 Climate Policies and Economics  
  C2 Ecosystem Services  
  C3 Global Economy

## C6 Sport Ecology

|                            |  |
|----------------------------|--|
| Responsible for the Module | Sport Ecology, UBT   |
| Structural Content         | Sport Ecology, UBT   |
| Learning Objectives        | Upon completion of the module Sport Ecology, students understand the interactions between sports and ecological systems and are able to illustrate them with practical examples. They can identify quantitative relationships regarding the effect of outdoor sports on ecological systems from scientific publications and reflect them critically.   |
| Course Content             | Student learn the complex and dynamic relationship between sport and the environment. The courses impart the importance of nature sports, their potential of conflict with goals in nature and environmental protection and the potential of sports in conveying ecological understanding and derived action strategies. Students collaboratively develop conceptual, functional, and methodological foundations to an economic view on ecology and nature protection and to an analysis of the interactions between human behaviour and ecological systems in the area of sports. |
| Teaching Style             | 1) Sportökologische Wechselwirkungen (Interactions of sport and ecology), Kleingruppenübung (Exercise), 2 SWS<br>2) Wirkungsanalyse von Outdoorsportarten (Impact Assessment of Outdoor Sports), Hauptseminar (Seminar), 2 SWS   |
| Prerequisites              | None   |
| Performance Assessment     | Written elaboration (report) or seminar presentation or written exam or oral exam (announcement at the outset of module) (graded)  |
| Workload                   | active participation in the courses, 60 hours<br>preparation and follow-up 60 hours<br>exam preparation; 30 hours<br>Total: 150 hours  |
| Credit Points              | 5 CP   |
| Semester Offered           | The module will generally be held in the winter term and possibly in English.  |
| Responsible for the Module | Sport Ecology, UBT   |
| Semester Offered           | Winter term  |
| Reference to Other Modules |  |

## C7 Land Use Policies, Markets and Ecosystems

|                            |   |           |
|----------------------------|---|-----------|
| Responsible for the Module | Ecological Services, UBT  |           |
| Structural Content         | Ecological Services, UBT  |           |
| Learning Objectives        | As an outcome of this module, students are able to: <ul style="list-style-type: none"> <li>• Evaluate different policies and market options in their effect on land use and ecosystem services</li> <li>• Interpret land use model results and put them in the context of real-world policies and markets</li> <li>• Identify feedback mechanisms and trade-offs in human environment systems</li> </ul>  |           |
| Course Content             | <p>Politics as well as national and international markets generally have a major impact on regional land use decisions and thus on the provision of ecosystem services. Individual land users (e.g., farmers, foresters, conservationists) are key actors in human environment systems, since they are the ones reacting to policies and market changes with their land use decisions.</p> <p>The lecture “Land Use Policies, Markets, and Ecosystems” addresses causes of changes in land use, in particular by using regional case studies to focus on the influence of markets and politics. In addition, various methods for quantifying land use change and its influence on ecosystem services are introduced and discussed.</p> <p>In the exercise, based on the current development of agricultural and environmental policies as well as markets, possible future land use scenarios are developed and analysed for case study regions. Existing models, such as agent-based models, will be adapted and parameterized. Changes in ecosystem services through land use decisions are integrated into the model using simple estimates.</p> |           |
| Teaching Style             | V Land Use Policies, Markets and Ecosystems C7a (2 SWS, 3 CP),<br>Ü Modelling Land Use, Markets and Ecosystems C7b (2 SWS, 2 CP)  |           |
| Prerequisites              | None  |           |
| Performance Assessment     | Lecture: Written elaboration (graded)<br>Seminar: Contribution in exercise (ungraded)   |           |
| Workload                   | Active Participation in 2 courses:  | 60 hours  |
|                            | Preparation and follow-up:  | 30 hours  |
|                            | Assessment component determined by instructor:  | 60 hours  |
|                            | Total:  | 150 hours |
| Credit Points              | 5 CP  |           |
| Scope of Time              | One Semester (Recommendation 3 <sup>st</sup> Global Change Ecology Semester)  |           |
| Semester Offered           | Winter semester   |           |
| Reference to Other Modules | B5 Global Change Impacts on Species Distributions<br>B7 Remote Sensing in Landscape Ecology<br>C1 Climate Policy and Economics<br>C2 Ecosystem Services   |           |

## C8 Biodiversity, Climate Change and Health

|                            |   |
|----------------------------|---|
| Responsible for the Module | Biogeography, UBT   |
| Structural Content         | Biogeography, UBT   |
| Learning Objectives        | At the end of this course, the students will have acquired a good understanding of how drivers such as loss of biodiversity, land use change or climate change can impact on human and animal health.   |
| Course Content             | <p>The lecture synthesizes information on the most important interlinkages between biodiversity, climate change and health. The current global situation of food and nutrition, water scarcity, pollution, migration and urbanization is synthesized and linked with human health. The lecture covers the concepts of One Health, Planetary Health and Ecohealth and includes an overview of reports from WHO, OIC, FAO, CBD, IPBES and related Sustainable Development Goals.</p> <p>In the seminar we review and discuss current contributions which cover impacts of global change on animal and human health especially for zoonotic infectious diseases and use this knowledge to articulate future research priorities.</p> |
| Teaching Style             | V Health implications of Global Change (2 SWS, 2 CP)<br>S Current Research in Health implications of Global Change (2 SWS, 3 CP)  |
| Prerequisites              | None  |
| Performance Assessment     | Lecture: Written elaborations and contributions (ungraded)<br>Seminar: Seminar presentation (graded)  |
| Workload                   | Active participation in course: 60 hours<br>Preparation and follow-up: 30 hours<br>Assessment components determined by instructor: 60 hours<br>Total: 150 hours   |
| Credit Points              | 5 CP  |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)  |
| Semester Offered           | Summer Semester   |
| Target Group               | Global Change Ecology   |
| Reference to Other Modules | C4 Global Policy and Governance<br>B1 Biogeography and Macroecology<br>B5 Global Change Impacts on Species Distributions  |

## 4.5 Module Area M “Methods”

This Module Area contains courses with a variety of content and range that are able to address the different needs of the students. Altogether, courses to the extent of 10-credit points are to be chosen from the methods-oriented partial modules listed below.

The selection is directed on one hand at previous knowledge students might already have and on the other, at course requirements. The individual design of methods training helps each individual supplement their knowledge and allows for efficient study of topic-oriented Modules. The spectrum of Methods in Global Change research is thereby covered. Particular attention is paid to data acquisition in eco-system research, in measuring and in field research about Global Change as well as in carrying-out of experiments. The significance of models in Global Change research is central to many of the courses.

Classes in Statistics Software R are taught as a basis for using many different evaluation procedures. Time series analysis covers investigation of temporal processes. Geographical information systems and remote sensing as modern tools of spatial analysis are included. Knowledge of chemical environmental analysis in different media can also be learned. Classes in environmental economics and environmental legislation enrich the spectrum of methods-oriented courses. Finally, general skills can be gained in the scientific writing and project-management classes.

## M Methods

Module area M is obligatory for all students and has an extent of 10-credit points. Students can choose freely in putting together the combination of different Modules listed below. For all -Modules in Module area M a Performance Assessment is required on a pass/fail basis

- M1 Introduction to R
- M2 Statistical Data Analysis with R
- M3 Vegetation Science
- M4 Foundations of Biogeographical Modelling
- M5 Remote Sensing
- M6 Time Series Analysis
- M7 Research at the Natural and Social Science Interface
- M8 Ecosystem Services Assessment of Landscapes
- M9 Life Cycle Assessment of Products
- M10 Scientific Writing in Biogeography and Disturbance Ecology
- M11 Project Management
- M12 Introduction to GIS
- M13 Advanced Multivariate Statistical Methods in Climate Research
- M14 International Environmental Law
- M15 Science and Communication
- M16 Modeling Ecosystem Services with the Soil and Water Assessment Tool (SWAT)
- M17 Academic Working Methods and Skills
- M18 Field Course in Vegetation Science
- M19 Quantitative Methods
- M20 Methods in Dynamic Vegetation Ecology
- M21 Spatial Statistics and Visualization with R
- M22 Mathematical Modeling for Climate and Environment (exercise)
- M23 Dynamic Ecosystem Modeling
- M24 Disturbance Ecology Field Trip – Europe
- M25 Disturbance Ecology Field Trip – Overseas

### Soft skill courses

- M10 Scientific Writing in Biogeography and Disturbance Ecology
- M11 Project Management
- M15 Science and Communication

## M17 Academic Working Methods and Skills

### Modelling, Remote Sensing and Geographic Information System

- M1 Introduction to R
- M2 Statistical Data Analysis with R
- M4 Foundations of Biogeographical Modelling
- M5 Remote Sensing
- M6 Time Series Analysis
- M12 Introduction to GIS
- M13 Advanced Multivariate Statistical Methods in Climate Research
- M16 Modeling Ecosystem Services with the Soil and Water Assessment Tool (SWAT)
- M19 Quantitative Methods
- M20 Methods in Dynamic Vegetation Ecology
- M21 Spatial Statistics and Visualization with R
- M22 Mathematical Modeling for Climate and Environment (exercise)
- M23 Dynamic Ecosystem Modelling

### Field Methods

- M3 Vegetation Science
- M18 Field Course in Vegetation Science
- M24 Disturbance Ecology Field Trip – Europe
- M25 Disturbance Ecology Field Trip – Overseas

### Methods at the Social Science Interface

- M7 Research at the Natural and Social Science Interface
- M8 Ecosystem Services Assessment of Landscapes
- M9 Life Cycle Assessment of Products
- M14 International Environmental Law

The Modules listed here can be taken additionally from the selection offered in Free Choice Module (F) as long as such courses have not already been given credit for Module M.

## M1 Introduction to R

|                            |  |
|----------------------------|--|
| Responsible for the Module | Biogeography, UBT  |
| Structural Content         | Biogeography, UBT  |
| Learning Objectives        | Aim of this course is to teach practically oriented information about data handling including the analysis and graphical presentation of data as well as simulation with the programming language R. |
| Course Content             | Assignments, objects, data types, data structures, and how to handle them; input and output of data; graphs; functions; efficient programming;   |
| Teaching Style             | V/Ü Introduction to R (2 SWS, 2 CP)  |
| Prerequisites              | None   |
| Performance Assessment     | Written elaboration (ungraded)   |
| Workload                   | Active participation in 1 course: 30 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 60 hours   |
| Credit Points              | 2 CP   |
| Scope of Time              | One semester (Recommended: 1 <sup>st</sup> Global Change Ecology semester)   |
| Semester Offered           | Winter semester  |
| Target Group               | Ecology-oriented master's programmes   |
| Reference to Other Modules | Basis for Modelling Courses  |

## M2 Statistical Data Analysis with R

|                            |   |
|----------------------------|---|
| Responsible for the Module | Ecosystem Analysis and Simulation, UBT  |
| Structural Content         | Ecosystem Analysis and Simulation, UBT  |
| Learning Objectives        | In this course, the participants will learn and practice different methods of data analysis. Also, participants will consolidate their use of the programming language R, which is the de facto standard for statistical data analysis. They will be enabled to understand basic concepts of statistics, to choose appropriate statistical methods to answer common ecological questions, to apply these methods in R and to interpret the results correctly. |
| Course Content             | Topics covered in the course include: using R and RStudio, descriptive statistics and visualization, hypothesis testing, linear models, generalized linear Models, mixed models, confounders, causality and Directed Acyclic Graphs (DAGs), data management and experimental design.  |
| Teaching Style             | V/Ü Statistical data analysis with R (2 SWS; 3 CP)  |
| Prerequisites              | None  |
| Performance Assessment     | Written report on a personal project (pass/fail)  |
| Workload                   | Active participation in course: 45 hours<br>Preparation and follow-up: 30 hours<br>Assessment component determined by instructor: 15 hours<br>Total: 90 hours   |
| Credit Points              | 3 CP  |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)  |
| Semester Offered           | Summer semester (Ü/S)   |
| Target Group               | Global Change Ecology, Geoecology   |
| Reference to Other Modules | B5 Global Change Impacts on Species Distributions<br>M6 Time Series Analysis<br>M13 Advanced Multivariate Statistical Methods in Climate Research   |

## M3 Vegetation Science

|                            |  |          |
|----------------------------|--|----------|
| Responsible for the Module | Disturbance Ecology, UBT   |          |
| Structural Content         | Disturbance Ecology, UBT<br>Biogeography, UBT;   |          |
| Learning Objectives        | Module aim is an advanced knowledge of theories and methods in vegetation science, vegetation mapping and vegetation monitoring. Students will be introduced to the full spectrum of historical and modern approaches in vegetation science. The lecture offers fundamentals for and bridging concepts to experimental community ecology, plant functional trait research, disturbance ecology, restoration ecology, ecosystem and landscape ecology, nature conservation, remote sensing and vegetation based ecosystem service analysis. Theory will be connected with practical experience in plant determination during various floristic field excursions.      |          |
| Course Content             | Contents of the module are current approaches in vegetation science, in vegetation mapping and in monitoring changes in vegetation pattern and dynamics. Student will develop an understanding of the functional characterization of habitats and of scale dependence in vegetation ecology. They will develop the ability to recognize the role of disturbance regimes for vegetation dynamics and develop an understanding of data processing requirements for linking vegetation ground data with remote sensing derived information. Thus, students will become familiar with different theories and methods of collecting and evaluating data in plant ecology. |          |
| Teaching Style             | V Vegetation Science (2 SWS, 3 CP)   |          |
| Prerequisites              | None   |          |
| Performance Assessment     | Written exam (ungraded)  |          |
| Workload                   | Active participation:  | 30 hours |
|                            | Preparation and follow-up:   | 30 hours |
|                            | Preparation for written exam:  | 30 hours |
|                            | Total:   | 90 hours |
| Credit Points              | 3 CP   |          |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)   |          |
| Semester Offered           | Summer semester  |          |
| Target Group               | Global Change Ecology  |          |
| Reference to Other Modules | B1 Biogeography and Macroecology<br>B2 Biodiversity and Ecosystem Functioning<br>B3 Disturbance Ecology<br>M18 Field Course in Vegetation Science  |          |

## M4 Foundations of Biogeographical Modelling

|                            |   |          |
|----------------------------|---|----------|
| Responsible for the Module | Biogeography, UBT   |          |
| Structural Content         | Biogeography, UBT   |          |
| Learning Objectives        | <p>"Biogeographical Modelling" concentrates on quantitative description of expansion and frequency of organisms on different spatial standards as well as recording of underlying mechanisms.</p> <p>Aim of the course is to teach practical knowledge about the most important modelling approaches, from data sources to data processing and from process oriented, individually based models to traditional statistical methods.</p> |          |
| Course Content             | Data sources, data processing, variable selection, vegetation models, distribution models, home range analyses  |          |
| Teaching Style             | V/Ü Foundations of Biogeographical Modelling (2 SWS, 2 CP)  |          |
| Prerequisites              | Knowledge in programming language R (obligatory)<br>V/S Concepts in Biogeographical Modelling (recommended)   |          |
| Performance Assessment     | Contribution (ungraded)   |          |
| Workload                   | Active participation in 1 course:   | 30 hours |
|                            | Assessment component determined by instructor:  | 30 hours |
|                            | Total:  | 60 hours |
| Credit Points              | 2 CP  |          |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)  |          |
| Semester Offered           | Summer semester   |          |
| Target Group               | Global Change Ecology   |          |
| Reference to Other Modules | Concepts in Biogeographical Modelling<br>B4 Spatial Ecology   |          |

## M5 Remote Sensing

|                            |   |
|----------------------------|---|
| Responsible for the Module | Biogeography, UBT   |
| Structural Content         | NN, University of UBT   |
| Learning Objectives        | Teaches theoretical and practical background of Remote Sensing, adapted to implementation in the context of global change   |
| Course Content             | Theoretical basics of Remote Sensing; Optical, Thermal, and Microwave Sensing; Sensor Systems and Properties of Remote Sensing Data; Image Processing and Classification using Open Source software and coding approaches |
| Teaching Style             | Ü Remote Sensing (2 SWS, 3 CP)  |
| Prerequisites              | None  |
| Performance Assessment     | Written elaboration (ungraded):<br>Data evaluation & Minutes of class meeting about a final project   |
| Workload                   | Active participation in 1 course: 30 hours<br>Preparation and follow-up: 20 hours<br>Assessment component determined by instructor: 40 hours<br>Total: 90 hours   |
| Credit Points              | 3 CP  |
| Scope of Time              | One semester (Recommended: 1 <sup>st</sup> Global Change Ecology semester)  |
| Semester Offered           | Winter semester   |
| Target Group               | Geography-oriented master's programmes  |
| Reference to Other Modules | B7 Remote Sensing in Landscape Ecology<br>M12 Introduction to GIS<br>M15 Science and Communication  |

## M6 Time Series Analysis

|  |  |                                    |          |                            |          |  |          |        |           |
|--|--|------------------------------------|----------|----------------------------|----------|--|----------|--------|-----------|
| Responsible for the Module                     | NN, UBT  |                                    |          |                            |          |  |          |        |           |
| Structural Content                             | NN, UBT  |                                    |          |                            |          |  |          |        |           |
| Learning Objectives                            | In this module, students should learn to evaluate, analyse and assess on their own typical environmental time series (climate and ecological data). In doing so, they will gain practice in using R.   |                                    |          |                            |          |  |          |        |           |
| Course Content                                 | <p>In this module linear and non-linear time series analysis will be taught and practiced by using different data sets from various environmental monitoring. Along with the classic procedure (auto and cross correlation, trend analyse, Fourier analyse, ARIMA-models) a focus is on non-linear methods recurring analysis, singular system analysis, wavelets, dimension reduction, etc.). The selection of procedure can change and is based on the interests of the students and current research projects.</p> <p>In the lecture the single procedures will be talked about and then with examples of short time series, this will be practiced in the tutorials. The second part of the module consists of a Block-Practicum. Students will choose appropriate methods to use for predetermined data sets and the results of the different procedures will be interpreted.</p> |                                    |          |                            |          |  |          |        |           |
| Teaching Style                                 | <p>V/Ü Time Series Analysis (2 SWS, 2 CP)</p> <p>P Time Series Analysis (2 SWS, 3 CP)</p>  |                                    |          |                            |          |  |          |        |           |
| Prerequisites                                  | Introductory course in statistics, basic knowledge in R  |                                    |          |                            |          |  |          |        |           |
| Performance Assessment                         | Seminar presentation (ungraded)  |                                    |          |                            |          |  |          |        |           |
| Workload                                       | <table border="0"> <tr> <td>Active participation in 2 courses:</td> <td>60 hours</td> </tr> <tr> <td>Preparation and follow-up:</td> <td>60 hours</td> </tr> <tr> <td>Assessment component determined by instructor:</td> <td>30 hours</td> </tr> <tr> <td>Total:</td> <td>150 hours</td> </tr> </table>   | Active participation in 2 courses: | 60 hours | Preparation and follow-up: | 60 hours | Assessment component determined by instructor: | 30 hours | Total: | 150 hours |
| Active participation in 2 courses:             | 60 hours   |                                    |          |                            |          |  |          |        |           |
| Preparation and follow-up:                     | 60 hours   |                                    |          |                            |          |  |          |        |           |
| Assessment component determined by instructor: | 30 hours   |                                    |          |                            |          |  |          |        |           |
| Total:   | 150 hours  |                                    |          |                            |          |  |          |        |           |
| Credit Points                                  | 5 CP   |                                    |          |                            |          |  |          |        |           |
| Scope of Time                                  | One semester (Recommended: 3 <sup>rd</sup> Global Change Ecology semester)   |                                    |          |                            |          |  |          |        |           |
| Semester Offered                               | Winter semester  |                                    |          |                            |          |  |          |        |           |
| Target Group                                   | Ecology-oriented master's programmes   |                                    |          |                            |          |  |          |        |           |
| Reference to Other Modules                     | <p>Knowledge in programming language R</p> <p>M2 Statistical Data Analysis with R</p> <p>Examples of time series are done in agreement with Climatology and Meteorology; in a practicum the model-based climate constructions are compared with observation data.</p>  |                                    |          |                            |          |  |          |        |           |

## M7 Research at the Natural and Social Science Interface

|                            |  |
|----------------------------|--|
| Responsible for the Module | Ecological Services, UBT   |
| Structural Content         | Ecological Services, UBT   |
| Learning Objectives        | Environmental problems require not only expert knowledge but also the ability to work together with different disciplines and societal actors. The aim of this module is to impart knowledge about the interface in inter- and transdisciplinary research. The possibilities and limits of these approaches are conveyed using examples. |
| Course Content             | This course teaches theory and practice of inter- and transdisciplinary research.  |
| Teaching Style             | S Research at the Natural and Social Science Interface<br>(1 SWS, 1 CP)  |
| Prerequisites              | None   |
| Performance Assessment     | Contribution (ungraded) and seminar presentation (ungraded)  |
| Workload                   | Active participation in 1 courses: 15 hours<br>Assessment component determined by instructor: 15 hours<br>Total: 30 hours  |
| Credit Points              | 1 CP   |
| Scope of Time              | One semester   |
| Semester Offered           | Winter semester  |
| Target Group               | Global Change Ecology  |
| Reference to Other Modules |  |

## M8 Ecosystem Services Assessment of Landscapes

|                            |   |
|----------------------------|---|
| Responsible for the Module | Ecological Services, UBT  |
| Structural Content         | Ecological Services, UBT  |
| Learning Objectives        | The aim of the exercise „Ecosystem Services Assessment of Landscapes“ is to introduce assessment methods that can be used by actors in business and politics to balance the environmental consequences of their decisions in landscape systems.       |
| Course Content             | In the exercise ecosystem services will be quantified or optimized in selected regions using spatially explicit models . Following this, scenarios of future land-use change are developed and impacts on different ecosystem services are simulated. |
| Teaching Style             | Ü Ecosystem Services Assessment of Landscapes<br>(2 SWS, 2 CP)  |
| Prerequisites:             | Basic knowledge in GIS (obligatory) and C2 Ecosystem Services (recommended)   |
| Performance Assessment:    | Written elaboration (report) (ungraded)   |
| Workload                   | Active participation in 1 course: 30 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 60 hours  |
| Credit Points              | 2 CP  |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)  |
| Semester Offered           | Summer semester   |
| Target Group               | Ecology and geography-oriented master's programmes  |
| Reference to Other Modules | C2 Ecosystem Services   |

## M9 Life Cycle Assessment of Products

|                            |   |
|----------------------------|---|
| Responsible for the Module | Ecological Services, UBT  |
| Structural Content         | Ecological Services, UBT  |
| Learning Objectives        | Aim of the exercise „Life Cycle Assessment of Products“ is to introduce assessment methods that can be used by business and political actors to assess the environmental consequences of their decision in product systems. |
| Course Content             | The method of Life Cycle Assessment LCA is introduced and students learn to use the LCA software with practical examples (e. g. assessment of energy products with Jatropha or wind energy).                                |
| Teaching Style             | Ü Life Cycle Assessment of Products (1,5 SWS, 2 CP)   |
| Prerequisites              | None  |
| Performance Assessment     | Written elaboration (report) (ungraded)   |
| Workload                   | Active participation in 1 course: 30 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 60 hours  |
| Credit Points              | 2 CP  |
| Scope of Time              | One semester  |
| Semester Offered           | Winter semester   |
| Target Group               | Ecology and geography-oriented master's programmes  |
| Reference to Other Modules | C2 Ecosystem Services<br>C3 Global Economy  |

## M10 Scientific Writing in Biogeography and Disturbance Ecology

|                            |   |
|----------------------------|---|
| Responsible for the Module | Biogeography, UBT   |
| Structural Content         | Disturbance Ecology, UBT<br>Biogeography, UBT   |
| Learning Objectives        | Students learn the rules of scientific writing.   |
| Course Content             | Students will get an overview of relevant publications and corresponding research instruments. Literature data banks will be discussed. Students will practice writing abstracts. An efficient way to title articles will also be discussed. Students will get practice in writing a „letter to the editor“. Using current manuscripts, their strengths and weaknesses will be discussed. Rules for pictures and tables will be dealt with. |
| Teaching Style             | S/Ü Scientific Writing (1 SWS, 1 CP)  |
| Prerequisites              | None  |
| Performance Assessment     | Written elaboration (report) (ungraded)   |
| Workload                   | Active participation in 1 course: 10 hours<br>Preparation and follow-up: 20 hours<br>Total: 30 hours  |
| Credit Points              | 1 CP  |
| Scope of Time              | One semester (Recommended: 3 <sup>rd</sup> Global Change Ecology semester)  |
| Semester Offered           | Winter semester   |
| Target Group               | Students writing their thesis in Biogeography and Disturbance Ecology from different study programs   |
| Reference to Other Modules | Basis for Master Thesis   |

## M11 Project Management

|                            |  |          |
|----------------------------|--|----------|
| Responsible for the Module | Biogeography, UBT  |          |
| Structural Content         | Biogeography, UBT  |          |
| Learning Objectives        | The aim of this module is to provide practical insight into project management, especially in a scientific environment. It seeks to prepare students to carry out tasks relating to coordination in research and the professional world.   |          |
| Course Content             | Depending on the needs and interests of the course participants, practical tasks in science management are addressed (the national and international research funding landscape, requesting funding, setting up research associations and international research networks, communication and quality control, public relations). In addition to such insights, the course also reflects on chances and risks in project management based on personal experience. |          |
| Teaching Style             | S Project Management and Scientific Coordination<br>(3 SWS, 2 CP, in small groups)   |          |
| Prerequisites              | No special prerequisites   |          |
| Performance Assessment     | Seminar presentation (ungraded) and/or written elaboration (report) (ungraded)   |          |
| Workload                   | Active contribution to the project and active participation in one course:   | 50 hours |
|                            | Seminar presentation and written Report:   | 10 hours |
|                            | Total:   | 60 hours |
| Credit Points              | 2 CP   |          |
| Scope of Time              | One semester   |          |
| Semester Offered           | Winter semester  |          |
| Target Group               | Ecology and geography-oriented master's programmes and BayNAT  |          |
| Reference to Other Modules | M modules depending on the selected project  |          |

## M12 Introduction to GIS

|                            |  |
|----------------------------|--|
| Responsible for the Module | BayCEER, UBT;  |
| Structural Content         | BayCEER (IT and Databases), UBT  |
| Learning Objectives        | Students will become familiar with the most important concepts and functions of Geographical Information Systems (GIS). After completing the course they will be able to conduct a simple spatial analysis independently.  |
| Course Content             | Training in GIS software and its functionality: modelling spatial information, spatial reference systems, ways to produce geodata, spatial and factual queries for geodata, selected methods of spatial analysis, formulation of analyses using process models, basic techniques of cartographic presentation. |
| Teaching Style             | Ü Introduction to GIS (2 SWS, 2 CP)  |
| Prerequisites              | None   |
| Performance Assessment     | Written elaboration (report) (ungraded)  |
| Workload                   | Active participation in 1 course: 30 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 60 hours   |
| Credit Points              | 2 CP   |
| Scope of Time              | One semester (Recommended: 1 <sup>st</sup> Global Change Ecology semester)   |
| Semester Offered           | Winter semester  |
| Reference to Other Modules | B4 Spatial Ecology<br>M5 Remote Sensing<br>M17 Academic working methods and skills   |

## M13 Advanced Multivariate Statistical Methods in Climate Research

|                            |  |          |
|----------------------------|--|----------|
| Responsible for the Module | Physical Geography with focus on climate research, University of Augsburg  |          |
| Structural Content         | Physical Geography with focus on climate research, University of Augsburg  |          |
| Learning Objectives        | Knowledge in Fundamental and Advanced Methods of multivariate Statistics   |          |
| Course Content             | Principal Component Analysis; Multiple Regression Analysis; Canonical Correlation Analysis; Cluster Analysis; Discriminant Analysis, Random Forests. |          |
| Teaching Style             | V Advanced Multivariate Statistical Methods (1 SWS, 1 CP)<br>Ü Advanced Multivariate Statistical Methods (1 SWS, 2 CP)                               |          |
| Prerequisites              | Basic knowledge of statistics and statistic-software R (e.g. from ModuleM2)  |          |
| Performance Assessment     | Written elaboration (ungraded): Exercise with protocol   |          |
| Workload                   | Active participation in 2 courses:   | 30 hours |
|                            | Preparation and follow-up:   | 30 hours |
|                            | Assessment component determined by instructor:   | 30 hours |
|                            | Total:   | 90 hours |
| Credit Points              | 3 CP   |          |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)   |          |
| Semester Offered           | Summer semester  |          |
| Reference to Other Modules | M2 Statistical Data Analysis with R  |          |

## M14 International Environmental Law

|                            |  |
|----------------------------|--|
| Responsible for the Module | African Legal Studies, UBT   |
| Structural Content         | African Legal Studies  |
| Learning Objectives        | Aim of this module is to teach fundamental knowledge in international environmental law.   |
| Course Content             | <p>After a general introduction to structures, functions, sources and implementation of international law, the basic principles of environmental law will be discussed (sustainability, prevention, "producer pays" and liability principles).</p> <p>In particular, the course deals with international law and agreements between nations on climate protection, biodiversity and other fundamentals for human existence on earth (e.g. the UN Convention UN-FCCC and UN-CBD).</p> |
| Teaching Style             | V International Environmental and Sustainable Development Law (2 SWS, 3 CP)  |
| Prerequisites              | None   |
| Performance Assessment     | Written exam (ungraded) or written elaboration (ungraded)  |
| Workload                   | Active participation in 1 course: 30 hours<br>Preparation and follow-up: 40 hours<br>Assessment component determined by instructor: 20 hours<br>Total: 90 hours  |
| Credit Points              | 3 CP   |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)   |
| Semester Offered           | Summer semester  |
| Reference to Other Modules | C4 Global Policy and Governance  |

## M15 Science and Communication

|                            |  |
|----------------------------|--|
| Responsible for the Module | Biogeography, UBT  |
| Structural Content         | Teaching assignment  |
| Learning Objectives        | The course provides an overview of the challenges associated with scientific communication, especially science outreach typically conducted by scientists to non-expert audiences. At the end of this course, the students will have acquired a good understanding of the multiple factors shaping the success of different communication strategies and tools. Importantly, this course aims to help support the development of critical thinking and decision making among students, while enhancing their communication skills. |
| Course Content             | Science communication skills are needed to get support for scientific research, to inform decision making, or to engage stakeholder. A major component of this course will be to provide students with the chance to apply knowledge acquired in previous modules to defend their envisaged solution to typical climate change or conservation challenges or discussions.  |
| Teaching Style             | V/Ü Science and Communication (2 SWS, 3 CP)  |
| Prerequisites              | None   |
| Performance Assessment     | Seminar presentation (ungraded) or Contribution (ungraded)   |
| Workload                   | Active participation in course: 30 hours<br>Preparation and follow-up: 30 hours<br>Assessment component determined by instructor: 30 hours<br>Total: 90 hours  |
| Credit Points              | 3 CP   |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)   |
| Semester Offered           | Summer Semester  |
| Target Group               | Global Change Ecology  |
| Reference to Other Modules |  |

## M16 Modeling Ecosystem Services with the Soil and Water Assessment Tool (SWAT)

|                            |  |          |
|----------------------------|--|----------|
| Responsible for the Module | Ecological Services, UBT   |          |
| Structural Content         | <p>The Soil and Water Assessment Tool (SWAT) is a widely used, powerful simulation model used to predict the impacts of climate, land use and management changes on hydrology and matter fluxes in river basins of various sizes. The objective of this module is to teach the major principles and theoretical background of the SWAT model, and its practical application for the investigation, interpretation, and assessment of environmental issues, specifically ecosystem services</p>                 |          |
| Course Content             | <p>The theoretical part introduces the different subroutines of the model including climate, hydrology, erosion, nutrient cycles, and plant growth, and explains the major input and output parameters.</p> <p>In the practical part, students will learn how to perform the model setup, parameterization, and calibration for a case study watershed. We will develop potential climate, land use change and management changes scenarios and evaluate their impacts with respect to ecosystem services.</p> |          |
| Teaching Style             | V/Ü Modeling Ecosystem Services with the Soil and Water Assessment Tool (SWAT) (2 SWS; 3 CP)   |          |
| Prerequisites              | None   |          |
| Performance Assessment     | Seminar presentation (ungraded) or written elaboration (report) (ungraded)   |          |
| Workload                   | Active participation in 1 course:  | 30 hours |
|                            | Preparation and follow-up:   | 30 hours |
|                            | Assessment component determined by instructor:   | 30 hours |
|                            | Total:   | 90       |
|                            |  | Hours    |
| Credit Points              | 3 CP   |          |
| Scope of Time              | One semester   |          |
| Semester Offered           | Summer semester  |          |
| Target Group               | Ecology and geography-oriented master's programmes   |          |
| Reference to Other Modules | <p>A4 Changes in Aquatic Ecosystems</p> <p>A5 Changes in Agroecosystems</p> <p>A10 Land Use Change and Microclimate</p> <p>C7 PLand Use Policies, Markets and Ecosystems</p>   |          |

## M17 Academic Working Methods and Skills

|                            |   |
|----------------------------|---|
| Responsible for the Module | Biogeography, UBT   |
| Structural Content         | Biogeography, UBT   |
| Learning Objectives        | The aim of this module is to train students with hands-on experiences in academic working methods and skills. The participants gain an overview of the central steps in knowledge processing: beginning with the selection of suitable sources of information up to structuring the content and preparing written reports and oral presentations. |
| Course Content             | Literature data bases, structuring with Mind Map, visualization, organization of written and oral presentations (poster, talk), discussion phase, stage fright, body language, feedback, video analysis of presentations.   |
| Teaching Style             | V/Ü Academic Working Methods and Skills (2 SWS; 2 CP)   |
| Prerequisites              | None  |
| Performance Assessment     | Contributions (ungraded)  |
| Workload                   | Active participation in 1 course: 30 hours<br>Preparation and follow-up: 30 hours<br>Total: 60 hours  |
| Credit Points              | 2 CP  |
| Scope of Time              | One semester (Recommended: 1 <sup>st</sup> Global Change Ecology semester)  |
| Semester Offered           | Winter semester   |
| Target Group               | Global Change Ecology   |
| Reference to Other Modules |   |

## M18 Field Course in Vegetation Science

|                            |   |           |
|----------------------------|---|-----------|
| Responsible for the Module | Disturbance Ecology, UBT  |           |
| Structural Content         | Disturbance Ecology, UBT<br>Biogeography, UBT;  |           |
| Learning Objectives        | <p>Module aim is an advanced practical experience in methods in vegetation science, vegetation mapping, and vegetation monitoring. Students are trained in the field across a variety of ecosystems and will understand the effort and the skills needed for ecological assessments. The field work will be affected at the scale of plant communities and ecosystems ranging from the inner-alpine arid valley slopes to the alpine zone and from bogs and mires to forests and natural grasslands. As all ecosystems require a specific scale of investigation and research question need to be tackled with appropriate approaches the methods learned before in theory are applied under field conditions. The recorded data will be analysed and compiled in written protocols. The final product will be an individual textbook of vegetation methods based on own work and experience.</p> |           |
| Course Content             | <p>Based on theoretical knowledge about different approaches and schools in vegetation science, different ways of data recording are applied in the complex terrain of the Alps that offers a large diversity of habitats and vegetation structures. Site conditions and ecosystem processes are related to key traits of vegetation including floristic and phytosociological relevés, transects, systematic data recording, biometry, biomass, and spatial assessments (mapping, remote sensing).</p>   |           |
| Teaching Style             | Ü Field Course in Vegetation Science (4 SWS, 5 CP)  |           |
| Prerequisites              | The knowledge from the lecture M3 Vegetation Science is prerequisite and also knowledge in plant determination.   |           |
| Performance Assessment     | Written elaboration (ungraded)  |           |
| Workload                   | Active participation:   | 90 hours  |
|                            | Preparation and follow-up:  | 15 hours  |
|                            | Written protocol:   | 45 hours  |
|                            | Total:  | 150 hours |
| Credit Points              | 5 CP  |           |
| Scope of Time              | One semester (Recommended: 2 <sup>nd</sup> Global Change Ecology semester)  |           |
| Semester Offered           | Summer semester   |           |
| Target Group               | Global Change Ecology   |           |
| Reference to Other Modules | B1 Biogeography and Macroecology<br>B2 Biodiversity and Ecosystem Functioning<br>B3 Disturbance Ecology<br>M3 Vegetation Science  |           |

## M19 Quantitative Methods

|                            |  |
|----------------------------|--|
| Responsible for the Module | Sport Ecology, UBT   |
| Structural Content         | Sport Ecology, UBT   |
| Learning Objectives        | Upon completion of the module Quantitative Sport Ecology, students are familiar with the measuring methods of Sport Ecology. They are able to evaluate collected data and critically reflect the results of the analyses. This enables them to efficiently quantify the interactions between sports activities and ecological systems.   |
| Course Content             | The module Quantitative Sport Ecology imparts methods for quantifying human user behaviour and the reaction of ecological systems using digital and technological advancements. This comprises the management and analysis of movement data, the data acquisition through wearables, automatic image classification, the linkage of health data with spatial use information as well as social media analyses. |
| Teaching Style             | Quantitative Sportökologie (Quantitative Sport Ecology), Hauptseminar (Seminar), 3 SWS   |
| Prerequisites              | Module Sport Ecology   |
| Performance Assessment     | Written elaboration or seminar presentation or written exam or oral exam (ungraded) (announcement at the outset of module)   |
| Workload                   | 45 hrs Active participation in main seminar<br>75 hrs Preparation and follow-up<br>30 hrs Exam preparation   |
| Credit Points              | 5 CP   |
| Semester Offered           | The module will generally be held in the winter term and possibly in English.  |
| Responsible for the Module | Sport Ecology, UBT   |
| Structural Content         | Sport Ecology, UBT   |
| Target Group               |  |
| Reference to Other Modules |  |

## M20 Methods in Dynamic Vegetation Ecology

|  |  |                                  |          |                            |          |  |          |        |           |
|--|--|----------------------------------|----------|----------------------------|----------|--|----------|--------|-----------|
| Responsible for the Module                     | Plant Ecology, UBT   |                                  |          |                            |          |  |          |        |           |
| Structural Content                             | Plant Ecology, UBT   |                                  |          |                            |          |  |          |        |           |
| Learning Objectives                            | The module's aim is to teach empirical methods used to estimate the primary production of ecosystems.  |                                  |          |                            |          |  |          |        |           |
| Course Content                                 | <p>Students learn how to use non-destructive methods to estimate net-primary-production (NPP). To achieve this the leaf area, photosynthesis, transpiration and respiration rates will be measured in field exercises. These data are used to derive estimates of NPP using the statistical script language R.</p> <p>Students learn how to access and use Earth observation data. The Geographical Information System functionality of R is used to analyze NPP trends observed in the satellite data.</p> <p>The NPP-estimates derived from the satellite and field measurements are compared and assessed. The findings are summarized in a report written in the style of an R tutorial.</p> |                                  |          |                            |          |  |          |        |           |
| Teaching Style                                 | Ü Methods in Dynamic Vegetation Ecology (5 SWS. 5 CP)  |                                  |          |                            |          |  |          |        |           |
| Prerequisites                                  | Basic R knowledge recommended  |                                  |          |                            |          |  |          |        |           |
| Performance Assessment                         | Written elaboration (report) (ungraded)  |                                  |          |                            |          |  |          |        |           |
| Work Load                                      | <table> <tr> <td>Active participation in Exercise</td> <td>60 hours</td> </tr> <tr> <td>Preparation and follow-up:</td> <td>40 hours</td> </tr> <tr> <td>Assessment component determined by instructor:</td> <td>50 hours</td> </tr> <tr> <td>Total:</td> <td>150 hours</td> </tr> </table>  | Active participation in Exercise | 60 hours | Preparation and follow-up: | 40 hours | Assessment component determined by instructor: | 50 hours | Total: | 150 hours |
| Active participation in Exercise               | 60 hours   |                                  |          |                            |          |  |          |        |           |
| Preparation and follow-up:                     | 40 hours   |                                  |          |                            |          |  |          |        |           |
| Assessment component determined by instructor: | 50 hours   |                                  |          |                            |          |  |          |        |           |
| Total:   | 150 hours  |                                  |          |                            |          |  |          |        |           |
| Credit Points                                  | 5 CP   |                                  |          |                            |          |  |          |        |           |
| Scope of Time                                  | One semester (Recommended: 2nd Global Change Ecology semester)   |                                  |          |                            |          |  |          |        |           |
| Semester Offered                               | Summer semester  |                                  |          |                            |          |  |          |        |           |
| Target Group                                   | Global Change Ecology, Environmental Geography, Biodiversity and Ecology, Geoecology, Physical Geography. Limited number of participants   |                                  |          |                            |          |  |          |        |           |
| Reference to Other Modules                     | B8 Dynamic Vegetation Ecology  |                                  |          |                            |          |  |          |        |           |

## M21 Spatial Statistics and Visualization with R

|  |  |                                   |          |                            |          |  |          |      |          |
|--|--|-----------------------------------|----------|----------------------------|----------|--|----------|------|----------|
| Responsible for the Module                     | Ecological Services, UBT   |                                   |          |                            |          |  |          |      |          |
| Structural Content                             | Ecological Services, UBT   |                                   |          |                            |          |  |          |      |          |
| Learning Objectives                            | Spatial data often require specific methods of analysis. The aim of this exercise is the development of skills in dealing with different types of spatial datasets. The focus is on learning statistical methods for the analysis of spatial patterns.   |                                   |          |                            |          |  |          |      |          |
| Course Content                                 | Different methodological approaches will be presented and practically implemented with the statistical software R. An exemplary selection of covered topics are: Visualization of spatial data, spatial point pattern analysis, variograms, and the modeling of areal data using SAR and CAR models. |                                   |          |                            |          |  |          |      |          |
| Teaching Style                                 | Ü Spatial Statistics and Visualization with R (2 SWS, 3 CP)  |                                   |          |                            |          |  |          |      |          |
| Prerequisites                                  | Experience in the use of the software R as well as basic statistical knowledge (e.g. from module M2)   |                                   |          |                            |          |  |          |      |          |
| Performance Assessment                         | Written exam (ungraded), seminar presentation (ungraded) or written elaboration (ungraded)   |                                   |          |                            |          |  |          |      |          |
| Workload                                       | <table> <tr> <td>Active participation in 1 course:</td> <td>30 hours</td> </tr> <tr> <td>Preparation and follow-up:</td> <td>30 hours</td> </tr> <tr> <td>Assessment component determined by instructor:</td> <td>30 hours</td> </tr> <tr> <td>Sum:</td> <td>90 hours</td> </tr> </table>            | Active participation in 1 course: | 30 hours | Preparation and follow-up: | 30 hours | Assessment component determined by instructor: | 30 hours | Sum: | 90 hours |
| Active participation in 1 course:              | 30 hours   |                                   |          |                            |          |  |          |      |          |
| Preparation and follow-up:                     | 30 hours   |                                   |          |                            |          |  |          |      |          |
| Assessment component determined by instructor: | 30 hours   |                                   |          |                            |          |  |          |      |          |
| Sum:   | 90 hours   |                                   |          |                            |          |  |          |      |          |
| Credit Points                                  | 3 CP   |                                   |          |                            |          |  |          |      |          |
| Scope of Time                                  | One semester (Recommended: 2nd Global Change Ecology semester)   |                                   |          |                            |          |  |          |      |          |
| Semester Offered                               | Summer semester  |                                   |          |                            |          |  |          |      |          |
| Target Group                                   | Ecology and geography-oriented master's programmes   |                                   |          |                            |          |  |          |      |          |
| Reference to Other Modules                     | <p>M2 Statistical Data Analysis with R</p> <p>M12 Introduction to GIS</p> <p>M13 Advanced Multivariate Statistical Methods in Climate Research Methods</p>   |                                   |          |                            |          |  |          |      |          |

## M22 Mathematical Modeling for Climate and Environment (exercise)

|                            |  |
|----------------------------|--|
| Responsible for the Module | Scientific Computing, UBT  |
| Structural Content         | Scientific Computing, UBT  |
| Learning Objectives        | Skills to implement and apply simple data assimilation techniques<br>Ability to formulate simple environmental and climate models and skills to implement them using e.g. Matlab |
| Course Content             | Physical principles, mathematical models, and selected numerical methods in climate and environmental sciences<br>Environmental modeling: Main applications and problem settings |
| Teaching Style             | Ü Mathematical Modeling for Climate and Environment (2 SWS; 5 CP)  |
| Prerequisites              | A9   |
| Performance Assessment     | Oral examination (on a pass/fail basis)  |
| Workload                   | Active participation in course: 30 hours<br>Preparation and follow-up: 80 hours<br>Assessment component determined by instructor: 40 hours<br>Total: 150 hours                   |
| Credit Points              | 5 CP   |
| Scope of Time              | One semester (Recommended: 3 <sup>rd</sup> Global Change Ecology semester)   |
| Semester Offered           | Summer semester (V)  |
| Target Group               | Global Change Ecology, Scientific Computing  |
| Reference to Other Modules | A9 Mathematical Modeling for Climate and Environment   |

## M23 Dynamic Ecosystem Modeling

|                            |   |
|----------------------------|---|
| Responsible for the Module | Ecosystem Analysis and Simulation, UBT  |
| Structural Content         | Ecosystem Analysis and Simulation, UBT  |
| Learning Objectives        | After successful completion, the participants are familiar with the basic methods in working with dynamic ecosystem models and can select, apply, and interpret these methods in hands-on model examples and according to a specific research question.   |
| Course Content             | Complex dynamic ecosystem models are crucial to understand the mechanisms that shape ecosystems, project their fate under different scenarios and communicate ecosystem functioning and the consequences of human-ecosystem interactions. This course covers the basic tools that are necessary to apply such models, e.g., chose the right model structure and complexity, run sensitivity analyses, calibrate the parameters, and quantify model uncertainty and performance. In addition to the theoretical instruction, all methods are applied in hands-on examples and further developed by the participants within the framework of a final project. |
| Teaching Style             | V/Ü Dynamic Ecosystem Modeling (4 SWS; 5 CP)  |
| Prerequisites              | Confident use of R  |
| Performance Assessment     | Written elaboration in form of a report on the final project (graded on pass/fail basis)  |
| Workload                   | Active participation in one course: 60 hours<br>Preparation and follow-up: 35 hours<br>Assessment component determined by instructor: 55 hours<br>Total: 150 hours  |
| Credit Points              | 5 CP  |
| Scope of Time              | One semester  |
| Semester Offered           | Summer semester   |
| Target Group               | Global Change Ecology, Geoecology   |
| Reference to Other Modules | A8 Biodiversity in the Tropics<br>B1 Biogeography and Macroecology<br>B4 Spatial Ecology<br>B8 Dynamic Vegetation Ecology   |

## M24 Disturbance Ecology Field Trip - Europe

|                            |   |           |
|----------------------------|---|-----------|
| Responsible for the Module | Disturbance Ecology UBT   |           |
| Structural Content         | Disturbance Ecology UBT   |           |
| Learning Objectives        | <p>Aim of this module is an advanced practical experience in disturbance ecology and vegetation dynamics while travelling hiking through remote landscapes. Students are trained in the field across a variety of ecosystems and altitudinal gradients and will understand the effort and the skills needed for analyzing natural and anthropogenic disturbance regimes and their effects on ecosystem dynamics in various regions. Field talks and scientific field work will be carried out at the scale of plant communities and ecosystems targeting various biomes. Concepts and methods taught in disturbance ecology and resilience, biodiversity and vegetation science are applied under field conditions. The final product will be an individual field-book of disturbance ecology and vegetation dynamics based on own work and experience.</p> |           |
| Course Content             | <p>Based on theoretical and methodological knowledge about different approaches in disturbance ecology and vegetation science, various ecological field talks and methods of data recording are applied to a large diversity of habitats and ecosystem dynamics. Site conditions and ecosystem processes are related to key plant functional traits and vegetation pattern. Methods include floristic relevés, vegetation transects, trait data recording as well as assessment of ecosystem functioning and resilience.</p>  |           |
| Teaching Style             | Ü/S Field Trip (5 SWS; 5 CP)  |           |
| Prerequisites              | <p>Knowledge based on the Modules B3 and M3.<br/>Skills in plant species determination are welcome. Physical fitness is needed.</p>   |           |
| Performance Assessment     | <p>Successful completion of the learning outcomes will be assessed based on a field talk during the field trip (graded pass/fail).</p>  |           |
| Workload                   | Preparation of the field talk:  | 30 hours  |
|                            | Attendance of field trip with data collection and species determination:  | 90 hours  |
|                            | Final protocol:   | 30 hours  |
|                            | Total:  | 150 hours |
| Credit Points              | 5 CP  |           |
| Scope of Time              | <p>This module is offered every other year during the spring/fall semester break or Pentecost week and shall be completed within one semester. It is taught in German and English</p>   |           |
| Semester Offered           | Irregular; according to announcement  |           |
| Target Group               | <p>Global Change Ecology, Geoecology, Environmental Geography, Biodiversity and Ecology</p>   |           |
| Reference to Other Modules | <p>A3 Extreme Events and Natural Hazards<br/>B2 Biodiversity and Ecosystem Functioning<br/>B3 Disturbance Ecology</p>   |           |

M3 Vegetation Science

M20 Methods in Dynamic Vegetation Ecology

## M25 Disturbance Ecology Field Trip - Overseas

|                            |   |           |
|----------------------------|---|-----------|
| Responsible for the Module | Disturbance Ecology UBT   |           |
| Structural Content         | Disturbance Ecology UBT   |           |
| Learning Objectives        | <p>Aim of this module is an advanced practical experience in disturbance ecology and vegetation dynamics while travelling hiking through remote landscapes. Students are trained in the field across a variety of ecosystems and altitudinal gradients and will understand the effort and the skills needed for analyzing natural and anthropogenic disturbance regimes and their effects on ecosystem dynamics in various regions. Field talks and scientific field work will be carried out at the scale of plant communities and ecosystems targeting various biomes. Concepts and methods taught in disturbance ecology and resilience, biodiversity and vegetation science are applied under field conditions. The final product will be an individual field-book of disturbance ecology and vegetation dynamics based on own work and experience.</p> |           |
| Course Content             | <p>Based on theoretical and methodological knowledge about different approaches in disturbance ecology and vegetation science, various ecological field talks and methods of data recording are applied to a large diversity of habitats and ecosystem dynamics. Site conditions and ecosystem processes are related to key plant functional traits and vegetation pattern. Methods include floristic relevés, vegetation transects, trait data recording as well as assessment of ecosystem functioning and resilience.</p>  |           |
| Teaching Style             | Ü/S Field Trip (5 SWS; 5 CP)  |           |
| Prerequisites              | <p>Knowledge based on the Modules B3 and M3.<br/>Skills in plant species determination are welcome. Physical fitness is needed.</p>   |           |
| Performance Assessment     | <p>Successful completion of the learning outcomes will be assessed based on a field talk during the field trip (graded pass/fail).</p>  |           |
| Workload                   | Preparation of the field talk:  | 30 hours  |
|                            | Attendance of field trip with data collection and species determination:  | 90 hours  |
|                            | Final protocol:   | 30 hours  |
|                            | Total:  | 150 hours |
| Credit Points              | 5 CP  |           |
| Scope of Time              | <p>This module is offered every other year during the spring/fall semester break or Pentecost week and shall be completed within one semester. It is taught in German and English</p>   |           |
| Semester Offered           | Irregular; according to announcement  |           |
| Target Group               | <p>Global Change Ecology, Geoecology, Environmental Geography, Biodiversity and Ecology</p>   |           |
| Reference to Other Modules | <p>A3 Extreme Events and Natural Hazards<br/>B2 Biodiversity and Ecosystem Functioning<br/>B3 Disturbance Ecology</p>   |           |

M3 Vegetation Science

M20 Methods in Dynamic Vegetation Ecology

## 4.6 Module Area F „Free Choice“

Modules with an extent of 5-credit points are allowed as well as single classes (in total 5-CP).

This Free Choice Module should be used to advance students' knowledge in their individually chosen areas of specialisation. Classes can be taken that are offered in other GCE-Modules, but which do not belong to a person's areas of specialisation. In general, modules from adjacent programmes can be chosen. Additionally, students are permitted to request credit for other courses and science schools as well.

In Module F, Performance Assessment must take place. No grades are given or are calculated into the total grade.

## 4.7 Module Area S “International Science Schools”

Summer and Winter Schools play an important part in our teaching concept. Each year the UBT offers a relevant “Science School” with workshop character. However, courses at other venues will be accepted if they deal with the issues of Global Change and its impact. The Programme Coordinating Office provides students with a course list being offered by the instructors. The Examination Committee for the Programme must accept any External Schools where courses might be taken; prior agreement for this is necessary.

This type of course is directed at connecting students to issues dealing with current developments in a rapidly changing field of science. Furthermore, such workshops and intensive courses enable participants to have contact not only with instructors and experts from practical backgrounds, but also to peers from other academic programmes, study venues and countries. In this way the Schools are very useful for developing individual networks that, particularly for this course of study, might be very significant for later career opportunities.

The students provide a written prove of the workload of each School from the organisers of the School. The credit points have different values due to the heterogeneity of international course offerings so that the Global Change Ecology coordination will approve the conversion of the credit points.

The total number of credit points earned in Module Area S may not be less than 5-credit points and not more than 10-credit points.

The Module listed here can be taken additionally from the selection offered in Free Choice Module (F) as long as such Science Schools have not already been given credit for Module S.

The following Module is offered as an example.

## S International Science Schools

|                            |   |
|----------------------------|---|
| Responsible for the Module | Biogeography, UBT   |
| Structural Content         | Alternating; International Consortium of Study Locations  |
| Learning Objectives        | Aim of this module is to provide a setting for advanced discussion and debate in small groups about current ecological topics dealing with Global Change. |
| Course Content             | Different current topics (both in content and method) will be offered.  |
| Teaching Style             | S/Ü Science School  |
| Prerequisites              | None  |
| Performance Assessment     | Confirmation of active participation and written report (ungraded): short report  |
| Workload                   | Active Participation: 150-300 hours<br>Total: 150-300 hours   |
| Credit Points              | 2 to 10 CP per school depending on the length, overall not less than 5 CP   |
| Scope of Time              | The length of time can be organised in a flexible manner  |
| Semester Offered           | No specification  |
| Target Group               | Global Change Ecology   |
| Reference to Other Modules | Alternates according to the topic<br>Basis for Master Thesis  |

## 4.8 Module Area I “Internships”

With the help of the Coordination Office, Programme instructors provide specific internship positions in four areas. Students are free to select in which area they would like to do their Internship. Internships must take place at institutions accepted by the Examination Committee, as well as in agreement with them concerning cooperation contracts, if required, for the position. The timing of the internships between the first and second semesters, as well as between the second and third, gives students an early opportunity of dealing with professional situations.

### Internship in Economy (Business Internship)

Collaboration in a Business Enterprise with international business relations.

### Internship in Science (Research Internship)

Collaboration with an internationally known research institution (e.g. Max-Planck-Institutes, Helmholtz-Centers, Leibniz Insitutes, Smithsonian Conservation Biology Institute (SCBI), Zoological Society of London (ZSL) etc.).

### Internship in Administration (Internship in a national or international agency or administrative department)

Placement and collaboration with national or international agencies or institutions (e.g. Bavarian State Department of the Environment, Bavarian State Office for Water Sources Management, Federal Agency of Nature Conservation (BfN), Environmental Agency in the EU).

Internship in International Organisations (Placement in a supranational organisation or non-governmental organisation (e.g. Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), Convention on International Trade in Endangered Species (CITES), Gesellschaft für Internationale Zusammenarbeit (GIZ), World Wildlife Fund (WWF), United Nations Environment Programme (UNEP), United Framework Convention on Climate Change (UNFCCC), International Union for Conservation of Nature (IUCN), Food and Agriculture Organisation (FAO)).

Teaching staff advises students about the selection of appropriate Internship positions. Help is given to make it easier to gain access to high-ranking and popular internship positions. There is great demand for our students heading towards the institutions named here.

# I Internships in Economy, Science, Agency Administration or International Organisation (Internships)

|                            |  |  |
|----------------------------|--|--|
| Responsible for the Module | Coordinating Office Global Change Ecology  |  |
|                            | <b>Internship in Economy</b><br>Collaboration with an international business enterprise <u>or</u>  |  |
|                            | <b>Internship in Science</b><br>Collaboration with an internationally well-known research institution <u>or</u>  |  |
|                            | <b>Internship in Administration</b><br>Placement in and Collaboration with an international Agency Administration <u>or</u>  |  |
|                            | <b>Internship in International Organization</b><br>Placement in and collaboration with a supranational or international organisation or NGO  |  |
| Learning Objectives        | Aim of this module is that students gain practical experience in an international business, an internationally oriented research institute, and a national or international agency or with an internationally oriented organisation. |  |
| Course Content             | Implementation of theoretical knowledge in a practical context that was gained in the previous courses.  |  |
| Teaching Style             | P Internship   |  |
| Prerequisites              | None   |  |
| Performance Assessment     | Confirmation of active participation and written report (ungraded): short report   |  |
| Workload                   | For 5 CP:  | Six weeks fulltime internship<br><u>or</u> |
|                            | For 10 CP:   | Twelve weeks fulltime internship           |
| Credit Points              | 5 to 10 CP depending on the length of the individual internship  |  |
| Scope of Time              | The length of the mandatory internship (one time six or twelve weeks; or two times six weeks) is chosen by the student   |  |
| Semester Offered           | No specification   |  |
| Target Group               | Global Change Ecology  |  |
| Reference to Other Modules | Depends on individual student  |  |

## 5 T Master Thesis

|                            |  |
|----------------------------|--|
| Responsible for the Module | All instructors involved in the programme  |
| Learning Objectives        | <p>The Master Thesis provides the opportunity for students to demonstrate their ability to do independent research in their selected field of specialised interest. Using the qualifications they have gained, students should implement this knowledge in a practical manner by working on a topic of their own choice.</p> <p>The aim is for students to apply the theories and methods they have acquired through their course of studies.</p> <p>The Master Thesis centers on a specific direction in method and discipline while at the same time showing a clearly recognizable relationship to the programme of study. This can take place through discussion of the issues (e.g. ecological consequences of climate change), of observation of shared criterion (global or at least, large-scale), of the object (ecological zones).</p> |
| Course Content             | Identification of a research question and discussion of a hypothesis, selection and application of a wide range of methods that have been taught, implementation and evaluation of literature research, data collection and evaluation, writing a scientific paper.  |
| Performance Assessment     | Master Thesis (graded)   |
| Workload                   | Completion time / individual mentoring (6 months): 900 hours<br>Total: 900 hours   |
| Credit Points              | 30 CP; The grade on the Master Thesis is the grade for the Module  |
| Scope of Time              | The Master Thesis is to be completed during the fourth semester, total extent of time: 6 months  |
| Reference to Other Modules | The Master Thesis enables an overall reflection of all skills and competencies gained in the entire course of studies  |

## 6 Course of Studies and Requirements (3 Examples)

### 6.1 Selected Field of Specialisation in Module Area A „Environmental Change“

| Module                       | Module   | CP         |
|------------------------------|--|------------|
| <b>1st Semester (Winter)</b> |  |            |
| O                            | Global Change Ecology Overview                             | 5          |
| A1                           | Climate Change   | 5          |
| B1                           | Biogeography and Macroecology                              | 5          |
| C1                           | Climate Policies and Economics                             | 5          |
| M17                          | Academic Working Methods and Skills                        | 2          |
| M2                           | Statistical Data Analysis with R                           | 2          |
| M10                          | Scientific Writing in Biogeography and Disturbance Ecology | 1          |
| Semester Break (Winter)      |  |            |
| S                            | Science School   | 5          |
| <b>Total:</b>                |  | <b>30</b>  |
| <b>2nd Semester (Summer)</b> |  |            |
| A10                          | Land Use Change and Microclimate                           | 5          |
| A2                           | Ecological Climatology                                     | 5          |
| A8                           | Biodiversity in the Tropics                                | 5          |
| B2                           | Biodiversity and Ecosystem Functioning                     | 5          |
| C8                           | Biodiversity, Climate Change and Health                    | 5          |
| Semester Break (Summer)      |  |            |
| I                            | Internship   | 5          |
| <b>Total:</b>                |  | <b>30</b>  |
| <b>3rd Semester (Winter)</b> |  |            |
| C2                           | Ecosystem Services   | 5          |
| A5                           | Changes in Agroecosystems                                  | 5          |
| B3                           | Disturbance Ecology  | 5          |
| F                            | Free Choice  | 5          |
| M6                           | Times Series Analysis                                      | 5          |
| Semester Break (Winter)      |  |            |
| S                            | Science School   | 5          |
| <b>Total:</b>                |  | <b>30</b>  |
| <b>4th Semester (Summer)</b> |  |            |
|                              | Master Thesis  | 30         |
| <b>Total:</b>                |  | <b>30</b>  |
| <b>Entire Total:</b>         |  | <b>120</b> |

## 6.2 Selected Field Module Area B „Ecological Change“

| Module                                  | Module                                   | CP         |
|---|--|------------|
| <b>1<sup>st</sup> Semester (Winter)</b> |  |            |
| O                                       | Global Change Ecology Overview           | 5          |
| A1                                      | Climate Change                           | 5          |
| B1                                      | Biogeography and Macroecology            | 5          |
| C1                                      | Climate Policies and Economics           | 5          |
| F                                       | Free Choice                              | 5          |
| Semester Break (Winter)                 |  |            |
| S                                       | Science School                           | 5          |
| <b>Total:</b>                           |  | <b>30</b>  |
| <b>2<sup>nd</sup> Semester (Summer)</b> |  |            |
| A2                                      | Ecological Climatology                   | 5          |
| B2                                      | Biodiversity and Ecosystem Functioning   | 5          |
| B8                                      | Dynamic Vegetation Ecology               | 5          |
| C4                                      | Global Policy and Governance             | 5          |
| M4                                      | Foundations of Biogeographical Modelling | 2          |
| M14                                     | International Environmental Law          | 3          |
| Semester Break (Summer)                 |  |            |
| I                                       | Internship                               | 5          |
| <b>Total:</b>                           |  | <b>30</b>  |
| <b>3<sup>rd</sup> Semester (Winter)</b> |  |            |
| A5                                      | Changes in Agroecosystems                | 5          |
| B3                                      | Disturbance Ecology                      | 5          |
| B4                                      | Spatial Ecology                          | 5          |
| C2                                      | Ecosystem Services                       | 5          |
| M6                                      | Time Series Analysis                     | 5          |
| Semester Break (Winter)                 |  |            |
| I                                       | Internship                               | 5          |
| <b>Total:</b>                           |  | <b>30</b>  |
| <b>4<sup>th</sup> Semester (Summer)</b> |  |            |
|   | Master Thesis                            | 30         |
| <b>Total:</b>                           |  | <b>30</b>  |
| <b>Entire Total:</b>                    |  | <b>120</b> |

### 6.3 Selected Field Module Area C „Societal Change“

| Module                                  | Module                                    | CP         |
|---|---|------------|
| <b>1<sup>st</sup> Semester (Winter)</b> |   |            |
| O                                       | Global Change Ecology Overview            | 5          |
| A1                                      | Climate Change                            | 5          |
| B1                                      | Biogeography and Macroecology             | 5          |
| C1                                      | Climate Policies and Economics            | 5          |
| M5                                      | Remote Sensing                            | 3          |
| M9                                      | Life Cycle Assessment of Products         | 2          |
| Semester Break (Winter)                 |   |            |
| S                                       | Science School                            | 5          |
| <b>Total:</b>                           |   | <b>30</b>  |
| <b>2<sup>nd</sup> Semester (Summer)</b> |   |            |
| A3                                      | Extreme Events and Natural Hazards        | 5          |
| B8                                      | Dynamic Vegetation Ecology                | 5          |
| C3                                      | Global Economy                            | 5          |
| C4                                      | Global Policy and Governance              | 5          |
| F                                       | Free Choice                               | 5          |
| Semester Break (Summer)                 |   |            |
| S                                       | Science School                            | 5          |
| <b>Total:</b>                           |   | <b>30</b>  |
| <b>3rd Semester (Winter)</b>            |   |            |
| A5                                      | Changes in Agroecosystems                 | 5          |
| B4                                      | Spatial Ecology                           | 5          |
| C2                                      | Ecosystem Services                        | 5          |
| C7                                      | Land Use Policies, Markets and Ecosystems | 5          |
| M19                                     | Quantitative Methods                      | 5          |
| Semester Break (Winter)                 |   |            |
| I                                       | Internship                                | 5          |
| <b>Total:</b>                           |   | <b>30</b>  |
| <b>4th Semester (Summer)</b>            |   |            |
|   | Master Thesis                             | 30         |
| <b>Total:</b>                           |   | <b>30</b>  |
| <b>Entire Total:</b>                    |   | <b>120</b> |