Degree Program Documentation Bachelor's Program Agricultural and Horticultural Sciences

Part A
TUM School of Life Sciences
Technische Universität München

General information:

- Administrative responsibility: TUM School of Life Sciences
- Name of degree program: Agricultural and Horticultural Sciences
- Degree: Bachelor of Science (B.Sc.)
- Standard duration of study and credits:
  6 Semesters and 180 credit points (CP)
- Form of study: full time
- Admission: Unrestricted Admission
- Start: Winter semester (WiSe) 2024/2025
- Language of Instruction: German
- Main location: Weihenstephan (Freising)
- Academic administrator (program design):
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1 Degree Program Objectives

1.1 Purpose

Agricultural and horticultural sciences are concerned with the scientific principles and production systems for the production of human and animal foodstuffs and biogenic raw materials. In addition to the inclusion of other scientific fields (biology, chemistry, physics, mathematics, computer science), there are independent specialisms in agricultural and horticultural sciences - plant cultivation sciences, animal sciences, agricultural engineering and agricultural economics.

The agricultural and horticultural sciences face major challenges in the 21st century. Their solutions and innovations will determine how the world's growing population can be fed with high-quality food, even under the conditions of climate change and increasing weather extremes, such as periods of heat and drought.

Agricultural and horticultural production systems utilize natural resources such as soil, water and biodiversity. The protection of these natural resources is a basic prerequisite for the design of sustainable agricultural and horticultural systems and for the preservation of our cultural landscape. At the same time, agricultural and horticultural businesses must generate an adequate income and be competitive. This results in conflicting objectives that must be recognized and weighed up against the premise of sustainability.

Modern agricultural and horticultural systems are characterized by technical innovations and increasing digitalization. Sensor and satellite-supported systems take on important monitoring and control functions. The importance of agricultural informatics, digitalization and robotics is therefore increasing in academic education, for example in precision farming, the digitalized detection of pest symptoms, the regulation of unwanted weeds, in crop/animal phenotyping, in livestock farming with the use of milking robots and automatic feeders or the digital recording of data on animal health and behavior.

The aim of the degree program is to train agricultural scientists as specialists or managers who work at the interface between science, administration, society and agricultural practice on a daily basis. Their fields of work are diverse and, in addition to agricultural production and agricultural research, include, for example, trade and marketing of agricultural products, environmental protection and nature conservation, agricultural policy, landscape planning and the development of rural areas. In development aid projects, they can contribute to solving urgent problems such as hunger and malnutrition.

The Bachelor's degree program trains agricultural and horticultural scientists who have a knowledge of natural sciences and economics that enables them to understand the mechanisms and interrelationships of agricultural and horticultural production at the level of soil, plants, animals and the environment, who know the production systems and can intervene in them to control them. The horticulture degree program deals with the cultivation of horticultural crops, especially ornamental plants, vegetables, fruit and special crops as well as the upstream and downstream areas, consulting, services, distribution and trade. New innovative systems such as vertical farming are an essential part of the degree program.

The degree program teaches the basic knowledge and its agricultural and horticultural applications from the natural, technical and economic sciences. Graduates are familiar with the challenges of a

multifunctional agricultural and horticultural sector and find solutions for future-proof, sustainable agricultural and horticultural systems.

The Bachelor's degree program offers a first professional qualification and provides a sound basis for a further science-oriented Master's degree program in agronomy-oriented degree programs or the Environmental Sciences, Resource Management and Biomass Technology degree programs (Figure 1).

1.2 Strategic Significance

Sustainability is the leitmotif of the research and teaching culture at TUM. In science, business, politics and civil society, competences are needed to solve sustainability-related issues that strengthen the competitiveness of our graduates in the global working world. Students are motivated to develop their own understanding of sustainability and empowered to use their knowledge and skills to make responsible decisions for a healthy future (TUM Sustainable Futures Strategy 2030).

Under the motto "One Health", the TUM School of Life Sciences uniquely combines the key competences required to research the foundations of our lives: from molecules to cellular systems to plant and animal organisms, from soil to ecosystems, from food to nutritional medicine, from biogenic raw materials to biotechnology using the advantages of artificial intelligence. Climate change, population growth and dwindling resources as well as the associated issue of food security require innovations. Because only if the interaction between humans, animals, plants, microorganisms, soil and the environment works will the world as a whole remain healthy and sustainable.

TUM's guiding principle of sustainability and the "One Health" concept of the TUM School of Life Sciences characterize the Agricultural and Horticultural Sciences degree program. The program teaches skills and abilities for designing sustainable agricultural and horticultural production systems. Future agricultural systems must preserve intact ecosystems as a basis for life and the economy, reduce climate risks and greenhouse gases and promote biodiversity. At the same time, they must be internationally competitive, ensure the viability of agricultural businesses and contribute to feeding the world's population.

The design of sustainable agricultural and horticultural systems requires students to have an in-depth understanding of biological and agro-ecological interrelationships, but also to be able to contribute their knowledge of production technology and economics to decisions on the further development of production systems. This is promoted by the interdisciplinary training throughout the program.

The program is designed in such a way that, building on the scientific foundations, the production systems of crop cultivation and livestock farming, and increasingly also alternative food production systems such as "cellular agriculture", are dealt with. Project-orientated modules, exercises and practicals are closely related to the issues and challenges of agricultural and horticultural practice.

The undergraduate degree program is the basis of education in agricultural and horticultural sciences at the TUM School of Life Sciences (Figure 1). Advanced Master's degree programs allow students to specialize with a focus on biosciences, systems science or economics and social sciences. Three Master's degree programs are oriented towards agricultural sciences (MSc Agricultural Systems Science, MSc AgriFood Economics, Policy and Regulation, MSc Agricultural Biosciences), while other

Master's degree programs focus more strongly on environmental sciences, resource management and biomass technology.

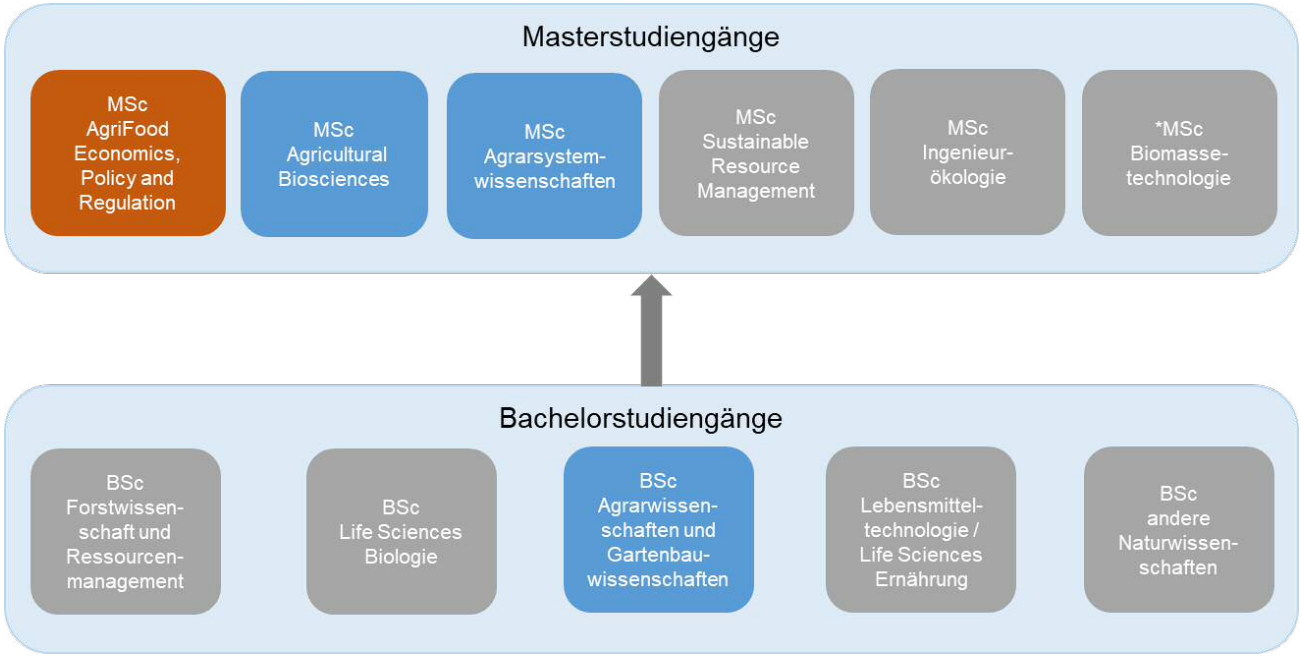


Figure 1: Study programs offered by the Department of Agricultural and Horticultural Sciences (blue, orange) in the context of adjacent study programs at the TUM School of Life Science (grey) and TUM Campus Straubing*

2 Qualification Profile

The content of the following qualification profile corresponds to the requirements of the Qualifications Framework for German Higher Education Qualifications (Hochschulqualifikationsrahmen - HQR) and the requirements contained therein (i) knowledge and understanding, (ii) use, application and generation of knowledge, (iii) communication and cooperation and (iv) academic self-conception/professionalism. The formal aspects according to the HQF (admission requirements, duration, degree options) are detailed in chapters 3 and 6 as well as in the corresponding subject examination and study regulations.

Knowledge and Understanding

The Bachelor's degree program in Agricultural and Horticultural Sciences aims to provide an excellent basic and science-oriented education and at the same time has a close practical focus through the integration of excursions, professional practice, practical exercises and project work.

Graduates have demonstrated a broad and integrated knowledge and understanding of the scientific principles of crop production, livestock farming and horticulture. After completing the degree program, students know and understand the scientific, engineering and economic principles of agricultural and horticultural production systems. They have a broad methodological understanding of chemical and biochemical analysis, molecular genetics and biotechnology, the analysis of material and energy flows in agricultural and horticultural ecosystems.

They know methods of analysis for assessing production systems and their components (soil, plants, animals, farm and market) and can classify the results of the analyses in relation to their condition and their control options. They know the interactions between production systems, the environment and society.

In the field of plant cultivation science, graduates master the basics of plant breeding, plant cultivation, plant nutrition and plant protection. Students who opt for an agricultural science orientation also acquire knowledge of animal nutrition, animal husbandry, animal hygiene and animal breeding. They have knowledge of agricultural engineering including new digital systems (agricultural robotics, automation) and the interactions between soil - plant - animal - human in agro-ecological and socio-technical systems.

Students who opt for a horticultural science orientation acquire in-depth knowledge of plant production in the field of horticulture. They are familiar with the specific production processes of horticultural crops in closed and open systems.

Graduates of this degree program have basic knowledge of farm and market analysis. They can analyze relationships between supply and demand and describe the components and mechanisms of agricultural and horticultural value chains. They have basic knowledge of operating and production systems, the management of companies in the agricultural and food industry and the marketing of agricultural and horticultural products.

Graduates are able to think in a networked and analytical way and to work in a method-orientated and scientific manner. They are able to evaluate new research results and scientific findings from

neighbouring areas of natural sciences and technology with regard to their applicability and implementation possibilities for the agricultural and horticultural sector.

Graduates of the Agricultural and Horticultural Sciences degree program have a critical understanding of the most important theories, principles and methods of their specialist discipline and are able to deepen their knowledge beyond their own specialist area, e.g. in the environmental and engineering sciences. They are able to assess and critically categorize the potential, risks and opportunities of new approaches and production systems, e.g. genetic engineering, vertical farming or robotics.

Use, Application and Generation of Knowledge

The Technical University of Munich aims to provide its students with excellent methodological and specialized knowledge as well as an interdisciplinary, comprehensive education of their personality. The Bachelor's degree program is characterized by an interdisciplinary approach.

Graduates of the Bachelor's degree program in Agricultural and Horticultural Sciences have acquired methodological skills that enable them to analyze, evaluate and design production systems in crop production, livestock farming and horticulture. They are able to use digital systems and methods for process monitoring and optimization. They will be able to analyze agricultural and horticultural systems with regard to production technology and processes, yields and performance, economic competitiveness, environmental and climate impacts and sustainability using methods from plant cultivation science, animal science, agricultural engineering, agricultural economics and agricultural sociology. Based on this, they can develop and implement their own solutions for the optimization of agricultural and horticultural systems.

Graduates can apply methods for analyzing farms and markets. They can analyze relationships between supply and demand and describe the organization of agricultural and horticultural value chains. They can analyze business and production systems and have initial experience in the organization of companies in the agricultural and food industry and the marketing of agricultural and horticultural products.

Graduates of the Bachelor's degree program in Agricultural and Horticultural Sciences have acquired research and methodological skills that enable them to carry out scientific work. They can apply research methods, for example measuring relevant parameters to describe the soil and phenotypes and genotypes of agricultural organisms. They know basic biotechnological procedures and other laboratory techniques that give them the necessary skills for research in plant and animal sciences and can apply these methods.

You will be familiar with statistical methods and the basics of experimental design and test planning in order to design your own experiments. They can carry out simple scientific studies themselves and analyze and document them in accordance with scientific methods. They have acquired the basic knowledge that enables them to critically reflect on the scientific approach.

Communication and Cooperation

The understanding of biological, ecological, economic and business contexts acquired during the course enables graduates to analyze social requirements responsibly and competently on a scientific and socio-economic basis and to recognize conflicting objectives.

Graduates can develop projects in a team, divide up tasks and work out solutions. They can apply theoretical knowledge in a solution-orientated manner to specific technical issues. They have learnt to select profile-forming specialist skills and develop key qualifications in a multi-layered subject. You will be able to conceptualize scientific presentations and present them to a specialist audience.

You will be able to communicate the current challenges in agricultural and horticultural systems and convincingly present the solutions offered by agricultural and horticultural sciences. You will be able to reflect on and take into account different points of view and interests and communicate with experts and non-specialists in order to solve a problem responsibly.

Scientific Self-image and Professionalism

The degree program enables graduates to develop an individual professional profile and their social and personal skills.

Graduates develop a professional self-image that is orientated towards the goals and standards of the agricultural and horticultural sector.

They are familiar with important framework conditions for professional activities such as legal requirements in the area of soil and plant protection as well as current quality standards in the area of food production and are able to apply these. They are familiar with the high social expectations of agricultural and horticultural production systems - from food safety, animal welfare and animal protection to environmental and climate protection.

They can critically assess the consequences and effects of their professional actions in relation to social expectations and consequences.

Throughout the program, graduates are motivated to develop their own understanding of sustainable agricultural and horticultural systems and are enabled to use their knowledge and skills to make responsible decisions for sustainable food production and the design of environmentally and climate-friendly agricultural ecosystems.

3 Target Groups

3.1 Target Audience

Applicants for this degree program should have an aptitude for science, mathematics and technology as well as an interest in nature, the environment and technology. A fundamental interest in current economic, political and legal developments in the context of the production and utilization of agricultural and horticultural products is a matter of course. The program is aimed equally at regional, national and international applicants.

Applicants should be able and willing to deal intensively with application- and practice-related issues during their studies. Communication skills, in particular presentation and argumentation skills, are advantageous.

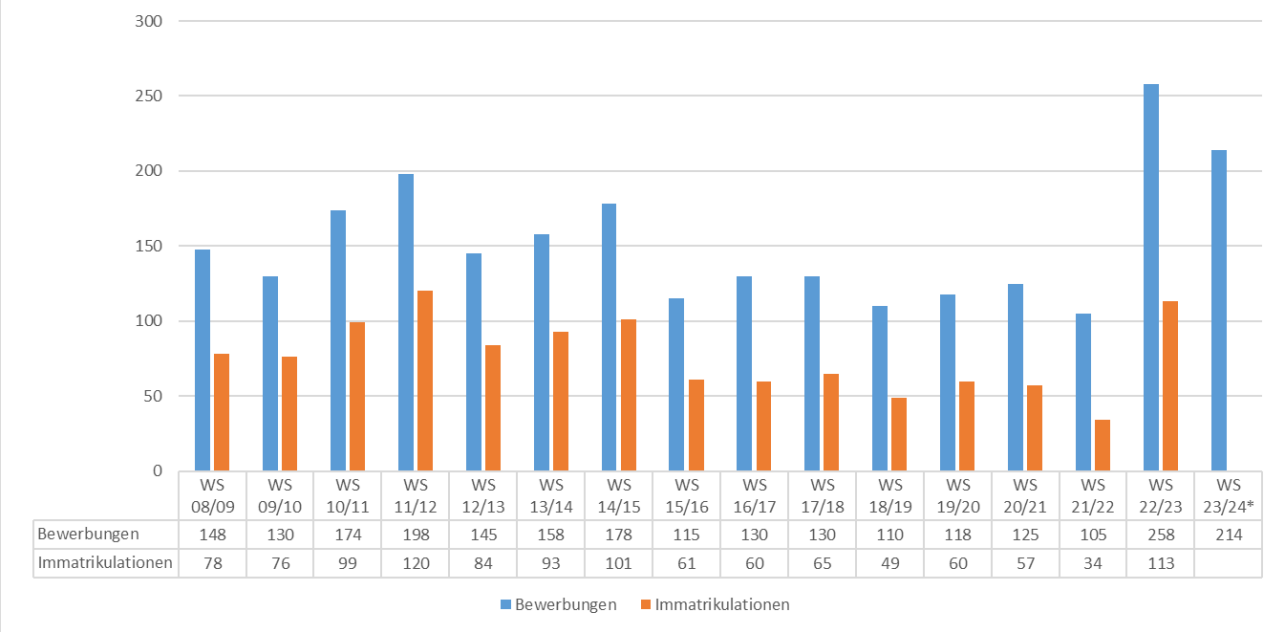
3.2 Prerequisites

For the Bachelor's degree program in Agricultural and Horticultural Sciences, the general admission requirements for studying at a university must be fulfilled in accordance with the current version of the Ordinance on Qualifications for Studying at Universities in the Free State of Bavaria. The prerequisite for the degree program is the general higher education entrance qualification or a comparable qualification. There are no other admission restrictions; the degree program is admission-free.

3.3 Target Numbers

Figure 2 shows the development of applicant and student numbers for the degree program.

After a decline in applications and enrollments until the winter semester 2021/22, partly due to the consequences of the coronavirus crisis, the number of applications and enrollments has risen sharply in the last two years. Interest in studying Agricultural and Horticultural Sciences at TUM has increased significantly. This is partly due to better advertising of the degree program, but also to a visible effort by TUM to improve the program with new professorships, for example in livestock science and soil science. The degree program has also been admission-free since 2022. In order to achieve the best possible balance between the quality of education and high demand from the labor market, TUM is aiming for a target number of up to 100 first-semester students per year.



	WS 08/09	WS 09/10	WS 10/11	WS 11/12	WS 12/13	WS 13/14	WS 14/15	WS 15/16	WS 16/17	WS 17/18	WS 18/19	WS 19/20	WS 20/21	WS 21/22	WS 22/23	WS 23/24*
Bewerbungen	148	130	174	198	145	158	178	115	130	130	110	118	125	105	258	214
Immatrikulationen	78	76	99	120	84	93	101	61	60	65	49	60	57	34	113	

Figure 2: Overview of applicants and enrollments in the Bachelor's degree program in Agricultural and Horticultural Sciences

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4 Demand Analysis

The Bachelor's degree program in Agricultural and Horticultural Sciences primarily trains students for consecutive Master's degree programs. The figures for the Agricultural and Horticultural Sciences program bundle show that between approx. 32% (winter semester 22/23) and approx. 51% (winter semester 20/21) of a cohort transfers to one of the Master's programs within the program bundle after successfully completing a Bachelor's degree. The other graduates mainly transfer to other Master's programs at TUM (see Figure 1) or other universities and colleges.

An important source of information for assessing the professional situation of graduates of the Agricultural and Horticultural Sciences degree program is the survey of graduates in the agricultural sector conducted by the VDL-Berufsverband Agrar Ernährung Umwelt. 522 people took part in the survey in 2021. Of the 335 university graduates, 67.5% had a Master's degree, 31% a Bachelor's degree and 3.3% a diploma. The conclusion of the graduate survey emphasizes that there is a clear shortage of skilled workers. This is reflected, among other things, in the fact that 33% of those surveyed had already taken up employment before graduating and then continued to do so, 30% within 3 months of graduating and 10% within 3 to 6 months of starting their first job.

All graduates of Bachelor's and Master's degree programs (universities and colleges) were asked about the professional qualification of their Bachelor's degree. Almost 40% consider the Bachelor's degree to be fully or predominantly professionally qualifying. Only 18% of Bachelor's graduates (university) are in regular paid employment. 29% switch to a postgraduate program (e.g. Master's degree) after completing their Bachelor's degree. The remaining graduates were in an internship/volunteering (7%), traineeship (2%), trainee program (1%), second degree (2%), self-employed (1%), working in their parents' company (7%) or in a casual job (13%). These figures relate to bachelor's graduates from universities.

13% of all graduates surveyed had changed their place of study, over 90% of the changes were within Germany. The three most frequently cited reasons for changing universities were subject-related reasons (e.g. facilities at the second university), personal reasons (e.g. gaining new experience) and career-related reasons (e.g. connections between the second university and potential employers). In retrospect, 80% were satisfied with the change of university and 70% would at least mostly do it again.

The largest proportion of graduates surveyed (27%) were working in the field of agriculture-related services or science when they started their careers. Furthermore, 23% of respondents worked in agriculture, 27% in upstream sectors of agriculture, 6% in downstream sectors and 12% outside of agriculture.

While the Bachelor's degree program primarily prepares students for a consecutive Master's degree program, graduates are also qualified for employment. Graduates are able to apply scientifically sound methods and procedures to solve problems relating to the production and marketing of high-quality plant and animal foods and non-food products. Due to their detailed knowledge of economic interrelationships, they are able to assess the development in the value chains from plant and animal production through processing to the product and evaluate it under environmental, social and political influencing factors.

Exemplary fields of activity are

- Plant and animal breeding companies,
- Agricultural engineering companies (manufacturers of agricultural machinery and equipment, buildings and structures),
- Chemical industry (in the areas of plant nutrition and plant protection),
- Feed industry,
- Quality management in the agricultural and food industry,
- Procurement and distribution in the agricultural and food industry,
- Business management and production technology consulting,
- Ministries and agricultural administration,
- International cooperation organisations.

5 Competition Analysis

5.1 External Competition Analysis

An evaluation of the national and international range of degree programs in the field of agricultural and horticultural sciences reflects the strong differentiation of the subject. Two trends can be identified: On the one hand, a focus on certain sub-areas, e.g. animal sciences and plant sciences. On the other hand, there are new degree programs, e.g. environmental engineering or bioeconomy, which previously addressed the traditional target groups of agricultural and horticultural science degree programs.

The range of programs with an agricultural and horticultural focus is therefore very diverse. Degree programs in agricultural sciences are offered in Germany at the universities of Munich, Berlin, Bonn, Halle-Wittenberg, Hohenheim, Gießen, Göttingen, Kiel and Rostock. Five of these locations offer the opportunity to specialize in their agricultural science degree programs, primarily with specializations in animal, plant, economic and social sciences. Apart from TUM, a full university degree program in horticultural sciences is only offered at HU Berlin and LU Hannover (major) and therefore tends to be unique. The Bachelor's degree program in Agricultural and Horticultural Sciences is characterized by its multidisciplinarity, which is a prerequisite for training in systems science and networked specialist science. Both lead to skills that distinguish agricultural and horticultural scientists from graduates of other degree programs and are in high demand on the labor market. The demand on the labor market in Bavaria currently exceeds the number of graduates.

A differentiated picture also emerges internationally. A look at leading agricultural science locations reveals a range of specialized degree courses, such as at Wageningen or Cornell University, a continuation of a broad-based bioengineering degree course, e.g. at Ghent University, or a mixture of both approaches, e.g. at the University of California in Davis.

In addition to the scientifically oriented degree programs at universities, universities of applied sciences offer more practice-oriented degree programs, which primarily appeal to first-year students with a high level of interest in professional fields in agriculture and horticulture. The degree programs offered by Weihenstephan-Triesdorf University of Applied Sciences (HSWT) are particularly noteworthy in this regard. It offers degree programs in agriculture at both the Weihenstephan and Triesdorf campuses. The Bachelor's degree programs comprise seven semesters (210 ECTS) due to the practical semester. The Weihenstephan Campus also offers the Bachelor's degree programs in Industrial Engineering, Agricultural Marketing and Management and Horticulture - Production, Trade, Services. In comparison to the Agricultural and Horticultural Sciences degree program at TUM, the degree programs at HSWT focus more on practical agriculture and less on scientific principles.

5.2 Internal Competition Analysis

Other faculties of the Technical University of Munich do not offer a degree program comparable to the Bachelor's degree program in Agricultural and Horticultural Sciences.

The natural sciences are a mainstay of the degree program. At the same time, the technical and engineering sciences, such as agricultural systems engineering, economics and social sciences, are also integrated into the program and shape its interdisciplinary character.

The Forest Science and Resource Management degree program is similar in structure to the Agricultural and Horticultural Sciences degree program. The systems science-oriented degree program focuses on forest and forest ecosystems, including their use and integration into technical and socio-economic systems. Despite the similarity in the systemic approach, this distinguishing feature is decisive for the offer of independent degree programs.

6 Program Structure

6.1 Curriculum

The Bachelor's degree program in Agricultural and Horticultural Sciences comprises a standard period of study of 6 semesters, including a vocational orientation (work placement) and the preparation of the Bachelor's thesis. A total of 180 ECTS credits must be earned within the framework of modules.

The degree program enables students to learn the basics of agricultural and horticultural sciences and at the same time build up an individual profile by supplementing the basics with approaches in systems sciences or specialized aspects of animal, plant or economic sub-disciplines.

The Bachelor's degree program has a **Y-structure**: the basic training in natural sciences, engineering and economics is combined with

- the Agricultural Sciences profile: in-depth training in crop production sciences (grassland and arable farming systems) and animal sciences or
- the Horticultural Sciences profile: in-depth training in horticultural cultivation systems.

Students make the decision in favor of an agricultural or horticultural science orientation in the 1st semester.

The Bachelor's degree program consists of:

- from 18 **required modules,** both interdisciplinary and subject-specific (93 credits),
- from 7 required modules for the agricultural science orientation (34 credits), or
- from 7 required modules for the horticultural science orientation (34 credits),

  The following **cliff modules** (12 credits per study orientation) were selected from the required modules, of which the students must have passed 2 cliff modules each by the end of the 2nd semester: LS20037 Biology (7 CP) as well as for the agricultural science orientation WZ1828 Anatomy and Physiology of Farm Animals (5 CP) and for the horticultural science orientation WZ1451 Introduction to Horticultural Sciences (5 CP).

- from a **compulsory elective module** (5 credits) on applied statistics with a choice between biometrics or econometrics
- the **Bachelor's thesis** (12 credits),
- **Elective modules** totaling 36 credits, of which 6 CP must be earned in modules of interdisciplinary qualifications.

Figures 3 and 4 show overviews of the curriculum of the degree program with the respective orientation. The overview of the curriculum shows the structure of the Bachelor's degree program in Agricultural and Horticultural Sciences. In general, 30 +/- 1 CP are planned per semester.

Figure 3: Example of a study plan for a Bachelor's degree program in Agricultural and Horticultural Sciences (here for the agricultural science orientation)

Sem	Modules							CP
1.	LS20037 Biology (required) K 7 CP	WI001062 Introduction to Economic Sciences (required) K 5 CP	MA9601 Advanced Mathematics 1 (required) K 5 CP	WZ1825 Soil Science (required) 2 CP	NAT0123 Fundamentals of General and Inorganic Chemistry (required) K 3 CP	WZ1828 Anatomy and physiology of Farm Animals (required AG) K 5 CP	WZ1830 Practical Course in Agriculture (required AG) LL (SL) 4 CP	31
2.	MGT001415 Accounting and Production Economics (required) K 5 CP	NAT9017 Practical physics (required) ÜL + LL 5 CP	LS10025 Plant production and Plant Nutrition (required) K 7 CP	 K 3 CP	LS10023 Organic Chemistry and Biochemistry (required) K 4 CP	WZ1843 Grassland and forage production (Mandatory AG) K 5 CP		29
3.	WI001203 Applied Statistics: Econometrics *) (compulsory elective) K 5 CP	WZ0086 Agroecosystems (required) K 5 CP	WZ1832 Phytopathology and plant breeding (required) K 6 CP	WZ1841 Animal nutrition (Required AG) K 5 CP	LS10019 Animal breeding, animal health and hygiene (Mandatory AG) K 5 CP	WZ1840 Plant production systems (required AG) K 5 CP		31
4.	WZ0064 Applied chemistry (required) ÜL 5 CP	WZ0095 Applied physics (required) K 5 CP	WZ0055 Operating and production systems (required) M 5 CP	MGT001414 Economics of the agricultural and horticultural sector and its WSK** (required) K 5 CP	WI001289 Agricultural and food policy (election) K 5 CP	WZ1867 Technical basics for smart farming (optional) M 5 CP		30
5.	WZ0054 Biotechnological methods (required) K 5 CP	WI001202 Corporate management and marketing (required) K 5 CP	LS10024 Occupational field orientation (required) 4 weeks work placement B (SL) 6 CP	LS10028 Agricultural technology, animal husbandry and behaviour (required AG) K 5 CP	LS10020 Introduction to scientific work in agricultural and horticultural sciences. (ÜFQ) INSTRUCTOR 3 CP	LS10009 Programming for Data Science in Agriculture (elective) B 5 CP		29
6. Mobility window	WZ0059 Bachelor's Thesis W 12 CP		WZ1505 Introduction to Resource and Environmental Economics (elective) K 5 CP	LS10027 Animal welfare, animal behaviour and management (elective) K 5 CP	SZ0488 English - Gateway to English Master's C1 (ÜFQ) M + K 3 CP	LS10029 Ecology and ecosystem functions of insects in agricultural landscapes (elective) K 5 CP		30

Sem	Modules	CP
Legend	Dark blue = required Bachelor's thesis module Light blue = elective modules Grey = required modules Green = subject-specific required modules Orange = required elective module	Sem. = semester; CP = credit points; SL = academic achievement, K = written examination; M = oral examination; LL = laboratory achievement; ÜL = exercise achievement; W = scientific paper; B = report ÜFQ = interdisciplinary qualification; WSK**) = value chains *) or WZ0056 Applied Statistics: Biometrics (compulsory elective module)

Figure 4: Example of a study plan for a Bachelor's degree program in Agricultural and Horticultural Sciences (here for the horticultural science orientation)

Sem	Modules							CP
1.	LS20037 Biology (required) K 7 CP	WI001062 Introduction to Economics (required) K 5 CP	MA9601 Advanced Mathematics 1 (required) K 5 CP	WZ1825 Soil science (required) 2 CP	NAT0123 Fundamentals of General and Inorganic Chemistry (required) K 3 CP	WZ1451 Introduction to Horticultural Sciences (required GB) K 5 CP	WZ1831 Practical Course in Horitculture (required GB) LL (SL) 4 CP	31
2.	MGT001415 Accounting and Production Economics (required) K 5 CP	NAT9017 Practical Physics (required) ÜL + LL 5 CP	LS10025 Plant production and Plant Nutrition (required) K 7 CP	 K 3 CP	LS10023 Organic Chemistry and Biochemistry (required) K 4 CP	WZ0057 Technical Principles for Horticultural Production K 5 CP		29
3.	WZ0056 Applied Statistics: Biometrics*) (compulsory elective) K 5 CP	WZ0086 Agroecosystems (required) K 5 CP	WZ1832 Plant Pathology and plant breeding (required) K 6 CP	WZ0091 Horticultural Physiology of Production (required GB) K 5 CP	WZ1848 Basics in Vegetable Crop Production (required GB) K 5 CP	WZ0124 Growth and Crop Physiology of Horticultural Plants K 5 CP		31
4.	WZ0064 Applied Chemistry (required) ÜL 5 CP	WZ0095 Applied Physics (required) K 5 CP	WZ0055 Agriculutral Production systems (required) M 5 CP	MGT001415 Accounting and Production Economics (required) K 5 CP	WZ1847 Basics of fruit growing (election) M 5 CP	WZ1860 Specialised vegetable growing (choice) K 5 CP		30
5.	WZ0054 Biotechnological Methods (required) K 5 CP	WI001202 Business Management and Marketing (required) K 5 CP	LS10024 Vocationall Field Orientation (required) 4 weeks Internship B (SL) 6 CP	WZ1850 Environmentally sound Horticulture: Fertilisation and Plant Protection (required GB) K 5 CP	LS10020 Introduction to scientific work in agricultural and horticultural sciences. (ÜFQ) ÜL 3 CP	WZ0113 Organic farming (choice) K 5 CP		29
6. Mobility window	WZ0059 Bachelor's Thesis W 12 CP		WZ1505 Introduction to Resource and Environmental Economics (elective) K 5 CP	WZ2530 Organismic Phytopathology (elective) K 5 CP	ED0038 Technology, Economy and Society (ÜFQ) W 3 CP	LS10029 Ecology and Ecosystem Functions of Insects in Agricultural landscapes (elective) K 5 CP		30

Sem	Modules	CP
Legend	Dark blue = required Bachelor's thesis module Light blue = elective modules Grey = required modules Green = subject-specific required modules Orange = compulsory elective module	Sem. = semester; CP = credit points; SL = academic achievement, K = written examination; M = oral examination; LL = laboratory achievement; ÜL = exercise achievement; W = scientific paper; B = report ÜFQ = interdisciplinary qualification; WSK**) = value chains *) or WI001203 Applied Statistics: Econometrics (compulsory elective module)

6.2 Modules

The degree program enables students to learn the basics of agricultural and horticultural sciences and at the same time build up an individual profile by supplementing the basics with approaches in systems sciences or specialized aspects of animal, plant or economic sub-disciplines.

Required modules

The **required modules include** general propaedeutics (*biology, fundamentals of general chemistry and inorganic chemistry, organic chemistry and biochemistry, practical physics, advanced mathematics) as* well as economics modules (e.g. *introduction to economics*).

Fundamentals of General and Inorganic Chemistry (3 CP) teaches the basic structure of atoms, basic structures of molecules and the different types of chemical bonds, acid-base concept, redox processes in the 1st semester in 2 SWS. This module thus forms the prerequisite for understanding the principles of organic chemistry and biochemistry (methods of biochemistry, metabolic processes and concepts, biological macromolecules, enzymes) in the subsequent module *Organic Chemistry and Biochemistry* (4 CP, 3 SWS) in the 2nd semester.

The required module *Practical Physics* is assessed in two examinations. The exercise course is taken during the lecture period to accompany the experiments carried out and the laboratory course is taken at the end of the lecture period. This ensures that the examination load in the examination period of the 2nd semester comprises 6 examinations.

These required modules are supplemented with subject-specific required modules from the fields of plant sciences (e.g. *plant cultivation and plant nutrition, phytopathology and plant breeding*), animal sciences (e.g. *animal nutrition, animal breeding, animal health and hygiene*), environmental sciences (e.g. *soil science, agroecosystems*) and technology (e.g. *plant production systems, agricultural engineering, animal husbandry and behavior*) as well as various practical training sections (*practical training in agriculture, practical training in horticulture, vocational orientation*). In these required modules, students acquire the specialist and methodological skills that make up the qualification profile of agricultural and horticultural scientists.

Modules that convey the systemic nature of agricultural and horticultural sciences are integrated early on in the degree program (e.g. *agroecosystems, plant production systems, horticultural production physiology*). Training in economics extends throughout the entire degree program (1st, 2nd, 4th and 5th semesters).

Students apply the knowledge acquired in the various disciplines in the middle of the degree program in the project-oriented required module "*Operating and Production Systems*". In small groups of up to four people, students use indicators to analyze the actual situations of pilot plants. Solution approaches are developed that consider the overall system and are presented and defended in a final

presentation. In the process, important social skills for professional life such as communication skills and team spirit are developed. Students practice conducting interviews with farm managers, using agricultural-specific software, analyzing farm data and working with simulation models.

Exercises throughout the program (semesters 1-5) serve to deepen theoretical knowledge through practical application.

This includes the dissection of organs of ruminants and monogastric animals in the exercise for the module *Anatomy and Physiology of Farm Animals*.

In the botanical exercises in the *Plant Cultivation and Plant Nutrition* module, students use a microscope to create microscopic plant specimens and scientific drawings. They use a scientific identification key to determine the most important plant families by their characteristics.

In the two-semester *Soil Science* module, students apply their knowledge in exercises on specific soil profiles in the field in the summer semester, depending on the season. The students are

This enables them to understand the formation of soils and their various properties depending on the location and to evaluate soils ecologically on the basis of soil profiles in the field. The prerequisite for this is the theoretical foundations taught in the previous winter semester.

The exercises in the *Plant Cultivation and Plant Nutrition* module take place in the experimental stations of the School of Life Sciences. The students characterize the plant populations in experimental fields with regard to nutritional status, deficiency symptoms and infestation with pathogens (e.g. fungi or animal pathogens).

In the *Applied Chemistry* module, students learn practical laboratory skills, e.g. to determine the nutrient content of soils and plants and derive the need for action (e.g. fertiliser recommendations).

The exercises in the *Biotechnological Principles* module enable students to apply various methods of molecular biotechnology, e.g. PCR, cloning, sequencing, qRT-PCR, RT-PCR, gene editing, CRISPR/Cas9. They can plan experiments independently and select suitable methods for a given problem.

Work placement as academic achievement

Practical vocational training is given high priority in the degree program (a total of 10 CP in the required area plus 10 CP in the elective area, see below). It begins in the first semester with an internship section, which establishes contact with the basic practical activities of the agricultural and horticultural sector. All students in the agricultural science orientation complete two agricultural technology courses and an animal husbandry course in the *agricultural economics internship* module (4 CP). Students in the horticultural orientation complete courses on greenhouse technology, measurement technology and conventional and biological plant protection in horticulture in the Practical *Horticulture module* (4 CP). In addition, they apply specific horticultural work techniques in practice: e.g. in-vitro cultivation technology, biotechnology and horticultural plant breeding.

These modules mainly serve to illustrate and carry out practical activities in agriculture and horticulture. The focus is not on imparting theoretical, specialized knowledge. Self-study is not required. For this reason, the workload of this module is assessed with 4 credits.

The required module *on professional orientation* (6 CP) in the fifth semester serves to familiarize students with various professional fields. Before starting this internship, students should have already developed an initial idea of their future professional field. Students spend this four-week internship (exclusively) in the upstream and downstream areas of agriculture or horticulture (in Germany or abroad) in order to familiarize themselves with professional fields. Meaningful internship reports serve to reflect on the professional field experienced.

Bachelor's Thesis

In the "Bachelor's Thesis" module (12 credits), students further develop their subject-specific key qualifications. This module consists of a scientific paper and an ungraded presentation on the topic of the scientific paper. The topic of the thesis can be freely chosen by the students in consultation with a supervisor.

Compulsory elective modules

In order to do justice to the variety of methods used in data analysis, students opt to specialize in either biometrics or econometrics in the **elective subject** Applied Statistics.

Elective modules

A total of 36 CP must be earned in the elective area.

Of these, 6 CP must be taken from the courses offered by the TUM Language Centre and the Carl von Linde Academy in order to further develop the **interdisciplinary qualification**.

From the fourth semester onwards, students have a catalogue of **elective modules at their** disposal that allow for individual interdisciplinary training. Modules totaling a further 30 CP must be completed from this catalogue. The individual selection allows for a broad, generalist education as well as specialization in one of the areas of plant sciences, animal sciences, environmental sciences, economics or technology.

Students can choose to complete a *work placement* (7 weeks, 10 CP, course credit) to intensify their practical experience. Students spend this internship in the upstream or downstream area of agriculture or horticulture (in Germany or abroad) or in an agricultural/horticultural business in order to familiarize themselves with or gain a deeper understanding of professional fields.

Studiability

The modular structure of the Bachelor's degree program in Agricultural and Horticultural Sciences enables all compulsory modules to be offered without overlap. All elective modules of a study orientation are also offered without overlap. This guarantees the possibility of graduating within the standard period of study.

In order to ensure a seamless transition to a further Master's program, including at other universities, the course-related examinations take place immediately after the lecture period.

6.3 Stays abroad as part of the Degree Program

The 6th semester is available to students as a mobility window. There are no required modules here. In addition to a semester abroad, it is also possible to use the mobility window to complete an internship abroad. Upon application to the Examination Board, coursework and examinations completed during the stay abroad can easily be transferred to the elective area of the degree program.

7 Organization and Coordination

The Bachelor degree program Agricultural and Horticultural Sciences is offered by the TUM School of Life Sciences.

Administrative aspects of study organization are partly the responsibility of the central departments of the TUM Center for Study and Teaching (TUM CST) and partly of the TUM School of Life Sciences (see overview below):

- Student counselling:
  Student Advising and Information Services (TUM CST)
  studium@tum.de
  +49 (0)89 289 22245
  Provides information and advising for prospective and current students (via hotline/service desk)
- Departmental Student Advising:
  Susanne Papaja-Hülsbergen
  agriculturalsciences.co@ls.tum.de
  +49 (0)8161 71 3781
- Academic Programs Office (within department/school), Infopoint, etc.:
  Campus Office Weihenstephan
  campus.office@ls.tum.de
- Study Abroad Advising/Internationalization:
  TUM-wide: TUM Global & Alumni Office
  internationalcenter@tum.de

  Departmental: Campus Office Weihenstephan
  international.co@ls.tum.de
- Gender Equality Officer::
  Prof Aphrodite Kapurniotu
  akapurniotu@mytum.de
- Advising – Barrier-Free Education:
  TUM-wide: Service Office for Disabled and Chronically Ill Students (TUM CST),
  handicap@zv.tum.de
  +49 (0)89 289 22737
- Admissions and Enrollment:
  Application and Enrollment (TUM CST)
  studium@tum.de
  +49 (0)89 289 22245
  Application, enrollment, Student Card, leave of absence, re-registration, de-registration

- Semester Fees and Scholarships:: Fees and Scholarships (TUM CST)
  beitragsmanagement@zv.tum.de
  Scholarships and semester fees
- Examination Office: Graduation Office and Academic Records
  (TUM CST)
  Graduation documents, notifications of
  examination results, preliminary degree certificates
- Departmental Examination Office:: TUM School of Life Sciences;
  Campus Office Weihenstephan
  Examination Affairs Team
  examination.co@ls.tum.de
- Examination Board: Prof Dr Kurt-Jürgen Hülsbergen (Chairman)
  Susanne Minges (Secretary)
- Quality Management: TUM-wide: Quality Management
  (TUM CST)
  https://www.tum.de/studium/tumcst/teams-cst/

  Departmental: Campus Office Weihenstephan
  Quality Management Team
  qm.co@ls.tum.de
  Organization of QM circles, evaluation, coordination
  module management

8 Enhancement Measures

TUM's Quality Management (QM) has set itself the goal of continuously transferring responsibility for the development of its degree programs to the schools on the basis of the results of internal and external QM circles and ongoing student evaluations. This chapter describes the measures for improving the degree program that were developed in the QM circle based on the results of the ongoing evaluation. In consultation with the student representatives and the degree program committee, the following adjustments were therefore implemented in the degree program:

The previous credit scope of the required modules totaling 145 CP has been reduced to a total of 139 CP (incl. Bachelor's thesis, 12 CP; coursework 10 CP).

In order to optimize the workload and the acquisition of skills, the following adjustments have been made to required modules. The two-semester *Chemistry* module with 5 CP was divided into two modules: *Fundamentals of General and Inorganic Chemistry*, 3 CP in the 1st semester and *Organic Chemistry and Biochemistry*, 4 CP in the 2nd semester.

The number of credits in the *Crop Production and Plant Nutrition* module has been increased from 6 CP to 7 CP.

The module *Agricultural and Horticultural Economics* (9 cp, 8 SWS, 2nd semester) is divided into the following two modules: *Accounting and Production Economics* (5 cp, 4 SWS, 2nd semester) and *Economics of the Agricultural and Horticultural Sector and its Value Chains* (5 cp, 4 SWS, 4th semester).

The area of animal sciences was strengthened by new appointments. Teaching in this area was reorganized in the following modules: *Animal Breeding, Animal Health and Hygiene* (5 CP, 3rd semester), *Agricultural Engineering, Animal Husbandry and Behavior* (5 CP, 5th semester)

The scope of the required work placement was reduced from a total of 12 to 8 weeks. At the same time, a new elective module *work placement* (7 weeks, 10 CP, course credit) was introduced. Students have the choice between an internship in the upstream and downstream sector or an internship in the production sector, which allows for a more individualized focus in the professional internship area.

At the request of the students, excursions are increasingly being integrated into the courses and offered to a greater extent. For this reason, it was possible to cancel the 4 required excursion days in the vocational orientation module.

Expansion of the elective area from 30 CP to 36 CP (instead of 6 elective modules now 7 elective modules). Of these, 30 credits must be earned in the subject-specific elective area and 6 credits in the area of interdisciplinary qualifications.

During the current reaccreditation, new topics were added to the elective program by newly appointed professors: *Ecology and Ecosystem Functions of Insects in Agricultural Landscapes; Programming for Data Science in Agriculture; Animal Welfare, Animal Behavior and Management; Vertical Farming*.

study

The degree program has been admission-free since the winter semester 2022/2023. Required modules have been named, which must be completed by the end of the 2nd semester (cliff modules). The selection has been adjusted for examination law and organizational reasons: the module *Plant Production and Plant Nutrition* from the 2nd semester has been removed. This optimizes the preparation phase for any repeat examinations that may be necessary for students. The following required modules (one basic module and one specialized module) from the first semester continue to function as cliff modules:

- *Biology*
- *Anatomy and Physiology of Farm Animals* for students of agricultural sciences or agricultural science.
- *Introduction to horticultural sciences* for students of horticultural sciences.