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Mathematics education for sustainable agriculture specialists

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Abstract. One of the Sustainable Development objectives is to promote life-long learning opportunities for all, but one of the Lifelong Learning competences is mathematical competence, which can be obtained studying mathematics at schools and universities. The question is how much and whether the course of mathematics should be included in the curriculum of the agronomy specialties at universities. The aim of the article is to highlight the insufficient amount of higher mathematics in the education of agriculture specialist in the context of sustainable development.
The objectives of the study: to identify the importance of mathematics for agronomy specialists by analysing the role of the mathematics education for agronomy specialists and to analyse the proportion of mathematics courses in the curriculum of the agronomy programmes in the Baltics States and the Baltic Sea region's higher education institutions. The mathematics education is important for agronomy specialists in many fields. Agronomy specialists need knowledge and skills in basic mathematics, in statistical analysis and interpretation, mathematical modelling, in scientific methods, in economic analysis. The knowledge and skills in a direct and indirect means is provided by mathematical studies at universities. In order to analyse the proportion of mathematics courses in study programmes of Agriculture, Agronomy and Horticulture, three universities of the Baltic States were compared: the Latvia University of Life Sciences and Technologies, Aleksandras Stulginskis University (Lithuania) and Estonian University of Life Sciences. For a more comprehensive analysis and comparison several universities from the Baltic Sea region were chosen that provide studies in agricultural sciences. Unfortunately, not all agronomy programmes in the Baltic Sea region contain the higher mathematics course that would help to understand the role of derivatives, integrals, and differential equations in the modelling process, as well as further developing general problem-solving skills.

Key words: agronomy specialist, mathematics competences, mathematics education, sustainable agriculture.

INTRODUCTION

We all live in any age where we need to think about the sustainable development of our planet and our people. To get rid of poverty and hunger in the world, as well as the worst of climate change effects, leaders from 193 countries created a plan called the Sustainable Development Goals (SD) in 2015 which consists of 17 goals (Sustainable

Development goals, 2015). The fourth SD objective is 'Ensure inclusive and equitable quality education and promote life-long learning opportunities for all'. It is essential for each individual in a knowledge-based society to acquire lifelong learning competences. The Recommendation of the European Parliament and of the Council sets out eight key competences for lifelong learning: 1) Communicating in a mother tongue: 2) Communicating in a foreign language; 3) Learning to learn; 4) Social and civic competences; 5) Cultural awareness and expression; 6) Mathematical, scientific and technological competence; 7) Digital competence; 8) Sense of initiative and entrepreneurship. The sustainability citizens need to have certain key competencies which would allow responsible engagement in today's world. Competences include cognitive, emotional, electoral and motivating elements. It is the interaction of knowledge, abilities and skills, motivation and affective attitudes (Education for Sustainable Development, 2017).

Sustainable agriculture is often described as a set of ideal objectives which it is supposed to achieve (Goals). Overarching goals are ethics, multi-functionality, safety, stability and resilience (Velten et al., 2015). Overarching goals can be divided into Environmental goals (Production- Specific and Non- Production- Specific), Social goals and Economic goals. In order to achieve these goals, different approaches and principles (strategies) can be used, such as adaptive management, cooperation, ecology-based strategy and economics-based strategy, holistic & complex systems thinking, knowledge & science, subsidiarity. In order to be able to acquire these strategies, agronomy specialists need to develop lifelong learning competences.

One of the Lifelong Learning competences is Mathematical, Scientific and Technological competence, which can be obtained by studying mathematics at schools and universities. Mathematical competence in general is the ability to design and apply mathematical thinking to solve a range of problems in everyday situations.

Mathematical education provides the skills to solve problems related to the acquisition of algorithms and formulas necessary for calculations. What is sustainability in mathematics? First, mathematical studies must develop mathematical competences. Secondly, studying mathematics, we can reveal three qualitatively different concepts of mathematics (Petocz & Reid, 2003):

– Components - Mathematics made up of individual components and we must concentrate our attention on different mathematical activities or aspects of mathematics, including the concept of calculation interpreted in the broadest sense, for example, the statistical components of a census of population;

– Models - Creating mathematical models we should translate some aspects of reality or specific situations into mathematical form, for example, a production line;

– Life - Mathematics is a way of thinking that helps to represent reality in mathematical terms, creating a strong personal relationship between mathematics and your life.

At the same time, learning objectives for sustainable education can overlain upon almost any mathematics course without losing the appropriate content. In the study programme we must carefully review the content of mathematics, enrich it with real examples and increase the involvement of students in the study process (Hamilton & Pfaff, 2013).

Like many other areas of life, mathematics plays an important role in agriculture, for example, in soil analysis, calculation of various fertilizer contents, use of statistics in estimation. Mathematics is also needed in estimation of requirements of fertilizers or insecticides, estimation of yield based on the sample of crop etc. (Pande, 2017).

The problem is that in recent years, the proportion of mathematics courses has decreased in the curricula of agronomy specialties of the Baltic States' universities which was highlighted in the XI Nordic-Baltic Agrometrics conference held in September 2018 (Nordic-Baltic Agrometrics conference, 2018). The question is how much mathematics should be taught in schools and whether the course of high mathematics should be included in the curriculum of agriculture specialties at higher education institutions.

The aim of the article is to highlight the insufficient amount of higher mathematics in the education of agriculture specialist in the context of sustainable development.

The objectives of the study:

1) to identify the importance of mathematics for agronomy specialists, to analyse the role of the mathematics education for specialists of agronomy, and

2) to analyse the proportion of mathematics courses in curriculum of the agronomy studies in the Baltic States universities and compare with the Baltic Sea region's higher education institutions.

MATERIALS AND METHODS

In the process of the study inductive approach, appropriate qualitative and quantitative research methods have been used: the general research, monographic, analysis and synthesis, comparative method, data grouping, statistical data processing method.

Mathematics studies have two impacts (Zeidmane & Sergejeva, 2013): i) a direct impact, which provides skills for solving and calculating various real, conjunct problems; ii) an indirect impact, which develops general problem-solving skills (Fig. 1).

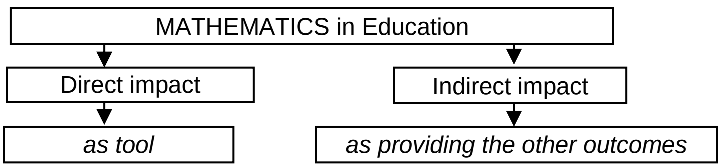

Figure 1. Mathematics impact in Education.

In order to investigate the first main role of mathematics in agronomy education, *a direct impact*, mathematics textbooks offered by the Internet resources to agronomists were examined to find out the necessary topics of mathematics. Further, agricultural areas requiring knowledge of mathematics were identified. In addition, trends in sustainable agriculture were studied in order to clarify the increasing role of mathematics in them.

To analyse the *indirect impact* of mathematics, the competences acquired with the help of mathematics were identified.

To analyse and compare the content of Bachelor's study programmes as well as to measure a proportion of mathematics courses, universities from the Baltic States which provide education related to agricultural sciences and agronomy and which are active Baltic and Nordic Agrometrics network members since 1998, i.e., Latvia University of Life Sciences and Technologies (LLU), Alexandras Stulginskis University (ASU), Estonian University of Life Sciences (EMU), were selected. The purpose of this cooperation network was the necessity to understand what kind of mathematics and what amount of it agriculture specialists need as well as to achieve common standards in higher agriculture education. To extend the scope of the research, universities from the Baltic Sea region were chosen for the comparison: University of Hohenheim (Germany), University of Helsinki (Finland), Swedish University of Agricultural Sciences (SLU) (Sweden), Aarhus University (Denmark).

Detailed descriptions of the study programmes were downloaded from the websites of each of the above mentioned universities. The courses of study programmes were divided into several groups: mathematics courses (higher mathematics, statistics, biometry with or without IT application), physics, general courses, industrial courses, the practice or project and a thesis. Based on the description of a study programme and study courses, the amount in ECTs credits and proportion of each group were determined.

To calculate the proportion of mathematics courses and other groups of courses in a study programme, the formula was used:

$$proportion\ of\ course\ group, \% = \frac{sum\ of\ courses\ credits\ in\ group\ (ECTS)}{total\ credits\ in\ study\ programm\ (ECTS)} \cdot 100\%$$

RESULTS AND DISCUSSION

There is no doubt that prospective farmers need mathematics, but the questions are:

– what kind of mathematics should be learned in the study process;
– how and what subjects related to mathematics should be included in the agronomy study course;
– whether the study process requires mathematics as a separate subject?

Importance of mathematics for agronomy specialists

The main objective in mathematics for agriculture is to provide an adequate overview of basic arithmetic, statistical interpretation and algebraic concepts for preparing students in mathematics involved in other agricultural and horticultural courses. There are textbooks for this purpose, for example, B.C Rogers ‘Mathematics for Agriculture’ (Rogers, 2000) which deals with parts of mathematics such as: Whole Numbers, Common Fractions, Decimals, Percent and Percentages, Interpretation and Analysis of Data, Introduction to Algebra, Linear Equations, Ratios and Proportions, Special Formulas, Measurement. The role of mathematics in agronomy courses has been studied by various authors. For example, an interview with 15 professional farmers, 13 vocational teachers in agriculture, 11 mathematics teachers who teach agricultural students and 40 secondary vocational education students was conducted (Muhman, 2015), and the results showed that percent, geometry and statistics were considered as the main areas of mathematics according to the respondents’ opinion. Similar information can be found in online resources (Masula, 2015; Jenkins, 2017) etc.. These subjects in mathematics are at the secondary level and textbooks are for special vocational schools. The problem is only that graduates from the secondary schools may also join the agricultural specialties at universities and they have not mastered this specific mathematics.

Research into agricultural sectors that require mathematics has been considered to be insufficient to complete secondary school mathematics. Agronomic work is closely linked to the knowledge of mathematics in economics. G. Beer mentions areas where mathematical skills are vital (Beer, 2016):

- Soil Analysis
- Calculation of various fertilizer contents
- For foreign markets, conversions to/from metric
- Areas of various shapes
- Market Protection Strategies
- Evaluation of Retailer Performance
- Application Rates
- Finance Decisions
- Piloting of airplane for more efficient travel

This creates the need for special courses in mathematics in the curriculum of agronomy at universities.

The emergence of new trends in sustainable agriculture causes the necessity of modelling different processes. The computational methods in applied mathematics blog (The Importance of Maths, 2017) indicate seven ways how and why mathematical models are used in agriculture:

1) Mathematics allows you to design better climate models;
2) Mathematics improves the accuracy of soil analysis;
3) Mathematics makes chemical content analysis for fertilizers more accurate;
4) Conversion of units at A drop of A hat requires A strong background in maths;
5) Planning, plotting, and laying out plot sizes and dimensions;
6) Improving estimates for expenditure and yields;
7) Mathematics lays the foundation for innovation in agricultural methods.

The question can be raised for a discussion: will an agronomy specialist be a creator or a user of these models. If agronomy specialists are involved in developing these models, then they need higher mathematics knowledge (even if they work in a team with a mathematician). In addition, agronomists should understand the mathematical meaning of the operation of these models when using them. For example, a model for the a nitrogen cycle in pasture has to deal with Distributed-delay-differential equations $y'(t) = y(t-T)$. The integral calculus and differential equations must be solved in the fundamental problem of optimal control theory to determine the probable control that maximizes (or minimizes) where u (t) is the parent infusion rate, and x (t) is the current mass of the fruit (Wake, 2008).

The area of agriculture, which has benefited from mathematics, is precision agriculture which increases agricultural efficiency by helping farmers identify which plants to plant, where and how to harvest them. Nowadays, more and more farmers introduce precision agriculture. Precision agriculture or precision farming, is a modern farming management concept which uses digital techniques to monitor and optimise agricultural production processes. CEMA, the European Agricultural Machinery Industry (CEMA, 2018), has given a detailed list of the most common technologies used in precision farming practices (Fig. 2).

Precise farming production has increased the demand for high-quality training in order to accurately assess the spatial variability in the countryside.

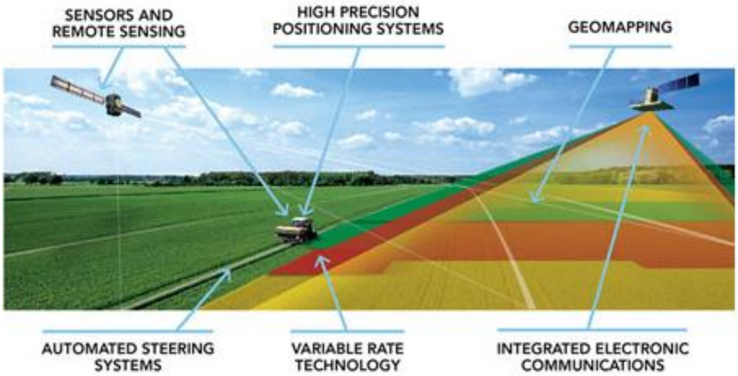

Figure 2. Precision Farming: key technologies & concepts, (adapted by CEMA).

With the increasing impact of precision farming, there has been an increased demand for quality training to accurately evaluate spatial variability within fields. The book 'Practical Mathematics for Precision Farming', which was issued in 2017, provides hand-on training and examples (Clay et al., 2017). The target audience for this book include certified crop consultants (CCAs), farmers, crop consultants, and undergraduate and graduate students. This book covers examples, how to conduct and analyse on-farm studies, write simple programmes, use precision techniques to scout for pests and collect soil samples, develop management zones, determine the cost of production, assess the environmental consequences of precision techniques, understand soil test results, and develop site-specific nutrient and plant population algorithms. Again, the questions arise: what core mathematics knowledge and skills of agronomists are necessary to be able to master the course and should this course or part of the course be included in the agronomy study curriculum in universities?

Mathematics plays an important part in everyone's life, but the increasing complexity of agricultural technology makes it mandatory that workers in agricultural occupations have skills in the analysis and solution of mathematical problems. In addition, the 13th International Conference on Precision Agriculture (USA), describing the current situation in agriculture (Ericson et al., 2016), emphasized that:

- It is often difficult to find skilled professionals to work in precision agriculture
- Ag school graduates not always 'field ready' to hit ground running
- Information-intensive future vs. current automated systems
- Lack of maths/analytic skills.

It makes us think about the competences, learning by studying mathematics. This also shows the indirect impact of mathematics in education. Mathematical competence in general is the ability to design and apply mathematical thinking to solve a range of problems in everyday situations. Mathematical studies at universities should develop the ability to ask and answer questions in and with mathematics, as well as the ability to deal with mathematical language and tools (Niss & Hojgaard, 2007). The ability to ask and answer questions cover four competences: mathematical thinking, problem tackling, modelling and reasoning competences. The ability to deal with mathematical language and tools cover other four competences: representing, symbol and formalism, communicating and aids and tools competences (Fig. 3).

Based on the above, it should be concluded that the proportion of maths courses in agronomy specialties in universities should increase. The reality is exactly the opposite: the proportion of mathematics courses has been reduced.

The analysis of the proportion of mathematics courses in curriculum of the agronomy programmes

Seven Bachelor's level study programmes were analysed in the framework of this study. These programmes have been chosen based on available information about their content on the webpages of universities. Fig. 4 contains a summary of information about volume, duration and other details of each programme. The universities provide 3 and 4 years study programmes in equal proportion. Only the Polish university provides 3.5 years study programme.

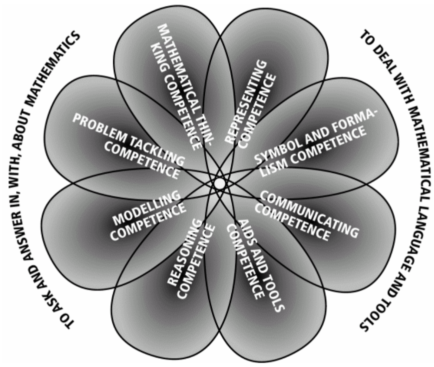

Figure 3. A visual representation of the 'KOM (Competences and the Learning of Mathematics) flower' of the eight mathematical competences presented and exemplified in the KOM report (Niss & Jensen, 2002).

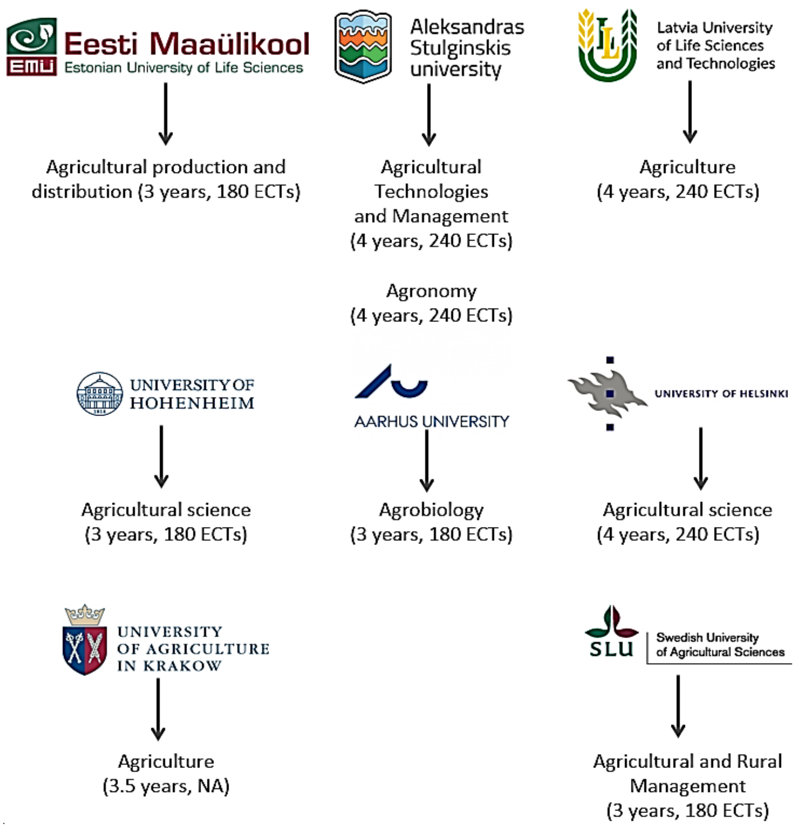

Figure 4. The basic information about programmes.

In this research programme courses are divided in six groups: mathematics, physics, other general courses, industrial courses, the practice or project and the thesis. Fig. 5 shows the proportion of different courses' groups in each particular programme of Baltic States universities: Alexandras Stulginskis University (ASU) in Lithuania, Estonian University of Life Sciences (EMU) and Latvia University of Life Sciences and Technologies (LLU).

For the comparison several programmes from the Baltic Sea Universities (Fig. 6.) have been analysed: University of Hohenheim (Germany, GE), University of Helsinki (Finland, FI), Swedish University of Agricultural Sciences (Sweden, SW), Aarhus University (Denmark, DM).

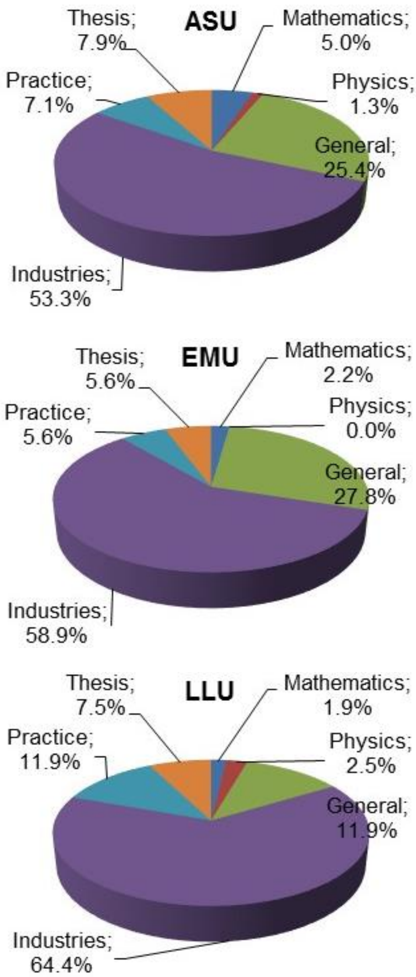

Figure 5. The proportion of courses groups in study programmes of Baltic States universities.

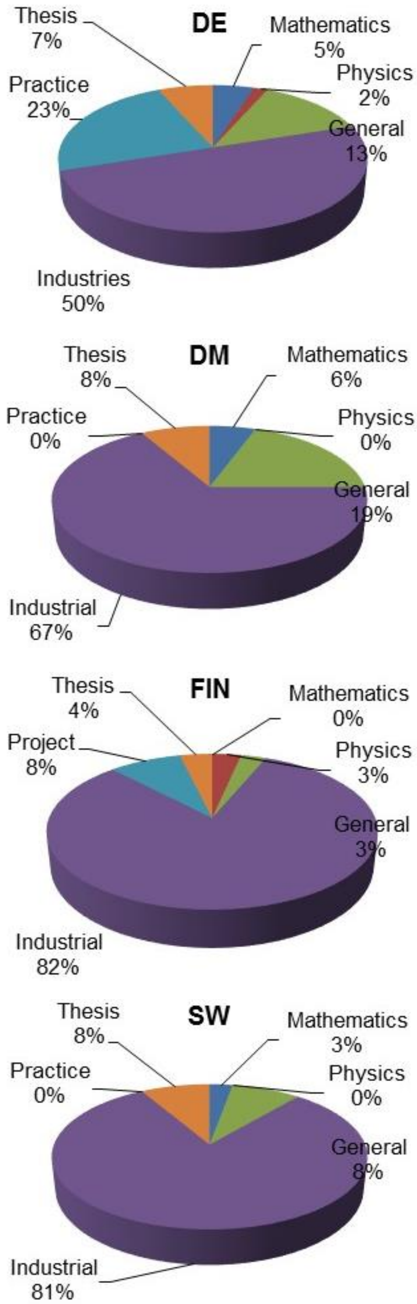

Figure 6. The proportion of courses groups in study programmes.

The largest proportion of mathematics courses is observed in programmes of Danish, German and Lithuanian universities. Physics is not always included in study programmes of the investigated universities. Physics is mostly studied in the Finnish university. The largest part of study programmes in all universities is devoted to industrial specialized courses.

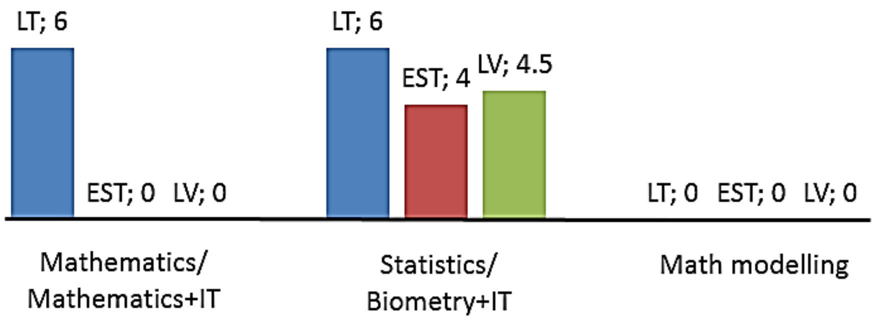

Figure 7. The distribution of credit points with mathematical content in the Baltic States' universities.

The comparison of the credit points given to courses with mathematical content in the Baltic States' universities (Fig. 7.) and other Baltic Sea region's universities (Fig. 8.) shows that Lithuanian study programme is the programme which provides students with knowledge and skills about basic concepts of higher mathematics. But the amount of mathematics in the course accounts only for 3 credits from 6 credits. The other focus in the course is on informatics, i.e., preparation of documents with spreadsheet, graphical analysis, database technology, projection of tables and their connections, completion of forms, questionnaires and reports.

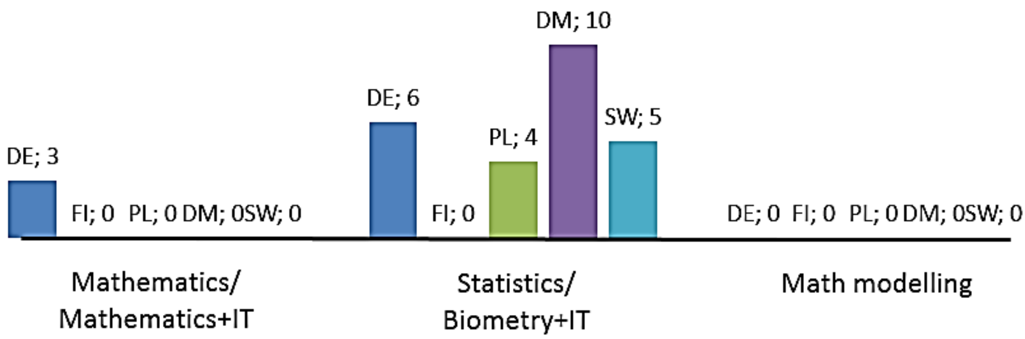

Figure 8. The distribution of credit points with mathematical content in the Baltic sea region's universities.

All three Baltic States' universities provide students with the statistical subjects. The detailed list of subjects can be seen in Table 1.

Table 1. The content comparison of Mathematics and Statistics in programmes of the Baltic States' universities

Subject	EMU	ASU	LLU
Matrices and actions with matrices. Determinants		x	
Linear equation systems and their solutions methods		x	
Elements of limit theory. Concept of a continuous function		x	
Function derivative. Derivative applications. Concept of function differential		x	
Concept and characteristics of indefinite integral. Applications of definite integrals		x	
Basic concepts of probability theory		x	
Random variables, characteristics, distributions and densities	x	x	x
Descriptive statistics	x	x	x
Testing of normal distribution	x		
Introduction to interferential statistics. Research methodology: statistics application		x	
Population. Statistical samples. Data classification		x	x
Statistical hypotheses and tests: t- test	x	x	x
F-test, chi-square test	x		x
Dispersion analysis - one and two factors			x
One and two-way ANOVA and their applications	x	x	
Correlation, regression analysis. Single and multifactor linear regression Non-linear single factor models	x	x	x
Interpretation and presentation results of statistical data analysis	x	x	x
Statistics with agronomic and economic databases	x		
Use of software packages (MS Excel)	x	x	x
Computer based application of statistics to agricultural research		x	

The content in statistical course programmes is almost the same, only the number of hours in auditoriums varies. Mathematical modelling is not included in any of the programmes. A similar situation can be observed in other universities of the Baltic Sea region. Only the university in Germany includes learning of mathematical basic concepts. The particular attention should be paid to the Finnish University which has not included mathematical courses in their programme at all. The Danish university devotes the largest amount of time to statistics. Similarly to the Baltic States' universities, the Baltic Sea region's universities have not included mathematical modelling.

The Lithuanian university is the only one that provides knowledge and skills about basic concepts of higher mathematics including an overview of main concepts of the probability theory. The set of statistical topics in study programmes of the Baltic States' universities is almost the same. The Lithuanian university devotes more attention to statistics application and research methodology including experiments in laboratories and field experiments which form 4.5 ECTs of the course volume from 6 ECTs.

CONCLUSIONS

Based on the literature studies on the need for mathematical content for agronomy specialists, it was concluded that agronomists need knowledge in mathematical areas such as algebra, geometry, percent and statistics. These subjects in mathematics are taught at the secondary level and textbooks are designed for special vocational schools.

In addition, work in agronomy is closely linked to the knowledge of mathematics in economics. This creates the need for special courses in mathematics in the curriculum of agronomy at universities.

The Lithuanian university is the only Baltic States' university that provides knowledge and skills about basic concepts of higher mathematics including an overview of the main concepts of the probability theory. All three Baltic universities provide students with the statistical subjects in their programmes, but the largest amount of credit points for statistics is devoted by Denmark among the universities of the Baltic Sea region.

Mathematical modelling is not included in the Bachelor's level studies of the Baltic Sea region's universities.

The analysis of different study programmes shows that the most proportion of mathematical courses is provided in programmes of the Danish university (6%), the German university (5%) and the Lithuanian university (5%).

The emergence of new trends in sustainable agriculture demands modelling of different processes. Using these models, agronomists should understand the mathematical meaning of the operation of these models. It requires additional knowledge in higher mathematics (differential, integrals, differential equations, etc.).

Nowadays, more and more farmers introduce precision agriculture. This requires the development of mathematical competences which, of course, are provided by mathematics studies. Based on the above, it should be concluded that the proportion of mathematics courses in agronomy specialties in universities should be increased. The reality is exactly the opposite: the proportion of mathematics courses has been reduced.

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