Imperial College London

source: https://netnature.wordpress.com/2012/04/28/caatinga-o-ecossistema/

MRes in Ecosystems and Environmental Change

Course Guide 2018 – 2019

Along with this course-specific guidebook, you will receive a copy of the Silwood Park Campus Student Guidebook, containing (among many other things) the following important information:

Introduction to Silwood Park and the Department of Life Sciences

Including key contacts and information on the library, IT, safety and seminars.

Academic regulations

The Student Guidebook provides information about the general regulations that apply across all of these courses. These includes academic integrity, plagiarism, employment during your studies, and complaint and appeals procedures.

Welfare and Advice

Imperial has a wide support network for students. The Student Guidebook provides details of the available support and key contacts and links.

Student Feedback and Representation

We are very grateful for feedback on the course and will ask you for it at regular intervals! However, there is a range of options for providing feedback and getting support on your academic studies. The Student Guidebook provides details.

Thesis Guidelines

How to prepare your thesis, including word limits, formatting, etc.

Project and Supervison Guidelines

How to choose a project, student research budgets, and what to expect (and not to expect!) from supervisors.

The FrEEC Symposium

All about the student-run Frontiers in Ecology, Evolution and Conservation (FrEEC) summer Symposium at Silwood.

Electronic copies of the Student Guidebook are available on the course website as well as Blackboard. A copy can also be obtained by emailing the Course Administrator Mrs Amanda Ellis (amanda.ellis@imperial.ac.uk).

Course Overview

Welcome to the MRes programme in ecosystems and environmental change (eeChange) at Silwood Park! And welcome to an area of science that is vastly complex, fascinating, perplexing... and one that we need to understand much better; because the human pressures on ecosystems are relentless, and now compounded by the inevitability of continuing climate change – to which both ecosystems and human activities must adapt.

A key feature of this course is that *75% of your time will be spent on a single research project*. There is a huge variety of topics (and supervisors) to choose from, so it's important to start thinking seriously – and early – about your choice. Potential topics range from theoretical and mathematical, for those so inclined, to computationally intensive, to field-based and practical, and combinations of these; from atmospheric physics to vegetation science; from curiosity-driven, fundamental research on ecosystem function, to policy-oriented analysis of ecosystem and water resources management. What's more, you are not confined to studying the topics that supervisors have suggested. You are free to discuss possible topics with potential supervisors, who will be more than happy to help you to design the right project for your interests and aspirations. Many Masters projects are carried out at Silwood with a supervisor from another Department, and this is a feature appreciated by staff and students alike – an opportunity to develop new collaborations and strengthen existing ones, and make new interdisciplinary science happen. It is even possible to design a project with a co-supervisor anywhere in the world, involving fieldwork anywhere in the world.

Another key feature of the course is its emphasis on wider relevance, and communication with a non-scientific audience. It's impossible to be seriously involved in ecosystem science, and especially the science of environmental change, without recognizing the human and policy dimensions of the subject and the importance of careful communication – for example, distinguishing policy-relevant scientific information (what science really 'says') from policy prescription (what you, as a citizen, personally think should be done!) Recognizing that communication with a wider audience is a necessary and specialized skill, and that a broad understanding of the social and policy context is essential background for future practitioners and researchers, the eeChange Masters includes several components designed to sharpen your faculties in these areas. There are group mini-projects to summarize information on various topics for a non-scientific audience, and modules in the social and policy context of environmental change and in science communication. It is also a requirement that all eeChange project theses include a separate summary of research findings, in terms accessible to policy makers, who do not necessarily have a science background.

The course runs for a full year, starting the first week in October, through to the end of September. Research projects start towards the end of the first term. But before you start your research project – through weeks 1 to 9 of the first term – you will receive intensive instruction in key skills and knowledge needed by all practitioners. Daily lectures and practicals, unless otherwise stated, begin at 10:00 and normally finish by 17:00, incorporating breaks. **Additional independent work is expected**: reading around the topics, and working on coursework assignments. Wednesday afternoons during this period are normally (but not always) reserved for private study, sports and leisure activities.

Teaching materials and other course materials will be provided using the online Blackboard virtual learning environment http://bb.imperial.ac.uk. Paper copies of lecture notes and handouts are *not* normally provided, but you will receive printing credit for use during the course on your security card.

When carrying out your research project, you are expected to work full-time on the project but with flexible hours. Students who work extra hours on the project generally do better, and get more out of the course. Some projects may absolutely require out-of-hours work, for example maintaining greenhouse experiments. As a researcher, you will be fully embedded in your main supervisor's research group and therefore you will participate in periodic lab meetings and activities, which are arranged independently by each supervisor.

The following sections provide a **summary** of the programme and assessment structure. The full programme specifications for the MRes are available on Blackboard and from the course website:

https://www.imperial.ac.uk/life-sciences/postgraduate/masters-courses/mres-in-ecosystem-and-environmental-change/

Course Administration

Please see the Student Guidebook for descriptions of the roles of the Postgraduate Administrator and Senior Tutor, and the Director of Postgraduate Studies. The Student Guidebook also includes information about other key staff.

Add 0207 59 to extension numbers to call from external phones.

Masters Co-ordinator:
Samraat Pawar (ext. 42213, s.pawar@imperial.ac.uk)

eeChange Course Director:
Professor Colin Prentice (ext. 42354, c.prentice@imperial.ac.uk)

eeChange Course Co-Director:
Professor Guy Woodward (ext. 42237, guy.woodward@imperial.ac.uk)

Postgraduate Administrator:
Mrs Amanda Ellis (ext. 42251, amanda.ellis@imperial.ac.uk)

Director of Postgraduate Studies:
Dr Niki Gounaris (ext. 45209, k.gounaris@imperial.ac.uk)

Senior Tutor:
Dr Julia Schroeder (ext. 49086, julia.schroeder@imperial.ac.uk)

eeChange Course Representative:
Up to you (see Student Guidebook for more details)

Course Aims

The course is designed to confer knowledge and understanding of the following subject areas:

- Key issues in the science of ecosystems and global change, ranging from the underlying human and physical causes of environmental change, through climate-change impacts on ecosystems, to the contemporary policy context.

- The drivers of the state and change of ecosystems, including both physical and human environmental factors influencing biodiversity and ecosystem function.

- The state of current information and knowledge about ecosystem processes and responses, and tools with which knowledge gaps can be addressed – from data collection to statistical analysis and mathematical modelling.

- The role of science in policy-making, with particular reference to contemporary environmental change.

Learning Outcomes

Students will be equipped with the knowledge and skills required for the analysis of problems in ecosystems and environmental change science, and for the wider communication of scientific findings in a policy context. Specific outcomes include the abilities to:

- Plan and safely execute field-based data collection (in the case of field-based research projects).

- Use a variety of computational tools and packages.

- Analyse scientific results and determine their strength and validity.

- Give oral presentations.

- Write concisely and effectively for both scientific and lay audiences.

- Use the scientific literature effectively and efficiently.

- Integrate and evaluate information from a variety of sources.

- Transfer techniques and solutions from one discipline to another.

- Use Information and Communications Technology.

- Manage resources and time.

- Learn independently with open-mindedness and critical enquiry.

- Learn effectively for the purpose of continuing professional development.

Transferable Skills

During the course you will acquire and practice a range of broadly tranferable skills:

- Research techniques, including literature search, information retrieval, experimental design and statistics, data analysis, modelling, sampling, field safety, and the analysis and presentation of results for a scientific audience.
- Multidisciplinary approaches to environmental problem solving, including the integration of quantitative and qualitative information from disparate sources.
- The formulation of explicit hypotheses, and research designs for the collection and analysis of data with which they can be tested.
- The choice of suitable modelling and decision support tools to translate scientific understanding into actionable, policy-relevant form.
- Planning, conducting and writing up a programme of original research.
- Management skills, including decision making, problem definition, project design and evaluation, risk management, teamwork and co-ordination.
- Communication of results through presentations in oral and written (poster, short report, scientific paper) forms.

In addition to the taught modules during weeks 1–9, all Masters students are strongly encouraged to attend:

Two lectures by Samraat Pawar on "Choosing and Designing a Research Project" and "Applying for PhD positions/Academic jobs/Industry jobs" (dates and times tba), and

Professional Skills Development sessions organized by the Graduate School (dates and times tba). These will consist of masterclasses and e-learning modules aiming to help students develop the skills needed both in their academic studies, and in obtaining jobs and progressing in their future careers.

In addition, the Careers Advisory Service provides training and support for students on career options, job seeking and interviews.

Course Activities and Assessment (overview)

The following table shows the breakdown of total course marks by Components/Elements.

Component/Element	**Percentage of total mark**	**Percentage of Component**
Coursework		
First assignment	12.5 %	50 %
Second assignment	12.5 %	50 %
Coursework total	25 %	100 %
Research Project		
Thesis	45 %	60 %
Viva (oral examination)	15 %	20 %
Symposium presentation	7.5 %	10 %
Supervisor's mark	7.5 %	10 %
Research Project total	75 %	100 %

The first and second assignments together constitute the **Assessed Coursework** Component of the course.

The **first assignment** is an analysis and writing exercise. The cohort of students will be divided into groups. Each group will choose a topic, in consultation with the Course Director. Within this topic, each student will take responsibility for a particular aspect. The group will work together to produce a four-page report, designed for a non-specialist readership, in the format of a Parliamentary Office of Science and Technology (POST) briefing note. Each student in the group will make a brief (5-minute) oral presentation of the key point(s) that they have worked on. Two examiners will mark the report (at group level), the individual students' contributions to the report, and the presentations.

The **second assignment** is a science communication exercise. Each student will devise a piece in their chosen medium (such as a popular science article), based on a topic related to their project. This work will be marked by the Science Communication team, and represents an opportunity to put into practice what has been learnt during the Science Communication module.

The **Research Project** component will be assessed in four different ways.

First, and most importantly, a **thesis** (aka dissertation) in the format of a scientific paper: see the Student Guide for details) must be submitted. eeChange theses must additionally **include a special two-page summary** aimed at policy makers, who may not have a science background. The hand-in date for the thesis, including its Summary for Policymakers, will be **29 August 2019 at 13:00**.

Theses will be marked by two independent examiners. Their assessment criteria will focus on scientific quality, originality and clarity of presentation. Note that the thesis is to be submitted electronically – there is no need for printing or binding.

Second, you will present your work at the three-day **Frontiers in Ecology, Evolution and Conservation (FrEEC) symposium**, which will take place during **10–12 September 2019**. Your oral presentation at the symposium will also be marked by the independent examiners.

Third, a **viva** (oral examination) led by your two examiners will take place during the **week of 16–20 September 2019**. In this thirty-minute session, you will be asked first to summarize the rationale and findings of your work (very briefly – three to five minutes at most). Then you will be engaged in a discussion about its content. Your viva performance will be marked by the examiners.

The fourth contribution to the overall project mark is the **supervisor's mark**, which does not assess scientific quality, but considers different aspects that the supervisor is best qualified to comment on, such as rigour and diligence.

Summer conference on ecosystems and environmental change. There is no assessement for this activity. Students from eeChange will work as a group, to organize and host a one-day or evening public event for a wide audience, to take place in June or July. Students will have to decide on a theme and format, and invite speakers from Imperial College or the greater London community to participate. It is expected that the whole eeChange cohort of students will fairly share out the work associated with planning and organizing this event.

Attendance at **Thursday seminars** (Thursdays at 13:00), given by local or visiting academics, is expected while students are located at Silwood Park. See:
http://www3.imperial.ac.uk/silwoodparkcampus/research/thursdayseminars
See the Student Guidebook for more information about seminars at Silwood Park, including **social seminars**.

External Examiner

The External Examiner is **Dr Martin Lukac**, School of Agriculture, Policy and Development, University of Reading (m.lukac@reading.ac.uk, 0118 378 8470).

Background Reading

There is **one textbook** that you should read for the insights it gives into environmental problem solving in general:

Harte, J. (1988) *Consider a Spherical Cow: A course in environmental problem solving*. University Science Books.

There is also a unique **reference text for the climate change**, which is the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC). The IPCC Reports, including this most recent one, are structured by Working Groups (WG). WG 1 deals with the physical science basis of climate change; WG 2 deals with impacts, adaptation and vulnerability, region by region and sector by sector; WG 3 deals with mitigation, including energy technology and economic aspects. These texts are extraordinarily detailed and wide-ranging. You will not want to read any single chapter right through. Instead, consider these (especially the Working Group 1 Report) as highly valuable, encyclopaedic reference works. The **entire AR5 is freely available online** at https://www.ipcc.ch/report/ar5/.

The following **edited volume** covers many aspects of global change science, including the societal context:

Cornell, S.E., I.C. Prentice, J.I. House and C.J. Downy (eds) (2013) *Understanding the Earth System.* Cambridge University Press.

There is **no** textbook, however, that covers the whole subject matter of the course; or even any large part of it. This does **not** mean that you don't need to read anything else!!! On the contrary: **it is your responsibility to read widely** around the taught material and, of course, to read intensively and be fully up-to-date with the most recent literature on the topic of your research project. You need to know the limits of our current understanding. This can only be known from the literature. Searching and reading the literature is a habit and skill you should develop early on, and should be part of your daily routine. Readings suggested in course modules should not be the extent of your reading! Expertise in research methods is gained through experience, but mastery can only be gained through your own analysis of the literature. You will find that reading will be a source of enjoyment and inspire new ideas and approaches to your research.

Course details and module descriptions

Key teaching staff

Wouter Buytaert (w.buytaert@imperial.ac.uk, ext. 41329)
Catalina Estrada (c.estrada@imperial.ac.uk, ext. 42217)
Robert Ewers (r.ewers@imperial.ac.uk, ext. 42223)
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Outline timetable

The taught modules will take place during the autumn term, as follows:

Dates	**Week number**	**Module name**
1–5 October 2018	1	Induction and Course Introduction
8–12 October 2018	2	Field Ecology Skills
15–19 October 2018	3	Biological Computing in R
22–26 October 2018	4	Statistics in R
29 October–2 November 2018	5	Spatial Analysis and Geographic Information Systems (GIS)
5–9 November 2018	6	Social Context and Policy
12–16 November 2018	7	Biogeochemistry
20–23 November 2018	8	Science Communication*
26–30 November 2018	9	Energy, Water and Plants

*The Science Communication module will take place on the South Kensington campus during 20-23 November. Daily transport from Silwood will be arranged. Additional activities may be arranged at Silwood Park on Monday 19 November.

Taught Module Descriptions

The following descriptions of the content and learning objectives of the weekly lectures do not include day-level timetables, because these will be available through the iCalendar (aka iCal) service: see http://www.imperial.ac.uk/timetabling/view/icalendar. The first week (Induction and Course Introduction) is an exception and you will be issued with a detailed timetable at the start of the first week.

1. Induction and Course Introduction (Week 1: 1–5 October 2018)

Convenor: Amanda Ellis

Aim of the module

This module is to introduce all of the new Silwood Masters students to key things that they need to know about their course, and about studying at Silwood Park. Thursday and Friday (4–5 October) will be devoted to general preparatory sessions run by the Graduate School.

2. Field Ecology Skills (Week 2: 8–12 October 2018)

Convenor: Catalina Estrada

Aim of the module

The aim of this module is to familiarize you with a wide range of basic techniques used to assess an ecosystem's productivity and describe its animal and plant populations and communities. The course will take place at Silwood Park. Our campus, with about 100 ha of land, has several types of natural habitats including grassland, scrubland and woodlands. It is also an active place of field research, hosting multiple long-term experiments.

Please wear suitable clothes and footwear for outdoor activities, according to the weather forecast. You must wear long trousers and fieldwork shoes (e.g. rubber boots or sturdy shoes). Waterproof jacket, hat, sun cream and water are recommended.

Learning outcomes

Learn general field sampling techniques for plants, insects and other invertebrates.
Learn to plan field surveys to describe and compare natural communities.
Learn basic taxonomic sorting and identification of common organisms in Silwood Park grounds (insects, plants, aquatic invertebrates).
Learn to estimate ecosystem productivity.
Become familiar with Silwood Park ecosystems and field experiments.

Reading

A good reference book for designing and planning ecological work aiming to survey populations and communities in a variety of habitats:

Henderson PA & Southwood TRE (2016) *Ecological Methods*. Fourth Edition. Wiley, 632pp.

The following book chapter contains the history of Silwood Park grounds, ecosystems and research:

Crawley MJ (2005) Silwood Park and its history. In: Crawley MJ, ed. *The Flora of Berkshire*. Harpenden, Hertfordshire, UK: Brambleby Books, 215–253.

Check this link to learn more about Silwood Park long-term field studies:

http://www.imperial.ac.uk/visit/campuses/silwood-park/research/silwood-lte/

Except for the initial lecture, teaching will take place on the Silwood Park grounds.

3. Biological Computing in R (Week 3: 15–19 October 2018)

Convenor: Josh Hodge

Aim of the module

In this module, you will learn how to use this freely available statistical software with strong programming capabilities. R has become tremendously popular in biology due to several factors: (i) many packages are available to perform all sorts of statistical and mathematical analysis, (ii) it can produce beautiful graphics, and (iii) it has a very good support for matrix algebra (you might not know it, but you use it!). So with R, you have an expanded and versatile suite of biological computing tools at your fingertips, especially for automating statistical analysis and the generation of figures. Therefore, R should become an indispensable component of your biological research workflow.

Learning outcomes

Learn how to use R for data exploration.
Learn how to use R for data visualization and producing elegant, intuitive, and publication-quality graphics.
Learn R data types, structures and control flows.
Learn how to write and debug efficient R scripts and functions.
Learn how to use R packages.

Reading

The *Use R!* series (the ‘yellow books’) by Springer are really good. In particular, consider:

A Beginner's Guide to R
R by Example

Numerical Ecology With R
ggplot2
A Primer of Ecology with R
Nonlinear Regression with R
Analysis of Phylogenetics and Evolution with R.

Ben Bolker's *Ecological Models and Data in R*.

With a focus on dynamical models: Soetaert & Herman (2009) *A practical guide to ecological modelling: using R as a simulation platform*.

There are also excellent websites. Besides

http://cran.r-project.org

(containing all sorts of guides and manuals), you should check out:

http://www.statmethods.net

and

http://en.wikibooks.org/wiki/R_Programming.

Also google `R Graph Gallery' for various sites showing graphing options and code.

Teaching will take place in the Hamilton Computer Room, except for the initial lecture.

4. Statistics in R (Week 4: 22–26 October 2018)

Convenor: Julia Schroeder

Aim of the module

In this week we will build upon the introduction to R you received in "Biological computing in R" week (or the Q/CMEE Bootcamp: Biological Computing in R week) and learn a core set of statistical methods that are of wide use in research projects. These statistical tests will form the basis for any data analysis you will do in the future. This week is shared with most courses and runs in two blocks A and B.

Learning outcomes

The module will familiarize you with:

Basic statistics for ecology and evolution, with a focus on applicability. Mostly parametric tests (descriptive statistics, t-test, ANOVA, correlations, linear models, hypothesis testing).

The following is a good introductory and reference text:

Crawley, MJ (2012) *Statistics: An Introduction Using R.* Wiley. Available at:

http://imperial.eblib.com/patron/FullRecord.aspx?p=827080.

A gentler introduction is:

Beckerman, AP and O Petchey (2012) *Getting Started with R : An introduction for biologists*. Oxford University Press. Available at: http://imperial.eblib.com/patron/FullRecord.aspx?p=886478.

Teaching will take place in *the Hamilton Computer Room.*

5. Spatial Analysis and Geographic Information Systems (GIS) (Week 5: 29 October–2 November 2018)

Convenor: Robert Ewers

Aim of the module

This week will teach key skills in using and handling GIS data, along with basic remote sensing to generate GIS data and the use of GIS data in a range of applications. We will use the open source GIS program QGIS (http://www.qgis.org/). We will look at creating and georeferencing both vector and raster data and how to use GIS tools to create a workflow to carry out simple analyses.

Learning outcomes

At the end of this module you should have:

Familiarity with a range of GIS data types.
Confidence in obtaining and handling GIS data.
Familiarity with open source tools for GIS.
Practical experience in applying GIS to ecological and evolutionary questions.

Reading

Longley, PA (2011) *Geographical information systems and science*. Wiley.
Rosa, I *et al.* (2013) Predictive modelling of contagious deforestation in the Brazilian Amazon. *PLoS ONE* 8:e77231.
Van Sickle, G (2010) *Basic GIS coordinates*. CRC Press.

6. Social context and policy (Week 6: 5–9 November 2018)

Convenor: Colin Prentice

Aim of the module

This module is designed to encourage students to adopt a broad perspective on the implications of environmental science, especially global change science, for society; and to understand how scientific information feeds in (along with other aspects) to policy making at national and international levels. It includes a discussion element – students will work in groups to present an interpretation of a specific area of controversy, and brief presentations will be followed by collective discussion.

Learning outcomes

At the end of this module, you should have gained:

An appreciation of the importance, and also the limits, of scientific information for policy making.

An overview of major contemporary issues in climate policy, and climate-change impacts on biodiversity and human health.

Understanding of how land-use influences ecosystems, biodiversity and the carbon cycle.

Knowledge of the history and current status of climate-change mitigation efforts, including the role of the Intergovernmental Panel on Climate Change.

Reading

The following book is a must-read: insightful and provocative, in the best sense.

RA Pielke, Jr (2007) *The Honest Broker: Making Sense of Science in Policy and Politics*. Cambridge University Press.

7. Biogeochemistry (Week 7: 12–16 November 2018)

Convenor: Terhi Riutta

Aim of the module

The aim of this module is to provide an introduction to biogeochemical cycles at the global and ecosystem scales, with a particular focus on the carbon cycle.

Learning outcomes

By the end of the module, you will have gained an understanding of:

The main biotic and abiotic drivers of global biogeochemical cycles.

The various sources of data and information about the global carbon cycle, past and present.

The nature of the anthropogenic perturbation of the carbon cycle, and its interactions with other biogeochemical cycles.

The key findings from enhanced CO_2 experiments at the plant and ecosystem scales.
The fate of anthropogenic CO_2.

Reading

C Le Quéré *et al.* (2018) Global Carbon Budget 2017. *Earth System Science Data* **10**: 405–448.

Y Malhi *et al.* (2013) The productivity, metabolism and carbon cycle of two lowland tropical forest plots in south-western Amazonia, Peru. *Plant Ecology and Diversity* **7**: DOI: 10.1080/17550874.2013.820805.

RJ Norby & DR Zak (2011) Ecological lessons from free-air CO_2 enrichment (FACE) experiments. *Annual Review of Ecolology, Evolution, and Systematics* **42**: 181–203.

8. Science communication (Week 8: **20**–23 November 2017)

Convenors: Alexandra Fitzsimmons and Stephen Webster

Aim of the module

The UK Government's Chief Scientific Adviser, Sir Mark Walport, once said: 'The science isn't done until it is communicated'. This short but intense course, delivered by Imperial's well-known Science Communication Unit, will help you find ways to communicate your work with the wider public and to colleagues from other disciplines. The course is highly practical, interactive and hands-on. Skills covered include TV/video, writing, and exhibition display. We will also consider the political and social aspects of contemporary science, and consider how scientists should communicate controversial work.

Learning outcomes

By the end of the module, and the assignment, you will have:

Learnt about, discussed, and reflected on the relationships between science, society and the media.
Articulated the value of your own research for society as a whole.
Developed and practised communication skills in a range of media, including producing an assessed written piece.

Please note that this module will take place on the South Kensington campus, Tuesday through Friday. Transport will be provided.

9. Energy, Water and Plants (Week 8: 26–30 November 2018)

Convenors: Wouter Buytaert and Colin Prentice

Aim of the module

This module aims to convey knowledge of the key principles of environmental physics, climatology and hydrology as they influence and interact with terrestrial ecosystems. Material covered includes the standard model for photosynthesis and the nature of the coupling between energy, water and CO_2 exchanges at the scales from leaf to catchment. The module will begin by introducing students to the fundamentals of the Earth's climate system and how it generates the observed climate zones; proceed to consider processes by which soils, climate and plants interact; and end by showing how these processes bring about the observed spatial distribution of primary production and vegetation. A class exercise will serve the function of 'bringing to life' quantitative approaches to estimating fluxes of energy, water and CO_2 between ecosystems and the atmosphere through hands-on group work.

Learning outcomes

The students will acquire an understanding of:

The principles of climatology and meteorology including atmospheric structure, the Earth's energy balance, energy transport in the atmosphere, drivers and patterns of atmospheric motion, and the major wind belts and climatic zones

The principles and practice of ecohydrology, including the components of the catchment water balance, the role of soil water storage in supporting primary production, key processes determining rates of transpiration and interception, and the main approaches to the estimation of evapotranspiration

The fundamentals of hydrochemistry, including geochemical concepts in hydrology, interactions between subsurface and stream water, water isotopes, and geochemical and isotopic tracers of hydrological processes and water movement

Plant carbon and water exchanges, including plant hydraulics and the soil-plant-atmosphere continuum, stomatal control of water and CO_2 exchange, the energy balance of leaves and canopies, the biochemical controls of photosynthesis, carbon isotopes, plant water and carbon economies, and the effects of CO_2 concentration on plants

Global patterns of vegetation and primary production, including how climate determines vegetation structure and function, how satellites monitor vegetation properties, eddy covariance data on water and CO_2 exchanges, andthe basics of ecosystem modelling

Reading

RG Barry and RJ Chorley (2009) *Atmosphere, Weather and Climate*. Routledge (9th edition).

E Wohl *et al.* (2012) The hydrology of the humid tropics. *Nature Climate Change* **2:** 655–662.

HG Jones (2013) Plants and Microclimate: A Quantitative Approach to Environmental Plant Physiology, 3rd edition. Cambridge University Press.