List of the English modules at the Faculty of Agricultural, Nutritional and Engineering Sciences

This document contains all courses offered by the Faculty of Agricultural, Nutritional and Engineering Sciences at the University of Bonn that are held in English. They are sorted by study program, whereby many of the modules can be taken in different programs, and listed alphabetically.

Content

B.Sc. Agricultural Sciences & B.Sc. Nutrition and Food Sciences

- **Introduction to World Food Economics (Einführung in die Welternährungswirtschaft)**
  - ➔ issues of population growth and food security, experience in wealthy vs. developing countries, prerequisites necessary for regional and global food security in the 21st century, interplay between international cooperation (e.g., trade, food aid, development cooperation) and national policies (e.g., food security and poverty reduction measures, institutional design of the economic process), importance of agricultural development to overall economic growth in developing countries, case studies of individual world regions

M.Sc. Agricultural and Food Economics (AFECO)

- **Advanced Applied Econometrics**
  - ➔ review of the General Linear Model, OLS and GLS practicing matrix algebra; model specification (functional form and variable choice); endogenous regressors (instrumental variable estimation, Generalised Method of Moments, identification strategies); panel data analysis; maximum likelihood estimation; limited dependent variable models
- **Advanced Environmental Economics**
  - ➔ critical interpretation and discussion of theoretical models and applications in environmental and resource economics; examples from forest and biodiversity conservation, pollution and waste, non-renewable resources, transboundary resource use, and international environmental agreements
- **Advanced Methods of Market and Consumer Research**
  - ➔ theories and methods concerning the measurement and analysis of consumers' attitudes, perceptions, evaluations, and preferences using non-parametric tests, moderation/mediation analysis, regression models, factor analysis, structural equation modelling, cluster analysis, and (discrete) choice experiments
- **Agricultural Production Economics**
  - ➔ fundamentals of agricultural production economics and management; factors influencing the operational outcome and sustainability of farms; theoretical and applied efficiency and productivity analysis; management challenges related to agricultural production; farm production organization
- **Applied Modelling of Agricultural Systems**
  - ➔ developing/improving an existing partial or general equilibrium model and applying, documenting and presenting it
- **Applied Trade Theory and Policy**
  - ➔ observing trade: technological differences (Ricardian model), differences in factor endowments (Heckscher-Ohlin Model), increasing returns to scale; gains from trade: the country perspective, the "within country" or agent perspective, deviations from the perfect market assumption; trade and welfare impacts: import tariffs import quotas, export subsidies, non-tariff measures; gains of trade agreements: multilateral trade agreements (WTO), regional trade agreements, regional versus multilateral agreements; the effect of multinational firms on trade
- **Behavioral Economics in Agri-Food Markets**
  - ➔ rational choice in neoclassical economics, bounded rationality, framing, anchoring and endowment effects, status quo bias, heuristics and cognitive errors, nudging, libertarian

paternalism, experimental economics, altruism, fairness and reciprocity, introduction to cognitive neuroscience

- **Bio-Economic Modelling at Farm-Scale**
  - ➔ simulation models; farm-scale simulation models; linear programming; GAMS; modelling core bio-economic interactions at farm scale (herd dynamics, crops, rotations, labour use); modelling investments and financing decisions; modelling risk and risk behaviour; state-contingent decision variables; dynamic stochastic programming

- **Communication in the Food Sector**
  - ➔ information economics; communication theory and communication models; media research (e.g. uses and gratification approach, agenda-setting, knowledge gap, cultivation theory); perception and communication (e.g. narrative paradigm, dissonance theory, attitude change); marketing; advertising and commercials in the food sector; labelling policies

- **Complex Systems Modelling of Human-Environment Interactions**
  - ➔ human-environment (H-E) interactions in social-ecological systems, introduction to Python as a common-purpose programming language; game theory: modelling strategic interactions; dynamical systems: modelling change and stability, ball-and-cup resilience; agent-based modelling: modelling collective behaviour from interacting agents; synthesis: modelling intelligent agents as dynamical systems; conservation, pollution and waste, non-renewable resources, transboundary resource use, and international environmental agreements

- **Data Wrangling, Visualization and GIS Data Analysis with R**
  - ➔ different kinds of data visualization/plotting methods; GIS analyses; spatial data projections, spatial data types (raster and vector data), spatial data in R

- **Development Economics**
  - ➔ empirical patterns in economic development, economic growth models, causes of differential economic growth and development across countries (including the role of institutions), labour markets and migration; sustainable management of natural resources for development and poverty reduction: key theoretical concepts, critical discussion of empirical policy problems (regarding water and land management), energy access and transition, the impact of high resource endowments on development, opportunities and challenges posed by climate change in developing countries

Economics on Sustainability
  - ➔ basic approaches of ecological and environmental economics; intertemporal allocation of renewable and non-renewable resources; Hartwick rule; definition and indicators for sustainability (genuine savings); environmental Kuznets curve and pollution haven hypothesis; life-cycle-analysis and rebound-effects, food consumption and sustainability, monetary valuation of environmental impacts

- **Environmental Economics and Policies**
  - ➔ general environmental policy: public goods, common pool resources and institutions, theoretically optimal policy instruments (Coase, Pigou); pragmatic policy instruments (with real-world examples): environmental liability, command and control approaches, taxes, subsidies, emission trading; asymmetric information and incentive compatible instruments; eco-tax and double dividend; agricultural environmental policy: property rights, taxes and agri-environmental measures (AEM), performance-based AEM, auctions in AEM; influences from other sectors on agri-environmental policy implications

- **Ethics in Food Consumption and Production**
  - ➔ ethical theories; ethical arguments; application of ethical reasoning to food topics (e.g., global hunger, food biotechnology, livestock welfare/animal rights); ethics and consumer choice, behavioural consumer models, influencing consumer choice (e.g., food labelling

policies; nudges); ethics and business in the food sector, Corporate Social Responsibility (CSR)

- **European and International Agricultural Policy**
  - ➔ theoretical background for evaluating agricultural policies, reference to e.g. (new) welfare economics, cost-benefit analysis, public choice; economic analysis of agricultural policies of important global players (e.g. EU, US, China), developing, transition countries; current topics and future challenges in international agricultural policy (e.g. rural development, sustainable intensification)

- **Excursion in Agricultural and Food Economics**
  - ➔ visits to farms, to enterprises along the food chain, to institutions relevant to agricultural and food economics and policy; preparation of presentations about and background information to contemporary problems and settings, future challenges and sustainability

- **Extended Methods of Empirical Research**
  - ➔ ethics in empirical research, quantitative research (e.g., statistical distribution theory, Bayes theorem; logistic regression; inference and hypothesis testing), and qualitative Research (e.g., research in Social Science, grounded theory; methods of qualitative research (observation, interview, focus groups)

- **Financial Accounting**
  - ➔ annual financial statements as required by German commercial law (HGB) and as proposed by the Agricultural Ministry for farms; deeper insight into accounting; the balance sheet and the financial statement of a firm, being able to analyze it for rentability, solvency and stability of a firm

- **Food Industrial Economics**
  - ➔ structure and characteristics of the European food sector; competition (competition concepts, competition policy in Europe); Structure Conduct Performance framework; market structure (barriers to entry/exit; monopoly/monopsony power, dominant firm, oligopoly); business conduct (cooperative and non-cooperative strategies, price discrimination, product differentiation and monopolistic competition, advertisement, information policy); market performance (level and persistence); real-world cases dealing with structural economic issues and focusing on agricultural and food markets

- **Food Marketing**
  - ➔ marketing concept: impact of marketing (attitudes, behaviour change, conditioning, external influences), neuromarketing, the role of the competitive environment (information technology, concentration, sourcing cooperations, competition, buyer power, vertical integration), the marketing fields of action (product, price, distribution and promotion) with specific focus on food enterprises; marketing management: marketing strategies (e.g. brand portfolio strategy, segmentation policy)

- **Food Security and Sustainable Food Systems**
  - ➔ synergies and tradeoffs between human health and planetary health goals; concepts and measurement of food security, dietary quality, malnutrition and related policy interventions; food systems topics from a comprehensive sustainable development perspective; case studies on organic farming, GMOs, meat consumption, palm oil, nutrition-sensitive agriculture, and the supermarket revolution

- **Global Agricultural and Food Markets**
  - ➔ supply, demand, and trade of major food markets (European/global); interdependencies between agricultural and food markets; legal framework for international markets; private versus public standards in agricultural and food markets; relevance and evaluation of non-tariff trade barriers in agricultural and food markets; relevant actors on agricultural and

food markets; spatial and enterprise concentration in the agricultural up- and downstream sector; basics of modelling agricultural markets

- **Impact Evaluation of Conservation & Development Projects and Environmental Policies**
  - ➔ role of impact evaluation in guiding the design of development and environmental conservation initiatives; understanding and developing a theory of change; overview, hands-on application, and critical assessment of quantitative evaluation methods including experimental and quasi-experimental research designs; evaluation case studies; advanced topics, such as impact heterogeneity and mediation analysis

- **Internship in Agricultural and Food Economics**
  - ➔ four weeks of full-time work in a relevant field outside the university, e.g., at research institutes, private companies or (non-)governmental institutions

- **Investment and Financing**
  - ➔ planning and evaluation of single investment projects using dynamic concepts; simultaneous planning of investment and financing, overview and analysis of typical and novel, sustainable investment projects in the agricultural and food sector; financial management and evaluation in the agricultural and food sector; evaluating investments under uncertainty

- **Methods in Management Research**
  - ➔ management research; quantitative and qualitative research methods, e.g., surveys, means-end chain modelling, social network analysis, patents and data analysis, group concept mapping, structural equation modelling, choice modelling, science-fiction prototyping; application of these methods for a range of relevant units of analysis: products, processes, companies, entire supply chain, broader development of technology innovation systems in the setting of agribusiness; relevant software and databases

- **Microeconomics**
  - ➔ choice and demand: utility maximization, expenditure minimization, Slutsky equation market demand, welfare measures; product supply and factor demand: production functions, cost minimization, profit maximization; coordination of supply and demand through competitive markets for products and primary factors & strategic interaction (game theory), common pool resources, imperfect competition

- **Organizational Management**
  - ➔ applying theory concepts of management and organization to the particularities of the enterprises and chains that are operating mainly in the sectors of agriculture, food and supporting industries; discussing case studies & scientific articles from different domains, e.g., Strategic Management (e.g. Resource-based view), Organizational Management (e.g. Value chain analysis), Entrepreneurship (e.g. business models)

- **Partial and General Equilibrium Modelling**
  - ➔ introduction to GAMS, Multi-Commodity models (MCMs), Computable General Equilibrium models

- **Research Seminar in Agribusiness**
  - ➔ literature studies, preparation of a research concept and a proposal; presentations of the state of the art in a thematic field which is close to the research question; scientific discussion of own research topic and topic of others

- **Research Seminar in Agricultural and Development Policy**
  - ➔ literature studies, preparation of a research concept and a proposal, presentations of the state of the art in a thematic field which is close to the research question; scientific discussion of own research topic and topic of others

- **Research Seminar in Market and Consumer Research**

- → literature studies, preparation of a research concept and a proposal, presentations of the state of the art in a thematic field of market and consumer research; scientific discussion of own research topic and topic of others
- **Research Seminar in Resource and Environmental Economics**
  - → literature studies, preparation of a research concept and a proposal; presentations of the state of the art in a thematic field which is close to the research question; scientific discussion of own research topic and topic of others
- **Risk Management in the Agribusiness**
  - → different concepts of risk measures and risk management; risk management instruments in the agricultural and food sector; theoretical concepts addressing risk in decision-making; accompanying exercises and case studies
- **Seminar in Innovation Management and Entrepreneurship**
  - → how to prepare presentations related to the specific topics focused on technology and innovation management as well as Entrepreneurship in the domain of life sciences and sustainability transition; how to lead and moderate discussions and to conceptualize a managerial system for problem support in enterprises, institutions and other organizations in the future; how to select an appropriate theoretical framework on the specific research topic; how to deliver a consistent report on it
- **Seminar Markets and Consumers**
  - → in-depth insights into a topical issue linked to agricultural and food markets, food marketing or consumer behaviour; knowledge about research techniques (e.g., literature search, gathering and analyzing data) and paper writing (structuring research papers, technical writing guidelines); presentation of results; moderation of discussions
- **Seminar on Environmental Economics and Policy**
  - → topical and policy-relevant issues in environmental and ecological economics; e.g., policies for tropical forest conservation, sustainable green and bioeconomy, international trade and the environment
- **Seminar Policy Analysis**
  - → topical issues on agricultural policy at the European and international level will be analyzed in presentations and written term papers
- **Seminar Production Economics and Farm Management**
  - → case studies related to agri-business and productivity analysis and planning problems, application of efficiency analysis and implementation with statistical software
- **Special Project in Agricultural and Development Policy**
  - → research topics from the field of Agricultural and Development Policy: explaining a selected policy issue, selecting and applying theories and appropriate qualitative and quantitative tools of analysis, evaluating alternative options/evaluating alternative policies with respect to economic impacts, synthesizing academic literature, contributing to a current policy debate, identifying research gaps
- **Special Project in Environmental Economics**
  - → topic from the field of environmental, ecological or resource economics: obtaining deep knowledge of selected environmental policy issues, interpreting advanced environmental and ecological economic concepts and applying them to topical policy debates, applying advanced skills in literature and data analysis, synthesizing complex debates on environmental policy design
- **Special Project in Market and Consumer Research**
  - → topic from the field of market and consumer research; applying appropriate theories and methods for one's research project; identifying/selecting appropriate methods in data analysis; reflecting research results
- **Special Project in Production Economics**

- ➡ special research-oriented project work with topics from the field of production economics, where interdisciplinary research topics are encouraged
- **Special Project in Technology and Innovation Management**
  - ➡ research project in line with a topic from the field of "Technology and Innovation Management in Agribusiness"
- **Strategic Technology and Innovation Management**
  - ➡ ability of organizations to innovate, including relevant tools, frameworks, processes, strategies, and structures; strategic technology and innovation management tools; creation of an innovation-oriented and innovation-supporting environment; development and evaluation of appropriate strategies for the implementation of new product and technology development processes; tools for the development and implementation of strategic innovation concepts in the context of agribusiness; generation of a unique business model
- **Sustainability and Risk**
  - ➡ fundamentals of the terms 'sustainability' and 'risk'; 2030 Agenda for Sustainable Development, Sustainable Development Goals (SDGs); pertinent economic concepts, economic growth, economic systems towards sustainability (e.g., bio-based economy, circular economy); sustainable business models; role of the individual in the sustainability and risk debate

M.Sc. Agricultural Science and Resource Management in the Tropics and Subtropics (ARTS)

- **Advances in Plant Breeding Methodology**
  - ➡ construction of plant breeding programs by regarding several scenarios; maximizing the selection response of different populations; new analytical and molecular methods
- **Agricultural Production Systems**
  - ➡ (sub)tropical plant production: field crops, vegetables, fruits, agro-forestry plant diseases and protection, plant nutritional disorders and nutrient management, energy value and use of plants, management of plant production systems, modelling of agricultural production systems; (sub)tropical animal production systems: breeding, nutrition, animal health, mechanization, differentiation, integration of production goals
- **Animal Breeding and Genetics**
  - ➡ principles of animal breeding and genetics; animal genetic resources; modern animal breeding techniques; breeding for sustainable animal production and diversity
- **Animal Production Systems in the Tropics**
  - ➡ animal (cattle, sheep, goat, buffalo and poultry) production systems in tropical climate; association between production system, species distribution and climate zones; challenges of animal production system in various climatic zones
- **Conservation and Use of Genetic Resources**
  - ➡ importance of genetic resources for agriculture; seed sciences, gene bank management, molecular genetics in plants and animals, and modern biotechnological approaches to characterize, utilize and manipulate genes and genomes
- **Crop Abiotic Stresses**
  - ➡ experiments in the greenhouse in which crops are exposed to different abiotic stresses (nutrient deficiencies, salinity, drought, submergence and iron toxicity); monitoring of stress responses in contrasting genotypes by non-invasive measurements including

manual phenotyping, spectral reflectance measurements, gas exchange measurements; biochemical analyses in the laboratory (e.g., mineral analyses)

- **Crop and Ecosystem Analysis and Modelling**
  ➔ systems theory and methods of systems analysis; types of models; conceptualizing of crops or ecosystems systems; mathematical formulation of relationships; implementation of mathematical algorithms; methods of model calibration and parameterization; sensitivity and uncertainty analysis; model verification, validation and evaluation

- **Crop Breeding Research**
  ➔ domestication, genetic variation, crop evolution, quantitative traits, phenotyping, molecular breeding tools, population genetics, genetic resources and the concept of germplasm, information management, mapping, QTL analysis, marker-assisted selection, introgression, genotype-by-environment interactions, gene transfer, breeding informatics

- **Crop Ecology, Water Management and Bioclimatology**
  ➔ strategies and implications of water management incl. model applications; methods & application of climatology in agro-ecosystems; botany and ecological requirements of major crop types and species; effects of temperature, precipitation, humidity, radiation, day length and wind on microclimates of non-uniform terrain, and crop responses; crop adaptation strategies to changing ecological conditions

- **Crop Physiology**
  ➔ physiological processes important for the determination of crop yield; consumable parts of the plant; physiological adaptations to stress situations; crop physiology that integrates cell biology, biochemistry and molecular biology

- **Current Issues of Research Management**
  ➔ new trends in resource management; presentations by guest speakers; participation at international conference

- **Data Analysis and Visualization**
  ➔ introduction to planning of field experiments and their analysis; introduction to statistics and the statistical software R: exploratory data analysis and visualization of data, hypothesis testing, analysis of variance, regression. Introduction to research data management; introduction to system analysis and modelling

- **Decision Analysis and Forecasting in Agriculture**
  ➔ introduction to decision analysis; forecasting and cognitive biases; calibration training; participatory modelling building; decision modelling in R; group project on decision analysis

- **Ecological Conditions and Climate Change**
  ➔ structure and use of resources (soil, water, plant, animal, genes, ecosystem) for agricultural production within their changing biophysical environment; effects of agriculture on and the contributions to desertification and climate change; ecological conditions for agricultural production, including geodynamics, climate systems, soil and water resources and ecosystem services; trends and processes of climate change and their implications and trade-offs for crop and animal production systems

- **Element Cycles in Tropical Agroecosystems**
  ➔ pools, fluxes and transformation processes of major elements (water, C, N, P, S) in tropical environments; ecological conditions and implications for the nutrition of tropical crops; waste treatment and treatment technologies (composting, anaerobic digestion) and use of organic waste as fertilizer; use and potential of staple isotopes

- **Genome Analysis in Plant Breeding**
  ➔ molecular analysis of inheritable traits in crops, transfer of improved traits for establishing new crop varieties; a broad range of methods for genome analysis using DNA marker techniques and recent state-of-the-art whole genome DNA sequencing; marker by trait

association, gene isolation and functional analyses of genes; the concept of molecular breeding for the establishment of new varieties

- **Horticultural Production and Research**
  ➔ major horticultural production systems in regional and global contexts; horticultural value chains; horticultural approaches to agricultural development; sustainability concerns in horticulture; climate change and its impact on horticulture; horticultural modelling; critical discussion of horticultural literature

- **International Research Management and Proposal Writing**
  ➔ international organizations for technical, scientific and financial support; donors for international research and development projects (aims, scope, requirements); discussion strategies for research planning; technical aspects of proposal planning and development (budget, time plan, break-down structure, Log Frame); dos and don'ts in proposal writing; basic understanding of teamwork and research ethics; principles of peer-reviewing; proposal writing, presentation and defence

- **Irrigation Agriculture**
  ➔ the extent and significance of irrigation in agriculture; when crops have to be irrigated and how to estimate the irrigation water demand; which technical devices are supportive for irrigation; how relevant measurement devices work (e.g., to measure soil water content or stomatal conductance) and how to use them

- **Land Use and Land Degradation**
  ➔ land uses, resource management strategies and their implications; applying simple field methods for ecosystem analysis; presenting case studies

- **Land Use Systems in the Tropics and Subtropics**
  ➔ diversity of land use systems; ecosystem services, threats to biodiversity and conservation practices; species interactions and adaptation strategies in different land uses; attributes and management in dryland, wetland and forest use systems; human development and environment policy effects on land use

- **Lecture Series on Future Competent Agricultural and Food Systems**
  ➔ transformation of current agriculture and food systems into future competent ones: aspects of sustainability, supply chains, planetary health, innovative production systems, biodiversity, life cycle assessment, digitalization

- **Organic Agriculture in the Tropics and Subtropics**
  ➔ approaches in organic agriculture research; development and assessment of sustainable production systems; ecological effects of inappropriate land use; soil fertility management; rotation design, performance of leguminous crops and BNF, agroforestry, alley cropping, ecological challenges in tropical agriculture; organic agriculture and world nutrition; cropping systems and techniques of important crops such as rice, sugar cane, cotton, coffee, cocoa, citrus, vegetables and fruits

- **Production Ecology**
  ➔ biotic interactions: e.g., competition, compensation, facilitation, complementation, parasitism, herbivory, symbiotic relationships, allelopathy; applications of ecological theory in cropping systems: e.g., crop diversification, evolutionary plant breeding, optimal foraging theory in grasslands, provision of ecosystem service

- **Resource Conservation**
  ➔ abiotic interactions: e.g., with regard to water, crop nutrients, and CO_2; applications for resource conservation and provision of ecosystem services: e.g., through irrigation, tillage, rotation design

- **Scientific Communication**
  ➔ scientific communication strategies; targeting research journals based on aim and scopes; structuring/analyzing scientific data for oral presentations or posters; analyzing/composing research papers

- **Simulation of Agricultural and Biological Systems**
  - ➔ R programming language, statistical notions for system modelling; nature of dynamic system models, basic processes of plant growth and development, effects of CO2 level; uncertainty and sensitivity analysis, model calibration and model evaluation
- **Soil Microbiology**
  - ➔ role of microorganisms: their contribution to the biogeochemical cycle, esp. their role in carbon and nitrogen cycling; biotic and abiotic factors that determine the life of soil microorganisms; methodological approaches that allow to analyze the presence and activity of microorganisms in soil
- **Soil Resources of the World**
  - ➔ major soil types according to World Reference Base of Soil Resources (WRB) classification, principles of their genesis, major properties and land-use options; specific processes associated with different soils relevant for global element cycles or food security; classifying soils according to WRB and Soil Taxonomy on the basis of analytical data sheets, photographs and/or archived soil monoliths and/or field sites in Western Germany with relicts of tropical soils
- **Technology and Sensors in Precision Crop Production**
  - ➔ sensors used in precision farming and the motivation for their use, including the fundamentals and use of precision localization systems (e.g., GNSS and differential GNSS) for control traffic farming, planting, and site-specific management; the use of different sensors and sensing technology to estimate farm and crop health including multi-spectral imagery at different scales (e.g. from satellites, UAVs)
- **Tree Phenology Analysis with R**
  - ➔ computing common chill and heat metrics; illustrating/evaluating temporal trends in thermal metrics; designing functions for additional metrics; relating phenology data to temperature records using multivariate statistics; identifying temperature response phases of temperate tree crops; generating past and future impacts of climate change on thermal metrics; participating in a phenology monitoring experiment under semi-controlled conditions; analyzing a phenology dataset and compiling a report about their findings; using git and github for version control and collaboration and R-Markdown for report writing

M.Sc. Animal Sciences & M.Sc. Crop Sciences

- **Advanced Biometry**
  - ➔ multivariate descriptive and inferential analysis methods (e.g., Principal Component Analysis, Multiple Regression, Generalized Linear Model)
- **Agricultural Entomology**
  - ➔ beneficial and harmful organisms: functional morphology and anatomy, identification of insects, host-parasite interactions, development of symptoms, case studies from major crop types, antagonists of insect pests, use of insects in IPM approaches, options for insect control, insecticide resistance
- **Agricultural Nematology**
  - ➔ biology of the most important groups of plant-parasitic and entomopathogenic nematodes: functional morphology and anatomy, identification of nematodes, host-parasite interactions and their mechanisms, development of plant symptoms, case studies in important crop plants, nematode antagonists, application and mode of action of entomopathogenic nematode, options for nematode control

- **Excursion Crop Sciences**
  - ➔ one-week excursion to destinations in the industry, research institutions, and organizations on changing topics
- **Projects in Crop Protection Research**
  - ➔ project activities in close association with ongoing research projects; application of state-of-the-art methodologies; understanding of research concepts and problems associated with microbial and animal pathogenic organisms

M.Sc. Geodesy and Geoinformation

- **Advanced Machine Learning**
  - ➔ advanced methods of machine learning, neural networks, deep learning
- **Collocation and Applications**
  - ➔ interpolation theory - collocation - least squares collocation - wiener filter - empirical covariance estimation - covariance models - example of 1D time series filtering - example of 2D inverse gravimetric problem - example of gravimetric geoid determination - MATLAB software development
- **Scalable Machine Learning for Remote Sensing Big Data**
  - ➔ remote sensing systems, electromagnetic radiation and its interaction with the atmosphere and land cover classes, satellite missions, forms of learning, automatic classification with machine learning, basics of parallel computing
- **Sythetic Aperture Radar**
  - ➔ acquisition principle, radiometric aspects (radar equation, speckle), geometric aspects (shadow, foreshortening, and layover), mathematical description of SAR geometry ("range-doppler" equations), orthophoto generation, mosaicking, ascending & descending merge, SAR polarimetry (Pol-SAR), SAR interferometry (InSAR), differential SAR interferometry (D-InSAR), polarimetric SAR interferometry (Pol-InSAR), coherent and non-coherent change detection

M. Sc. Geodetic Engineering
General Selection

- **Computational Foundations of GIS**
  - ➔ foundations of geoinformation systems; vector and raster models; spatial referencing of objects in geoinformation systems; metric spaces; topological spaces and topological relations; object-oriented modeling of geoinformation; spatial databases; spatial queries; geometric algorithms for spatial analysis
- **Coordinate Systems**
  - ➔ euler angles; quaternions; homogeneous coordinates; typical transformations (similarity, affine, projective); local 3D Systems; registration and georeferencing; number of parameters depending on conditions; concat-enation of transformations; transformation from GNSS to local systems; global and local systems; UTM and Gauß-Krüger; ellipsoids; International Terrestrial Reference Frame (definition, scale, datum, no-net-translation, no-net-rotation, velocity field, no-net-translation-rate, no-net-rotation-rate); earth's motion in space; earth-fixed and celestial coordinate systems; global and local coordinate systems; reference systems and reference frames; projected coordinate systems in cartography and GIS; map distortions and consequences for GIS-based computations
- **Geodetic Earth Observation**
  - ➔ concepts of global reference systems and reference frames; representation of earth rotation and earth orientation parameters (EOPs); concepts of reference ellipsoid, geoid,

and gravity field; satellite orbits for geodesy and remote sensing (Kepler and J2 effects); basics of space-geodetic observing techniques; propagation of electromagnetic waves; atmosphere; principles of timing systems; space environment

- **Global Navigation Satellite Systems**
  - ➔ basic principle of Global Navigation Satellite Systems; coordinate systems, time systems, and satellite orbit representations; GNSS signals and receiver technology; observables, atmospheric effects, and multipath; positioning procedures: single point positioning, relative GNSS with carrier phases, precise point positioning; RTK GNSS; network GNSS; kinematic GNSS; GNSS attitude determination; GPS, GLONASS, Galileo, and BeiDou; GNSS applications
- **Statistics and Adjustment Theory**
  - ➔ least squares estimation; regression analysis; probability theory (Random variables, probability distribution, statistic moments and their propagation); best linear unbiased estimator (BLUE, Gauss-Markov-model); confidence regions; hypothesis testing

Profile: Geodetic Earth System Science and Data Analysis

- **Advanced Data Analysis**
  - ➔ fundamental of potential theory, boundary value problems, physical geodesy, geoid determination; basic concepts of geostatistics, deterministic approximation (polynoms, finite elements, splines), stochastic approximation (stochastic processes, stationary, covariance functions, Wiener-Kolmogorov-filtering, kriging, collocation)
- **Advanced Methods in Satellite Geodesy**
  - ➔ Special methods in satellite geodesy (tracking, intersatellite ranging, gradiometry); principles and data processing of in pulse-limited and delay-Doppler radar altimetry; special methods of orbit integration, complete force model for near-Earth satellites, non-conservative force modelling, precise orbit determination; fundamental of relativistic modelling, relativistic effects in satellite geodesy
- **Geodetic Earth System Science and Data Analysis (GES) - Project**
  - ➔ extension of the existing MATLAB toolbox "Space Geodesy Simulator Bonn" including simulations of measurement processes in space-geodetic observing techniques such as SLR, VLBI, GPS, altimetry, and gravity missions; simulation of perturbing effects, earth rotation and transformations; methods of processing satellite data, observing models, simulations of data analysis processes, and planning of new satellite missions or observing stations; extension of the toolbox's module handbook
- **Mass Transport Modellig and Monitoring**
  - ➔ principles of physical oceanography, Navier-Stokes and geostrophic equations, ocean currents, boundary layer; fundamentals of Earth's climate and radiation budget; topics in hydrology, hydrological cycle, hydrological observation and modelling, glacial cycles, loading, and viscoelastic earth models, principles that govern sea level, the sea-level equation; interpretation of time-variable gravity and of sea level changes; analysis of data products, data assimilation, sampling properties of satellite orbits; design of satellite missions
- **Monitoring Water and Cryospheric Change from Space**
  - ➔ Satellite Altimetry: monitoring of water level change from radar measurements from space; conventional, delay doppler, wide-swath radar altimetry and near-nadir interferometry concepts; applications to geodesy, oceanography, hydrology and geophysics; multi-sensors space and in-situ data combination, data analysis and data reconstruction; interpretation in the context of climate change, long-term changes and extreme events, sea level prediction
  - ➔ Ice Sheet Signals: introduction to the physical workings of ice sheets, their importance for climate, sea level, and their connection to atmospheric and oceanic variability; ice sheet

dynamics and instabilities; determination of mass balances (input/output method, use of satellite techniques); solid-Earth feedbacks; present and future evolution of the Greenland and Antarctic Ice Sheets; discussion of topical research questions based on scientific journal articles

- **Numerics in C++**
  - ➔ working in a LINUX environment; C++ basics (data types, loops, conditional statements, integral and floating point numbers, arrays and pointers, memory management, functions); templates and standard library; object-orientated programming, classes in C++ (operators); I/O; compiling and linking programs (libraries, preprocessor, compiler and linker, make/cmake); program optimization; modern features of C++; standard libraries for linear algebra (Basic Linear Algebra Subprograms and Linear Algebra Package); introduction to parallel computing, concepts of parallel architectures, introduction to the message passing interface (basic idea and features, point to point and collective communication, parallel adjustment procedure)

- **Profile Fundamentals**
  - ➔ fundamental spaces of matrices; vector space and orthogonal projectors; generalized solution of rank deficient systems; generalized inverses; spectral analysis of linear systems; Matrix algebra and decomposition techniques; sequential adjustment; deterministic vs. stochastic approximation; interpolation with polynoms, splines, and finite elements in 1D and 2D; Array-Algebra; numerics of linear equations; multivariate probability distributions; characteristics of the electro-magnetic spectrum; conversions of frequencies and wavelengths; relationships between frequency, cycle frequency, phase, and arc length; Doppler-effect; universal law of gravitation, mass, density, and gravity; Kepler's laws, planetary and satellite motion; motion w.r.t. inertial and non-inertial reference systems; rotation of rigid bodies; tides

- **Satellite Geodesy and Earth System**
  - ➔ introduction to geometric space-geodetic techniques (SLR, GNSS, VLBI, DORIS , radar altimetry, intersatellite ranging); earth in space; dynamical satellite geodesy; spherical harmonics and spherical harmonic computations; force model; gravity field representation; space gravimetry; effects of mass transports on geodetic observables (solid Earth, atmosphere, ocean, hydrosphere); rotation of a rigid body and a deforming Earth; geo-physical fluid effects on polar motion and changes in length-of-day

- **Stochastic Processes**
  - ➔ interpolation theory - collocation - least squares collocation - wiener filter - empirical covariance estimation - covariance models - example of 1D time series filtering - example of 2D Inverse Gravimetric Problem - example of gravimetric geoid determination - MATLAB Software Development

Profile: Geoinformation and Spatial Development

- **Advanced Algorithms for Geo-Information Systems**
  - ➔ design, analysis, and implementation of algorithms for problems of spatial analysis and the visualization of spatial information; geometric integration of spatial data; analysis of trajectories; map matching; automatic generalization; line simplification; aggregation of spatial information; automatic map labelling; automation in geo-information science and cartography based on combinatorial optimization, including efficient algorithms, exact algorithms, and heuristics

- **Geoinformation and Spatial Development (GSD) – Project**
  - ➔ current topics of geoinformation and spatial development
  - ➔ Qualification goals: Successful students are able to work in a group on an open research problem related to geoinformation and spatial development. They are able to define

realistic project goals, to choose and apply appropriate methods and tools for accomplishing these goals, and to assess their results critically.

- **Geo-Information Management in an Interdisciplinary Research**
  - ➔ advanced concepts of spatial databases, representation of knowledge in formal ontologies, open and linked data, research data management, tools and methods for metadata annotation
- **Land Management**
  - ➔ land policy; land tenure, land cadastre, land register; land law and land tax, land use rights and burdens on land, public and private stakeholders; instruments of private and public law for building land development and provision: land use planning, planning safeguarding, land readjustment and land reallocation, urban development measure; urban contracts, land acquisition, voluntary and sovereign land management procedures; expropriation, infrastructure provision, urban development measures; land management in urban regeneration and urban redevelopment; processes, actors, and funding urban land management projects
- **Land Markets and Valuation**
  - ➔ structures, elements, and trends of land and real estate markets, public and private stakeholders; interrelations between urban development and land markets; economic, legal, and financial mathematical principles of real estate valuation; determinants of land and real estate values; methods of land and real estate valuation; instruments for creating transparency on the property market; national standards of valuation methods: income approach, cost approach, sales comparison approach; international standards of valuation methods; residual method, special tasks of valuation; actors and institutions of land valuation
- **Location-Based Services**
  - ➔ navigation systems and their components; graph-theoretical concepts and algorithms for location-based services; network analysis and visualization; algorithms for routing problems; algorithms for map matching; trajectory analysis, route choice models; landmark-based navigation; cartographic visualization for navigation systems; automatic generation of schematic network maps; routing in public transport networks
- **Profile Fundamentals (for Geoinformation and Spatial Development)**
  - ➔ principles and framework of regional and urban planning; strategies of rural development; framework of land management and land tenure; mechanism of land markets, interrelation of planning and property value; design and analysis of algorithms (e.g., incremental algorithms, dynamic programming); fundamental data structures (e.g., arrays, binary search trees, hash tables); object-oriented modeling and programming, profound knowledge of at least one programming language; relational databases and object-relational spatial databases; foundations of geo-information systems (GIS), including GIS standards (e.g., the OGC simple feature specification) and data formats (e.g., GML); cartographic visualization
- **Rural Development**
  - ➔ structures, types, and trends of rural regions; demographic and economic changes, problems of peripheral rural regions, urban-rural-cooperation, public, private, and societal stakeholders; community involvement; rural infrastructure and land consolidation: legal background, targets, and procedures; international approaches of rural development; theory of regional and endogenous development, LEADER approach, change management, village renewal
- **Spatial Decision Support Systems**
  - ➔ methods of operations research in spatial planning; spatial unit allocation; districting; facility location; mathematical modelling; mathematical programming; linear and integer linear programming; neighborhood analysis; applications of neighborhood graphs, Voronoi diagrams, and triangulations in planning, theories of decision making in spatial

planning; cost-benefit-analysis; dynamic urban calculation; scenario planning; multiple criteria assessment methods; risk, vulnerability and resilience assessment, site assessment, SWOT-analysis, optimization of land use planning

- **Urban Development**
  - ➔ current determinants and trends in urban development: reurbanization, suburbanization, urban sprawl, demographic change, climate change, energy demand; models and principles for sustainable urban development and a resiliency city; quantitative and qualitative methods of planning (MCA, UVP); strategies and instruments of sustainable and resilient urban development: cost, land and resource efficiency, climate adaptation; social housing, participation models; planning and land management approaches to internal development: gap between buildings, redensification, brownfield redevelopment; cooperative and sovereign action; strategies and legal instruments of city renewal: urban regeneration, social urban renewal and urban reconstruction, urban design and urban preservation; urban monument protection

Profile: Mobile Sensing and Robotics

- **Application and Evaluation of Kinematic Mobile-Sensor-Systems**
  - ➔ planning and performing measurement campaigns with kinematic sensor system setups in urban or agricultural environments; data processing of raw data (Inertial sensors, GNSS, laser scanner, cameras) to generate georeferenced point clouds or other 3D information; point cloud processing and data interpretation; quality assessment of the final or intermediate results
- **Advanced Techniques for Mobile Sensing and Robotics**
  - ➔ camera models; sensor calibration; system calibration; relative orientation; simultaneous localization and mapping; bundle adjustment; advanced sensor modeling; time series analysis; correlation; shaping filter; advanced Kalman filters; 3D environment models; point clouds; visual features; feature matching; RANSAC; path planning
- **GNSS - Methods for Quality Assurance**
  - ➔ common and state-of-the-art techniques to minimize systematic observation errors; handling of GNSS equipment and post-processing software packages; conception and realization of suitable field test; interpretation of GNSS data and processing results; implementation of standard code-based position determination
- **Mobile Sensing and Robotics (MSR) – Project**
  - ➔ moving objects; pose estimation and localization; trajectory estimation; simultaneous localization and mapping; sensor calibration; sensor fusion; advanced sensor data interpretation; pointcloud processing; machine learning for perception; AI techniques for robot navigation
- **Modern C++ for Computer Vision**
  - ➔ programming in C++; revision control using git; solving typical image processing task using C++ and OpenCV; feature extraction; clustering; segmentation; matching
- **Point Cloud Processing**
  - ➔ handling of laserscanner equipment and processing software packages; interpretation of Point-Cloud data, point cloud processing algorithms, and processing results (e.g registration, resampling, color/normal vectors/scalar fields management, statistics computation, sensor management, interactive or automatic segmentation, etc.)
- **Profile Fundamentals (for Mobile Sensing and Robotics):**
  - ➔ random and systematic measurement error; variance propagation; probability basics (conditioning, marginali-zation, independence, Bayes' rule); Bayes filter basics; traverses; total stations (angular measurements, elec-tro-optical distance measurements, relevant uncertainties, propagation of light in atmosphere); reference system of height; camera

basics (pinhole modes, mapping points); relative orientation of the image pair and fundamental matrix; feature extraction & matching
- **Robot Perception using ROS**
  ➔ the Robot Operating System ROS; developing ROS modules; classification and machine learning for robot navigation; advanced perception; robot navigation systems
- **Sensors and State Estimation**
  ➔ sensors (inertial sensors, accelerometer, gyroscope, IMU, magnetometer, laser scanner, GPS, RTK GPS); odometry; geometric and probabilistic motion models; inertial navigation; basic probabilistic models of range sensors; environment models; Recursive Bayes filter, Kalman filter, and extended Kalman filter; Particle filter, Monte-Carlo localization; smoothing

M.Sc. Nature Conservation and Landscape Ecology

- **Geomatics (I and II)**
  ➔ basics of spatial and environmental data processing; ecopolitical functions of environmental information and environmental information processing; development of environmental information systems; legal foundations and framework conditions: Environmental Information Act, EU-INSPIRE Directive, EU Copernicus Program, Intellectual property and free data; selected environmental monitoring programs, their technical and methodological foundations in the ecological and political context

M.Sc. Nutritional Sciences & M.Sc. Molecular Food Technology

- **Research Seminar Nutrition and Food Sciences**
  ➔ insights into current research topics in nutrition and food sciences; interdisciplinary aspects of the subject area