LOCAL AND REGIONAL CHALLENGES OF CLIMATE CHANGE ADAPTATION AND GREEN TECHNOLOGIES

PROCEEDINGS

THE UNIVERSITY OF WEST HUNGARY FACULTY OF FORESTRY

Editors:

Polgár, András – Bazsó, Tamás – Nagy, Gabriella – Gálos, Borbála

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A KLÍMAVÁLTOZÁS HELYI ÉS REGIONÁLIS KIHÍVÁSAI, ZÖLD TECHNOLÓGIÁK

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Preface

The proceedings include the scientific contributions of the "International Workshop on Local and Regional Challenges of Climate Change Adaptation and Green Technologies" that has been organized 19th September 2014 at the University of West Hungary, Faculty of Forestry.

The aim of the workshop was to synthetize the main results of the RECLAND (Erasmus Multilateral Projects, 526746-LLP-1-2012-1-ES-ERASMUS-EMCR, MSc Programme in Climate Change and Restoration of Degraded Land) and VITEG (Green Technology European Virtual Gateway 527296-LLP-1-2012-1-UK-ERASMUS-ECUE) projects. The wide spectrum of the presented scientific topics refers to the multi- and interdisciplinar aspects of climate change and green technologies. Successful adaptation to the projected climate change and the rise of the awareness regarding to green technologies can only be achieved in the frame of international cooperations (in both projects experts from Spain, England, Rumania, Estonia and Hungary have been involved) as well as by integration of the results of recent research projects into education.

In the first part of the proceedings the key outcomes of the two projects are introduced with special focus on the module content and accreditation of the developed MSc program and teaching methods. In the second part the underlying research activities are discussed, addressing the following topics: climate change mitigation, climate change impacts on forests and water balance, adaptation to climate change, restoration of degraded land, urban soils, life cycle assessment, green technologies.

The organisers of the workshop thank all speakers and presenters for the contributions, the Dean of the Faculty of Forestry Prof. Dr. Ferenc Lakatos for making possible to organize the workshop at the University of West Hungary in Sopron, as well as the RECLAND and VITEG projects for the financial support.

the Editors

Sopron, September 2014

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Előszó

A kiadvány a Nyugat-magyarországi Egyetem Erdőmérnöki Karán, Sopronban, 2014. szeptember 19-én megrendezett „A klímaváltozás helyi és regionális kihívásai, zöld technológiák" című tudományos workshop előadásainak írásos összefoglalóját foglalja magában.

A rendezvény célja a RECLAND (Erasmus Multilateral Projects, 526746-LLP-1-2012-1-ES-ERASMUS-EMCR, MSc Programme in Climate Change and Restoration of Degraded Land) és a VITEG (Green Technology European Virtual Gateway 527296-LLP-1-2012-1-UK-ERASMUS-ECUE) projektek keretében elért legfrissebb eredmények bemutatása volt. Az elhangzott tudományos előadások sokszínűsége a klímaváltozással és a zöld technológiákkal kapcsolatos témák multi- és interdiszciplináris jellegét igazolja. A klímaváltozáshoz való hatékony alkalmazkodáshoz és a zöld techológiák iránti nyitottság növeléséhez nélkülözhetetlen a nemzetközi együttműködés (mindkét projekt spanyol, angol, román, észt és magyar kutatók bevonásával valósult meg), valamint a legfrissebb kutatási eredmények oktatásba történő beépítése.

A konferencia kötet első része a RECLAND projekt keretében kidolgozott MSc szintű képzés tananyagát és akkreditációját, valamint a VITEG projektben kifejlesztett oktatási módszereket mutatja be. A kiadvány második része az oktatás alapjául szolgáló tudományos kutatások eredményeit összegzi, a következő témák érintésével: klímaváltozás mérsékelése, klímaváltozás hatása az erdei ökoszisztémákra és a hidrológiai ciklusra, alkalmazkodás a klímaváltozáshoz, rekultiváció, városi talajok, életciklus elemzés, zöld technológiák.

A szervezők köszönik a résztvevőknek, hogy előadásaikkal, posztereikkel gazdagították a rendezvényt, Prof. Dr. Lakatos Ferenc dékánnak, hogy helyet adott a workshopnak az Erdőmérnöki Karon, valamint a RECLAND és VITEG projekteknek az anyagi támogatás biztosításáért.

a Szerkesztők

Sopron, 2014. szeptember

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Proceedings / Előadás összefoglalók

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Accreditation Description of a MSc Programme in Spain Developed Under the Erasmus Multilateral Programme

M.P. Arraiza[1], M. C. Gimenez[1*], J.L. Garcia[1], C. Cordón[1], C. Calderón[1], J.V. López[1], Juan Carlos Santamarta[2]

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Abstract

In Spain, there are several possibilities for the accreditation of a Lifelong learning Master Degree. One option is the internal accreditation, through the Technical University of Madrid (UPM) post-graduate degree, as MASTER, SPECIALIZATION, EXPERT, and CONTINUOUS TRAINING. These degrees lead our students to be successful in the labour market, so as the enhancement and reorientation of their professional careers, because all degrees have a clear professional orientation.
The second option is given by the "National Agency for Quality Assessment and Accreditation of Spain", ANECA, which is a Foundation whose aim is to provide external quality assurance for the Spanish Higher Education System and to contribute to its constant improvement. In order to perform its activities (evaluation, certification and accreditation), ANECA has developed several evaluation Programmes with the purpose of integrating the Spanish system into the European Higher Education Area (EHEA).
UPM is leading the Lifelong Learning Master Degree RECLAND (MSc Degree on Climate Change and Restoration of Degraded Lands), which is currently accredited as UPM post-graduate degree, and in the future it will be accredited as an official degree by ANECA.

Keywords: competences / accreditation / masters programme / aneca / certification / degree

INTRODUCTION

The first part in accreditation process involves the justification and objectives of the Master RECLAND.
The United Nations Climate Change Conference, Durban 2011, delivered a breakthrough on the international community's response to climate change. In the second largest meeting of its kind, the negotiations advanced, in a balanced fashion, the implementation of the Convention and the Kyoto Protocol, the Bali Action Plan, and the Cancun Agreements. The outcomes included a decision by Parties to adopt a universal legal agreement on climate change as soon as possible, and no later than 2015.
One of the decisions adopted by COP 17 and CMP 7 regard to the land use, land-use change and forestry, and invites the Intergovernmental Panel on Climate Change to review and, if necessary, update supplementary methodologies for estimating anthropogenic greenhouse gas emissions by sources and removals by sinks resulting from land use, land-use change and forestry activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol.

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DESCRIPTION OF MSc RECLAND PROGRAMME

This Programme was designed to modernise the curriculum provision in partner countries by implementing a strategic approach for applied and unified credit transfer type of postgraduate education that prepares students for the regional and global postgraduate job market. To jointly develop and deliver a European Masters modules programme technology enhanced in MSc Programme in Climate Change and Restoration of Degraded Lands based on the "Tuning" project framework.

Land degradation is a human-induced or natural process which negatively affects the productivity of land within an ecosystem. The direct causes of land degradation are geographically specific. Climate change, including changes in short-term variation, as well as long-term gradual changes in temperature and precipitation, is expected to be an additional stress on rates of land degradation.

- Climate change-induced land degradation is expected through;
- Changes in the length of days and/or seasons;
- Recurrence of droughts, floods, and other extreme climatic events;
- Changes in temperature and precipitation which in turn reduces vegetation cover, water resource availability, and soil quality;
- Changes in land-use practices, such as conversion of lands, pollution, and depletion of soil nutrients.

Adaptation-related projects on land degradation should apply incremental reasoning during the design and preparatory phase. The focus of projects should be on reducing the impacts of climate change on land degradation over and beyond measures that would normally be undertaken as a land degradation focal area activity. In line with the adaptation funding window that applies in this case (see below), maintaining and/or strengthening the resilience of ecosystems and communities to climate change by reducing the rates of land degradation (caused by climate change) is a priority. Projects should reflect dynamic, long-term response measures that can effectively contribute towards the reduction of climate change-induced land degradation.

EU Policy on Climate Change (WHO/Europe, Parma Italy, 2010) for member states envisage to strengthen health, social and environment systems and services to improve their capacity to prevent, prepare for and cope with climate change. Within this context the consortium of this project evaluated EU' HE offer of Climate Change and Degraded Land to identify if the next generation of environmental scientists and managers are offer a solid and well prepared curricula. A survey of existing curricula at educational institutions in partner institutions was conducted and followed by a thorough analysis. This survey covered the ways how the practice is organized for students. This and all other data was discussed in the preparatory phase of the project idea. The proposed project draw lessons from this evaluation identified educational practices that need to change to embrace climate change and land degradation and restoration as a subject, gaps in education from employers and professionals perspective. Based on this a MSc programme of modules will be accredited jointly or dually at partner institutions and the overall MSc will be jointly piloted by the consortium leader, UPM, with the intention to offer restoration of degraded land within an interdisciplinary context with enterprises support and endorsement; and that opportunities, such as internships and other methods of applied learning, are included in the curriculum as a result of the partnership with stakeholders. All partners will participate in the piloting of the MSc on Climate Change, and Restoration of Degraded Land and will also include accredited modules in their accredited MSc programmes offer with the intention of joint delivery.

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Objectives of the MSc Recland

There is strong scientific evidence indicating that land degradation has become a substantial problem for most of Europe as a result of climate change. This has been highlighted by the EUROPEAN COST Action FP0601 "Forest management and the Water Cycle"

- The results of the United Nations Climate Change Conference, Durban 2011, delivered a breakthrough on the international community's response to climate change and ratified the importance of the land use and land use change as related to Climate Change.
- For the restoration of degraded land and mitigation of the effects of climate change in land use there is a need for greater awareness and training among ground staff.
- There is a serious shortage of staff specialised in the technology enhanced restoration of degraded land in Spain, the UK, Romania, Hungary and Estonia.
- Many EU students have still not being involved in a mobility programme and therefore the proposed MSc programme is intending to encourage students from partner Universities to become involved with exchange programmes and to study some of the MSc at partner institutions were jointly accredited.

The main Master's educational objectives are:

a. To develop teaching materials that utilise learning objects
b. To develop modules tailored to technology assisted on Climate Change and Degraded Land
c. To develop a virtual learning environment that facilitates learning and assessment
d. To disseminate the results to a wider European audience
e. To exploit the results by organising the transfer to other practitioners
f. To develop and validate jointly a MSc modules programme on enhanced technology on Climate Change and Restoration of Degraded Land.
g. To update existing libraries,
h. Development of an innovative joint continuing postgraduate education curriculum and coordinated continuing education organizational structure for partner countries represents good example of optimal and coordinated resource utilization. The proposed MSc modules programme will provide provision for continuing education and cover the shortage of skills and educational resources on Climate Change and Restoration of Degraded Land at European level.

TARGET GROUP

This Master will be addressed to Graduates of Environmental Management and Rural Development faculties who intend to work in the climate change mitigation sector, graduates of planning faculties who intend to specialise in land restoration, science, geography and engineering graduates, or professionals from either a science or technical background.

Existing specialist specialists who intend to develop their competence. The online option allows practitioners to enhance their professional development within their current employment.

Secondary target group/ beneficiaries: graduates from countries affected recently by degraded land that are based in their communities, such as countries from Africa, Asia and Latin America. The fact that the course is given both in English and Spanish will make possible to reach all these beneficiaries despite of their nationality.

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ACCREDITATION SUMMARY

Educational mode (full-attendance, semi-attendance or distance education):
- distance education (e-learning)

Duration:
- Months: 12 Hours: 1500 (1ECTS = 25 hours)
- Start: September, 1, 2015 End: May 31, 2016

Credits ECTS:
- 60 ECTS

Nº of available places:
- Maximum Number: 27
- Minimum Number: 10

Nº of scholarships and allocation criteria:
- Scholarships offered by Institutions outside UPM: 2
- Scholarships for UPM personnel: 2

Allocation criteria:
- Curriculum
- Academic record

All offered degrees are available in e-learning mode:
- Specialist in Restoration of Degraded Lands. Modules 2, 3, 5, 6 and 7.
- Expert in Water Management. Modules 4 and 5.
- Expert in Climate Change and Waste Management. Module 3.
- Expert in Project Management. Module 10.
- Expert in Applied Statistics in Degraded Lands. Module 10.

Selection Criteria

Students who have the ability to study and produce the work expected for a Masters level, and having enough real experience to relate their learning experience with his/her work experience. For these reasons, the selection criteria should be flexible, realistic and recognize a range of qualifications and previous experience.

All prospective students must have current experience in the field of climate change/ degraded areas (at least one year). Prospective students must have a "HE Level" (Higher Education), demonstrating their ability to study in an academic environment. This requirement may be waived if the candidate has exceptional expertise in mitigating climate change and the university staff to believe that the candidate would get success in the programme.

While the faculty seeks flexibility in entry requirements to the program is unlikely to accept applications for people with no prior experience or without adequate climate change and restoration of degraded lands academic qualifications.

Selection will be based on:
- Cover letter from the applicant
- Current Degree and academic record
- Current Degree subject field
- Professional experience
- Level of English
- Optional Interview (videoconference)
- The information will be presented to the Programme Committee for the final decision

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Monitoring And Evaluation

The evaluation will be on-line in each module. In line with the innovative nature of the master, the evaluation strategy used a mix of assessment methods. Evidence of achievement of learning outcomes will be as follows:

- Written and practical work
- Participation in discussions and exercises
- Production of a portfolio of case studies
- Review
- Approximately 20,000 words Dissertation (with 10% tolerance).

Both assessment methods, learning and continuous training will be used throughout the programme. Learning assessment creates a meeting point for both students and tutors in order to evaluate the development, learning consolidation and planning ahead.

Continuous evaluation allows recognition of progression to other studies, reports to participants the level of achievement, and validates learning processes.

Each module requires students' participation in a two days' workshop. The first day will be used for applied modeling science and then, on the second day the student will remain in the center of residence to work in practical cases, group assignments, reports and debates.

Students are expected to apply theoretical understanding in a variety of different scenarios and employing a variety of approaches to the expression and distribution of tasks. At the end of the programme, students will have developed the necessary knowledge and skills to improve employment opportunities in the field of climate change.

The specialist and expert degree do not require a final dissertation. Shall be deemed to have been approved after passed each module exams.

Master will require the completion of a graduation report about subjects programme, written in English and must report copyright in favour of UPM, if the work has been performed in part or all in their facilities. In case that students do their Master thesis in Climate Change and Restoration of Degraded Land with a company, the student will retain his/her own copyright but must ensure that the information provided does not create a conflict of interest with that company, being responsible for the effects caused in this case. If the copyright remains the student property, he/she must perform an automatic transfer of rights to UPM for teaching and research only.

As part of the monitoring methodology of the programme, each student will have a mentor assigned according to their own profile. The student is expected fluid and frequent contact with their tutor in order to discuss the different aspects of their training.

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Bridging the Gap Between Climate Research, Forestry Practices and Education – Experiences from the AGROCLIMATE and RECLAND Projects

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Abstract

Climate change is expected to have severe consequences on the environment, on the economy, as well as on human health and wellbeing. Forestry sector is especially vulnerable to the projected changes. The already visible impacts are very likely to be much more severe throughout the 21st century, when extreme events are expected to occur with higher probability. In the frame of a joint EU-national research project Agroclimate, a decision support system is under development that provides information about the most important regional and local risks and mitigation options regarding climate change impacts for forest management and forest policy.
For rising the public awareness, the learning material in the forestry education should be continuously updated with the results of recent research. For this purpose a learning module "*Afforestation for Restoration of Land and Climate Change Mitigation"* has been worked out in the frame of the RECLAND project that discusses the impacts of present and projected climatic extremes on forests, on the ecosystem services of forests as well as the role of afforestation in the climate change mitigation.
In the focus of this paper is, how to bridge the gaps between climate research, forestry practices and education based on the experiences from the recent international and national research projects.

Keywords: climate change impact / adaptation / forest ecosystem / forest education

INTRODUCTION

According to the Working Group II contribution to the Fifth Assessment Report of the IPCC's "climate change will increase the likelihood of systemic failures across European countries caused by extreme climate events affecting multiple sectors" (IPCC 2014). In the Carpathian basin regional climate projections suggest more irregular rainfall and a warmer climate. Model studies largely agree in projecting a small increase of the winter precipitation sum and a significant decrease of the summer precipitation amount (Jacob et al. 2013, Vautard et al. 2013). These changes are expected to have profound consequences on the environment, on the economy, as well as on human health and wellbeing.
In the sensitive forest ecosystems, impacts of the consecutive dry periods in the last 20-years are already visible. Summer droughts altered the presence, vitality, health status and

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production of forests (Lakatos and Molnár 2009, Mátyás et al. 2010). These impacts of climate change in forestry are very likely to continue throughout the 21st century, when extreme events are expected to occur with potentially greater impact. Forestry requires long term planning. Therefore a thorough research is essential on future climate tendencies and on the regional and local risks in order to develop appropriate adaptation and mitigation strategies.

In the forestry practise following climate change related questions need to be answered:

- Are the native tree species able to adapt to the projected climate change?
- How is the production capacity, timber growth and yield affected in the next decades?
- Are future climate conditions lead to more and new insects, pests, diseases?
- Should we harvester earlier because of health status decline or mortality?
- Should foresters think on new tree species? From where should they come?
- What are the economic impacts of species change and mortality?

These questions motivated researchers to develop the Decision Support System “Agroclimate” in the frame of a joint EU-national research project. It provides GIS-supported information about the most important regional and local risks and mitigation options regarding climate change impacts, projected for reference periods until 2100.

This example shows that practice (experiences of local farmers and foresters) and stakeholders’ needs can help to generate research questions but on the other side research also drives the development of the practice, support decision making in forest management and forest policy. Of course the involvement not just of government but also civil society and educational institutions is important. For rising the public awareness, climate and forestry research should be communicated in an understandable way. Here, forestry education can play a key role if the learning material is continuously improved and updated with the recent scientific results.

In the focus of this paper is, how to bridge the gaps between climate research, forestry practices and education based on the experiences from the recent international and national research projects.

THE LEARNING MODULE

In the frame of the RECLAND project the Institute of Environmental and Earth Sciences of the University of West Hungary developed the learning module “*Afforestation for Restoration of Land and Climate Change Mitigation”* that address the above mentioned basic practice oriented questions.

The general aim of the module is to present a state of the art overview on the role of forests in the climate system regarding to climate change and the possible adaptation strategies and mitigation options. The learning material discusses the effects of present and projected climatic extremes on forests, on the ecosystem services of forests as well as the role of afforestation in the climate change mitigation based on the results of recent research. The module content synthesizes the theoretical and practical aspects by introducing a broad spectrum of methods applied in environmental sciences. From educational aspects, the aim of the module is to develop the skills of the students to understand the complexity of forest – climate interactions on different spatial and temporal scales and regions as well as the role of forests in the climate system.

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CLIMATE RESEARCH – FORESTRY PRACTICES – EDUCATION

This section provides a brief overview of the 5 main chapters of the module content based on the following structure:

- aim of the learning module chapter
- scientific basis of the chapter - i.e. how climate and forestry research support this aim
- possibilities for transferring the scientific results into forestry practices
- key competences and learning outcomes for students

1. Reforestation under climate change in temperate, water limited regions: current views and challenges

Aim. The first chapter introduces the main concepts, activities and recent research in this field. It gives a general introduction about the most important climatic and anthropogenic drivers of afforestation, deforestation and forest restoration worldwide and in Europe.
Scientific basis. Climate is a determining and limiting factor of forest distribution. At the sensitive lower edge of the closed forest belt (at the "xeric limits"; Mátyás 2009), survive and adaptation of forests are primarily limited and threatened by the recurrent droughts. The forest/grassland transition zone is therefore especially vulnerable to projected drastic temperature and precipitation shifts in the future (figure 1).

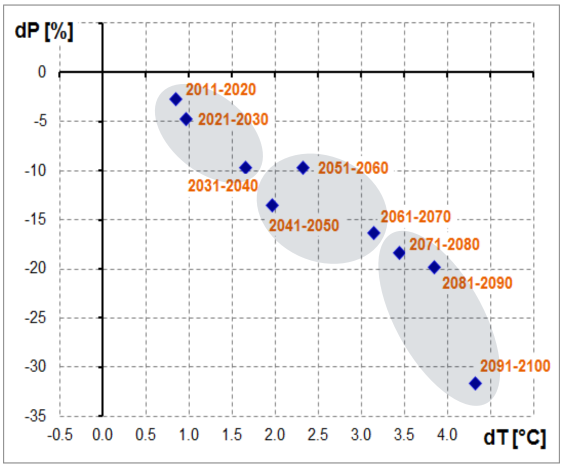

Figure 1. Projected temperature (dT) and precipitation changes (dP) for the 21st century relative to 1981-2010

Application in forestry practice. Because of the extreme long-term character of forestry, the consideration of projected future climate effects has to play a central role in management planning. Forest cover should be maintained in order to maintain the ecological benefits and services.
Key competences and learning outcomes. Students will be able to evaluate the ecological role of forests at the dryland edges, determine regions in the forest/grassland transition zone that are already affected and that could be affected by the consequences of changing climate conditions. Further on they will understand the importance and urgency of the appropriate decisions in forestry and nature conservation.

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2. Forests in a changing climate

Aim. This chapter discusses the effects of climatic extremes (and their expected changes) on the distribution, health status and vitality of forests, focusing on the vulnerable regions.
Scientific basis. The future of beech in Southeast Europe requires special attention, especially regarding to the projected climate change, because this region harbours significant populations living at or near their xeric distribution boundary. Impacts of droughts are already visible in the beech and oak forests that serves as basic experiences for the prediction of the possible impacts of climatic extremes for future time periods.
Simulation results of regional climate models indicate that although the mean annual values of precipitation remain almost constant, decreases in summer precipitation are projected to exceed 20-25 % until the end of this century. Warmer and dryer condition can lead to the increase of the probability and severity of droughts as well as to longer dry spells and heat waves with the higher frequency of temperature extremes (Gálos et al. 2013b, Gálos et al. 2014). The changes are expected to be faster than the adaptation of the native tree species. This can result in drastic decline of the health status, timber growth and production of beech and oak forests and to the reduction of their macroclimatically suitable areas (Rasztovits et al. 2012; figure 2). More frequent and increased drought stress will also increase vulnerability to pest and pathogenic damages. Long consecutive dry periods can lead to mass mortality (Mátyás et al. 2010).

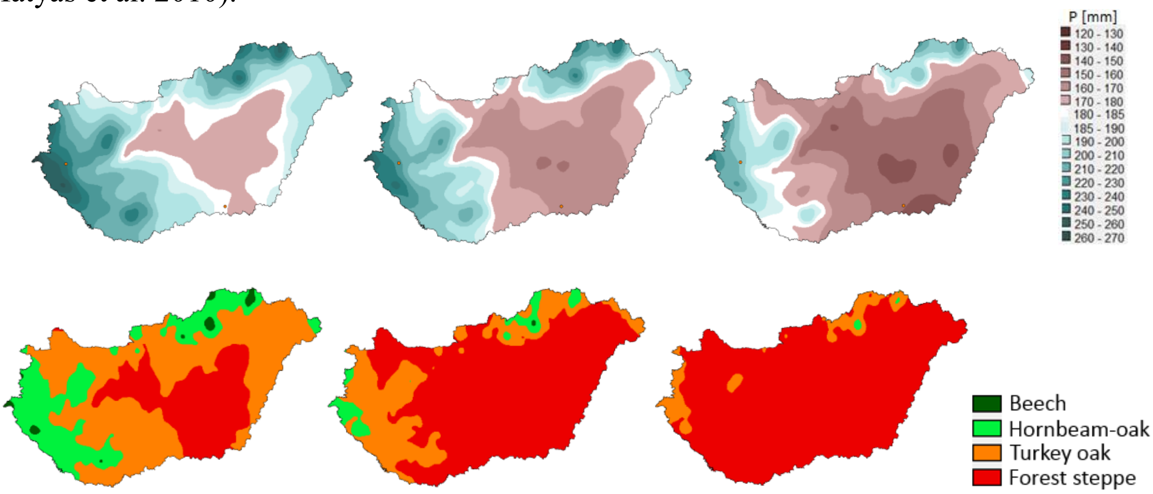

Figure 2. Projected decrease of precipitation (top row) and the corresponding change of the climatically suitable areas of the main forest types for (bottom row) for 1981-2010 (left), 2011-2040 (middle) and 2041-2070 (right) based on the forestry aridity index (Führer et al. 2013)

Application in forestry practice. The above mentioned scientific results is being transferred into the Agroclimate Decision Support System. In this way foresters can be informed about the suggested adaptation and mitigation options, on the possible species changes.
Key competences and learning outcomes. Students will be able to identify the climatic drivers of forest decline and mortality in the vulnerable regions, understand the importance of climate extremes in the processes at the lower limit of forest distribution as well as explain the climate sensitivity of beech. They get an impression on the complexity of the climate change related problems, on the causes and consequences and learn how to use it for decision making in forestry.

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3. Structure and functioning of forest ecosystems

Aim. This chapter provides an overview on the ecosystem services of forests and discusses the water-, energy- and carbon balance of forests and forest soils and their characteristics depending on climate conditions, region, season, diurnal cycle and forest ecosystem.
Scientific basis. For the development of the climate impact projections for the future, appropriate local scale measurements and modelling studies are essential. First, connections are tried to be found between meteorologic and hydrologic variables and the health status and carbon cycle of forests. Second, using climate information for the future, these functions can be extrapolated until the end of the century. Results of local scale case studies show the effect of warmer and dryer conditions on the evapotranspiration processes and ground water level in forested catchments as well as on the carbon content of forests and forest soil (e.g. Gribovszki 2010, Móricz 2010, Bidló et al. 2014).The fine scale observational time series can contribute to the evaluation and development of regional climate simulations and can built a part of the decision support system Agroclimate.
Application in forestry practice. Based on the monitoring activities, foresters get useful information on the actual weather and hydrologic conditions. Local scale modelling can be used as an effective tool for sensitivity studies and case studies.
Key competences and learning outcomes. The learning material of this chapter explains how to interpret the ecosystem services of forests in theory and practice (applying the measuring techniques of forest microclimate, analysing the results and drawing appropriate conclusions). In this way students can give arguments, why it is important to maintain forest cover.

4. Climatic effects of land cover change

Aim. Chapter 4 provides a summary on the climatic effects of land use and land cover change from global to regional scales, emphasizing the anthropogenic influence in the system. Further on a case study has been carried out on the country scale impacts of land use change in the last century.
Scientific basis. Based on the results of mesoscale model simulations, the Hungarian land use changes in the last 100 years caused an increase of +0.15 ° C daily temperature and +0.18 ° C dew-point depression during the vegetation period. This means that the near-surface air over Hungary is now warmer and drier than before, due to the land cover change. The Hungarian land cover change does not have a significant impact on the average precipitation nation-wide. However, the impact on the regional distribution of precipitation is considerable (Drüszler et al. 2010).
Application in forestry practice. Based on the assessment for the past, mesoscale climatic effects of suggested land use practice can be evaluated regarding to the projected climate change.
Key competences and learning outcomes. Students can distinguish the natural and the anthropogenic climate forcing and characterize the magnitude of the climatic effects of the historical land use change in different regions.

5. Afforestation as a tool for climate change mitigation

Aim. Chapter *5* introduces the results of regional-scale sensitivity studies carried out to investigate the role of afforestation in climate change mitigation for Europe.

Scientific basis. Large, contiguous forest blocks have robust effect on the climate on regional scale. In the most climate change affected regions climatic effects of afforestation are relatively small (figure 3). But in other regions they can play an important role in reducing the probability and severity of climatic extremes. Based on the simulation results, afforestation may lead to cooler and moister conditions in most parts of the temperate zone thus can reduce the projected climate change. In country scale, the strong warming and drying tendency projected for Southwest Hungary could be hardly compensated by forest cover increase. But in the northwestern region more than half of the projected climate change signal for precipitation can be relieved with enhanced forest cover (Gálos et al. 2013a).

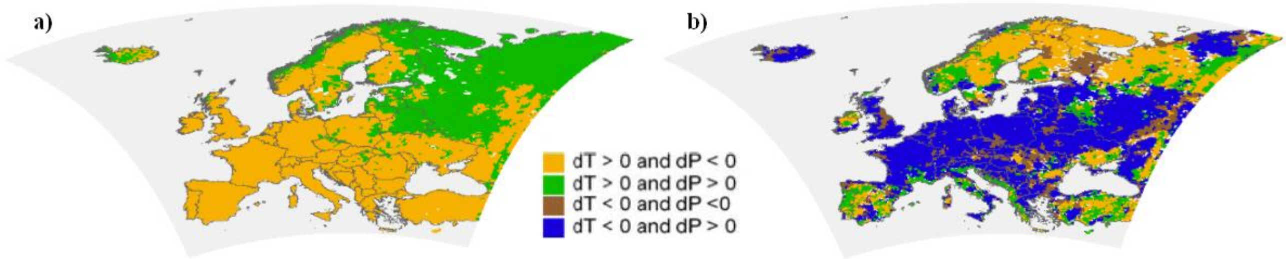

Figure 3. Climate change signal for temperature (dT) and precipitation (dP) due to emission change (a) and due to potential afforestation (b). (Gálos et al. 2013)

Application in forestry practice. Results can help to identify the areas, where forest cover increase is the most favourable and should be supported to reduce the projected climate change. In this way they can contribute to the future adaptation strategies and to appropriate forest and land use policy (and also to the selection of the most cost-effective mitigation option).
Key competences and learning outcomes. At the end of this module learners will be able to understand the complexity of the forest – climate interactions and feedback processes. Further on they can evaluate the climatic effects of land use and land cover change and the role of forests in climate change mitigation.

Related courses in the Faculty of Forestry. The module content has been accepted and included in the master curriculum of forester and environmental engineer students in English language, in the frame of the subject Afforestation for Restoration of Land and Climate Change Mitigation. On the Faculty of Forestry, climate impact of forest ecosystems and forest – climate interactions is part of several subjects in master programs and doctoral courses, e.g. Meteorology and Climatology, Weather extremes: impacts and adaptation, Global environmental systems, Land cover/land use change and climate, Ecological climatology.

SUMMARY

For developing appropriate adaptation and mitigation strategies in forestry, a thorough research is essential on future climate tendencies and on the regional and local risks. The stakeholders' needs motivated researchers to develop the Decision Support System "Agroclimate" that addresses the most important climate change impacts and adaptation options in the Carpathian basin. Climate information and knowledge as well as the recent scientific results should be also transferred into the forestry education. In this paper a learning module content has been introduced that synthesizes the theoretical and practical aspects in this field. From educational point of view, the aim of the module is to develop the skills of the

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students to understand the climate change impacts on forest ecosystems on different spatial and temporal scales and regions as well as the role of forests in the climate system. In this way it gives an excellent example for bridging the gaps between climate research, forestry practices and education.

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Higher Education and Green Technology in the European Context

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INTRODUCTION

In 2007, the leaders of the United Nations' Intergovernmental Panel on Climate Change (IPCC) were awarded the Nobel Peace Prize for their assessment of the physical science basis of global climate change. That report concluded that climate change of global and possibly irreversible scope and nature were the result of rising atmospheric concentration of carbon dioxide (CO2), and that human activity was accountable for this rise in CO2.

The implications of this climate change on future climatic conditions range from very bad to dire, depending on which end of the statistical planning ranges you use. Energy has always factored heavily into the political economy of the world. As energy supplies dwindle, and as emerging nations fan demand for energy to drive their growing economies, prices rise, interruptions in energy supply abound, and political and military tensions escalate. Many, with justification, view the current conflict in Iraq as revolving largely around U.S. needs to secure supplies of oil. A great many futurists identify the quest for energy (and water) as the defining issue of this new century. Whether the issue is energy security or climate change, both roads lead to the same destination. Against this backdrop, a group of university presidents and chancellors expressed their deep concern "about the unprecedented scale and speed of global warming and its potential for large-scale, adverse health, social, economic and ecological effects."

BACKGROUND

The European Opinion has placed a high priority on accelerating the transition to a "clean energy, green economy" across Europe, a priority that makes the vital connections between climate change, economic stimulus, energy security, and job training. The missing link in this interconnected system is the critical role that higher education must play in helping to make the clean energy, green economy a reality.

Transforming the European. economic, energy, and environmental systems to move toward a clean energy, green economy will require a level of expertise, innovation, and cooperative effort not seen since the second world war effort. Public engagement in this transition is essential: top-down solutions, such as regulating carbon emissions, alone will not suffice. A broad base of literate citizens must help to make this transition happen. Citizens will need to implement changes in business and personal practices, to support and help develop new technology and policy, and to confront the coming social and economic problems and opportunities arising from a changing climate. Architects, engineers, planners, scientists,

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business managers, financial experts, lawyers, entrepreneurs, political leaders, resource managers, and many others along with a green manufacturing workforce and environmentally literate consumers will all be needed to make this transition.

Higher education too has a critical role to play, and must help students understand the complex connections and interdependencies between the environment, energy sources, and the economy connections that underpin the concept of a clean energy, green economy. Only then will a broad segment of the population begin to pull in the same direction as those who are leading this transition.

NEW APPROACHES

The education required to accomplish this is a new way of thinking and learning about integrated, systemic solutions not just to the economic and environmental challenges but also to the interdependent health, social, and political challenges. Above all, this new way of thinking uses the green economy as the focal point for understanding the deep connections between economics, energy, the environment, and social well-being, often referred to as "sustainability."

Higher education is beginning to do its part. To date, a wide number of European tertiary institutions are working to develop action plans to make their campuses climate-neutral. Largely as a result of demand from students, the higher education sector is now the largest purchaser of green energy. In addition, campuses have conducted campus sustainability assessments, and hundreds more are planning to conduct such assessments in order to install solar panels or wind turbines. Over a dozen major higher education associations, including the Buckinghamshire New University in the UK, have made sustainability one of their guiding principles and top priorities.

Yet similar changes to the curriculum are lagging in universities across the continent. A recent report by EDUCAUSE Centre for Applied Research indicates that even though environmentally sustainable operations are now ranked among the highest priorities on campus, students today are no more likely than their predecessors to be environmentally literate when they graduate.

The European Union parliament is also beginning to embrace the need for education for a green economy.

The need to develop a skill base for each mitigation technology is obvious, both for technological expertise and soft skills. Students can benefit from a revised curriculum providing the necessary knowledge while professionals and blue collar workers need to be offered lifelong learning programmes. In both cases a multidisciplinary approach should be adopted. Encouraging the education system to take a broader view of how competences and qualifications are acquired is an important step. Involving the EU in promoting green awareness in education and increasing general public awareness of the green economy is equally important. The European Commission new skills for new jobs initiative promotes early identification of skills and labour market needs and also develops the green economy.

EU through Cedefop (European Centre for the Development of Vocational Training) and in cooperation with ILO (International Labour Organization)will continue to examine skill needs for greener economies with respect to new and changing occupational profiles, greening existing occupations, and identifying skills and occupations that become obsolete. The research is based on several country studies with primary focus on good practice examples of how national policies for greening economies are complemented by identification of skill needs and efficient skills response strategies.

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This study informs the new programs for tertiary education, vocational/technical schools, and K-12 schools to educate students about climate change and the green economy, including bolstering existing career pathways programs to provide more green educational and training opportunities for youth and young adults. This new climate change awareness drive offers an unparalleled opportunity to provide EU supported investment for educating a new generation of citizens in strategic green economy-related fields, including engineering, technology, science, mathematics, business, and policy, while also supporting broad public education about a green economy and climate change.

With great challenges come great opportunities, and the great opportunity in this transition is to build a more stable, sustainable, and secure economy. This will mean new jobs — jobs for which universities are well positioned to prepare workers. As a critical participant in this transition, IT departments can do at least three things:

- Set an example by minimizing the campus IT environmental footprint and moving toward climate-neutral operations (often saving some money in the process),
- Work with colleagues in other departments to help students connect the dots between energy security, environmental health, economic stability, and community well-being by infusing sustainability concepts into the teaching and curricula,
- Actively support efforts to pass the new legislation noted above.

The EU-28 had around 4,000 higher education (undergraduate and postgraduate) institutions, with just over 20 million students in 2011. Each year, higher education sends out into the workforce4.8 million graduates armed with the attitudes, skills, and knowledge either to advance a clean energy, green economy or to continue "business as usual." The impact, good or bad, of each of these 4.8 million individuals lasts a lifetime. As the old adage goes, we're either part of the solution or part of the problem.

CONCLUSION

The European Union tertiary education demonstrate progress in tackling the environmental impacts of campus activities. The thrust of work over the next few years will be to:

- Ensure that these environmental best practices are widely disseminated,
- Assist tertiary education in adopting and using Green Technology best practices effectively,
- Help institutions comply with requirements to reduce carbon emissions in line with government and funding council demands.

To help address these goals, in the UK, the JISC (Joint Information Systems Committee Ltd) has developed a tool to help institutions measure their carbon footprints. In addition, JISC is funding projects based in higher education institutions to grow the knowledge base around green technology and ICT, develop exemplar and demonstrator projects, and strengthen the capacity of the sector to implement these changes.

Overall, green technology or the environmental implications of ICT use and provision cannot be taken in isolation. Often efficiency gains in environmental terms go hand in hand with cost and wider efficiency savings, even if it is not always easy to connect capital and revenue budgets to enable these savings to be easily made. This indicate that there is much that has been done — but there is more to do.

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Integration of Green Technologies in Canary Islands - Low Enthalpy Geotermics

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Abstract

This paper presents the opportunities and initiatives in the use of low enthalpy geothermal resources in the Canary Islands, particularly in the construction industry. The Canaries face two problems related to electricity generation: on one hand it is an isolated system, on the other hand it is very expensive to produce electricity which mostly comes from fossil fuels. However the Canaries have favorable conditions to develop renewable energy, including shallow geothermal resources.

Keywords: renewable energy / energy efficiency / Canary Islands / building industry

INTRODUCTION

One of the most important reasons for promoting renewable energy in the Canary Islands, among which we include geothermal, is its insularity. We have total dependence on external energy resources, and therefore a great vulnerability to any energy-related crisis.

In this sense, the Canary Islands Government and other government agencies are promoting the use of renewable energy in all areas, including the building industry. In ideal conditions, the energy consumed by buildings should be balanced by the power they generate. This is the objective of the European Union on January 1, 2019: the construction of zero energy buildings, namely new buildings that produce as much energy as they consume. This energy production will have to be done by the use of renewable energy (solar, wind, geothermal, etc...)

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Figure 1. Photovoltaic plant on the island of Gran Canaria, Canary Islands

ENERGY CONSUMPTION IN THE CANARY ISLANDS

The Canarian electrical system is separated from that in mainland Spain. It is not connected to any main electrical grid and it is highly divided (Santamarta, 2013). The primary energy consumption has increased considerably in the Canaries (PECAN, 2007), with an average annual growth to 2004 of 2.9% compared to 3.2% until 2001. Hence, there is a moderating trend in growth in energy consumption.

Currently, renewable energy in the Canaries contributes only to 5% of the energy demand. This is significantly lower than the energy supplied by petroleum, namely 99.4%.

In summary, the combination of strong growth in energy consumption and CO_2 emissions in the Canaries (well above what Spain assumed under the Kyoto Protocol and subsequent distribution within the EU) will require a very active policy of efficient energy use. This implies the promotion of energy resources with low or no production of CO_2.

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Figure 2. Diesel Electrical Power Plant on the island of El Hierro, Canary Islands

The energy vulnerability of the Canary Islands is significantly larger than for the rest of Spain which, in turn, is much higher than the average of the European Union. This requires designing an energy strategy that promotes the rational use of energy and the exploitation of local energy resources at a reasonable cost.

The cost of energy generation in the Canary Islands in 2012 were (following the Canary Islands Government figures):

- Wind: 89 €/MW
- Photovoltaic: 145 €/MW
- Fossil fuel: 169 €/MW

GEOTHERMAL ENERGY IN THE CANARY ISLANDS

According to several reports of the Spanish Geological and Mining Institute (IGME, 1991), the Canaries are considered as a “geothermal region”. This is due to the volcanic origin of the islands and the existence of eruptive activity in historical and recent times.

The infiltration of seawater is of particular relevance in relation to air conditioning systems of shopping centers and hotels in coastal areas. The weather, latitude and altitude of certain islands, point to a great potential for geothermal installations in isolated houses that demand air conditioning and hot water.

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Since about 1980, IGME has conducted preliminary studies about the technical and economic feasibility of the use of geothermal energy in different areas of the Canary Islands. In this sense, it was established an agreement with the national company Adaro, for geothermal exploration in the Canary Islands (Dic., 1979). Different studies, including geophysical and geochemical surveys, were conducted in Gran Canaria, Lanzarote, La Palma, La Gomera and Tenerife. The most complete study was held in the Caldera de las Cañadas del Teide in 1991. This analysis consisted on geothermal prospecting with hydrogeochemical and geovolcanical studies, air thermography at El Teide crater and geochemical and isotopic studies of El Teide fumaroles. There were different geothermal studies in the late 80´s. From all these studies, it was chosen the ideal area for drilling a deep geothermal exploration borehole. The geothermal gradient that was measured in the borehole was much lower than expected, with mean values of 4.8°C / 100m and maximum values of only 9.4°C / 100m. (IGME 1993).

All studies that have been carried out in the islands reveal that the geothermal potential is manifested in various forms on the surface. On the one hand, on islands with abundant groundwater as Tenerife and Gran Canaria, these waters reflect the existence of geothermal indicators (high temperature, high contents of silica, fluorine, boron, etc .; abundance of gases, etc.); on the other islands where there have been historic volcanic eruptions, such as Lanzarote and La Palma, there remains a high thermal anomaly linked to these eruptions, so it is possible to measure temperatures of 300-400 °C in near-surface points.

Figure 3. Thermal waters in the island of La Palma, Canary Islands

Currently, there is a project called Geothercan 2011-2014 devoted to:

- 3D modelling to characterize geothermal resources in the Canaries.
- Study 4 areas in Tenerife, 1 in Gran Canaria and 1 in La Palma El proyecto se centra en 6 zonas 4 en Tenerife, 1 en Gran Canaria y 1 en La Palma.
- Carry out structural studies in all 6 areas (ULL-PETRATHERM)

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- Carry out geochemical analysis of gases and volatiles (ITER-INVOLCAN)
- Carry out self-potential studies in all 6 areas (ITER-INVOLCAN)
- Carry out magneto-telluric studies in all 6 areas (U. BARCELONA)
- Carry out muon tomography studies (ITER-U.TOKIO)

It is intended to perform a basic geothermal research providing a solid foundation for detailed studies (geothermal boreholes). This project also attempts to define efficient innovative research tools that facilitate the development of the first geothermal project in the Canaries. Moreover, Geothercan aims to replicate this experience in other areas of Spain and other similar volcanic environments in the world.

LOW ENTHALPY GEOTHERMAL RESOURCES

Low enthalpy geothermal energy is based on the capacity of the subsoil to accumulate heat and maintain a constant temperature between 10 and 20 m deep, throughout the year. Because the heat content of low enthalpy geothermal resources is insufficient to produce electricity, those resources with temperatures below 50 ° and even 15 ° C, can be used for domestic hot water and air conditioning, through a heat pump system

There are different facilities in the Canaries that are already using low enthalpy geothermal resources for air-conditioning, pool heating and preparation of hot water (DHW). These systems save in energy costs, but they also help to reduce the emissions of CO_2.

Some local experiences are:

Tenerife:

- Installation of 30 kW. Private house

Gran Canaria:

- Proposed instalation at a shopping center in El Tablero

Fuerteventura:

- Hotel Robinson Playa.- scheduled installation
- Hotel Meliá Sparrows. Planned installation of 140 kW
- Shopping Center Las Palmeras. Corralejo. Installation of air conditioning. Installation of 1,882 kW
- Shopping Center La Rotonda. Puerto del Rosario. Refrigeration. Facilities 1,285 kW

Lanzarote:

- Arrecife Gran Hotel. Facilities include air conditioning, pool heating, thalassotherapy and ACS. Installation of 1,076 kW.
- Casino Club Náutico in Arrecife. Pool heating. Installation of 115 kW.
- Hotel Las Costas. Puerto del Carmen. Installation of air conditioning, preheating ACS and pool heating. Installation of 849 kW
- Hotel Lanzarote Village. Puerto del Carmen. Installation of air conditioning, preheating ACS and pool heating. Installation of 622 kW.

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- Floresta Apartments. Puerto del Carmen. Pool heating and air conditioning in public areas. Installation of 311 kW.
- Acualava Waterpark. Pool heating.
- More than 7,200 kW of total installed capacity.

CONCLUSIONS

The geothermal potential in the Canary Islands would be intended for use as electric power in the case of medium and high enthalpy geothermal resources. Low and very low enthalpy geothermal resources would be used in households and facilities, in particular in the tourist sector, as well as the industrial sector, namely industrial areas, desalination plants , etc ...

Regarding the level of administrative authorizations required for the installation, it is not fully standarized, especially in open systems. Hence, the corresponding technician determines the criteria to follow for approval of the installation. This leads to a high uncertainty on the authorization of the installation, lengthening the time needed for it.

In any case, there is potential for exploitation of geothermal energy in buildings in the Canaries because of the weather conditions and the particular characteristics of the resource that is available.

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Cost Effectiveness of Using Forests to Mitigate Climate Change in Romania

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Abstract

The several constraints to achieving Sustainable Forest Management (SFM) raises questions regarding the cost effectiveness of using forests to reduce GHG emission compared to measures in other sectors. The use of forests to abate CO2 emissions is difficult to compare with more conventional technological measures in particular sectors, because of the several non-market benefits that forest management offer (arising from ecosystem services). Present paper is an attempt to evaluate, based on data available at this moment in Romania, the cost effectiveness of using forest to mitigate climate change.

Keywords: climate change / forest / sustainable forest management

INTRODUCTION

Even if the area is not yet systematized mainly because of the lack of the data, there are few examples where this has been done, and one case is in Russia, where the marginal abatement cost curve analysis also included afforestation/reforestation activities (see Figure 1 below). In this case abatement measures involving forests were profitable.

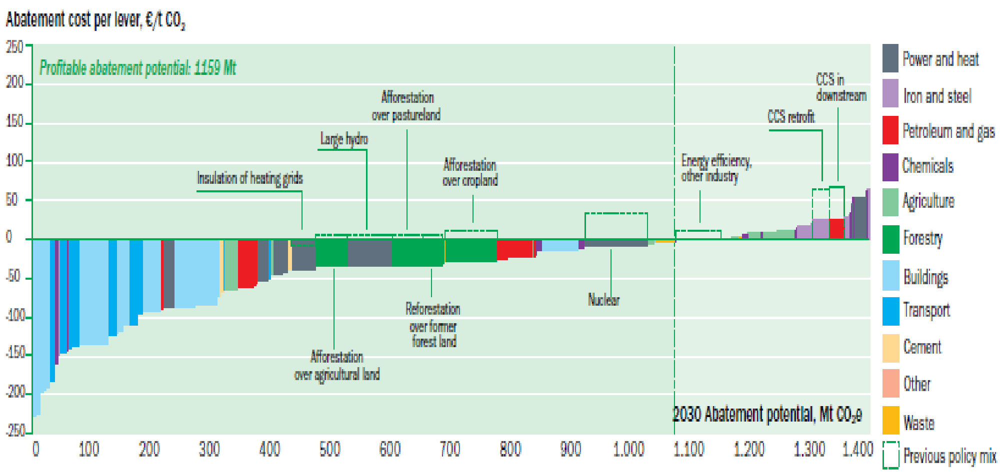

Figure 1. Abatement cost for Russia (WB 2008)

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Limited availability of data for the forest sector in Romania makes it difficult to present marginal abatement cost estimations for specific forest management approaches, similar to what was done in Russia.

MATERIALS AND METHOD

In place of a marginal abatement cost curve, the analysis estimates the discounted net benefits per ton of CO2eq sequestered through SFM of production forests, protection forests and afforestation. This approach is justified for the following two reasons:

(i) The CO2 sequestered is a co-benefit of the management practice. Accordingly using cost of the management practice per unit of CO2 would inflate the cost of generating emission reductions.

(ii) The aim is to determine whether there is a positive discounted net benefit that would justify further investments.

Due to data constraints, the estimation required using several assumptions. These are listed in Table 1.

Table 1. Assumptions used in estimation of discounted net benefits per CO2 ton (source: Authors)

	Main assumptions*
Estimating cost per tCO2 from production forests	The ratio of production and protection forest under Romsilva management is the same as the ratio of production and protection forest in the country Net profit figures per hectare from Romsilva (for 2012) are representative for all production forests Percentage of total income from timber sales is the same as in 2008 (i.e., 77%) Percentage of income from timber sales is proportional to percentage of total costs for management Average annual harvest for 2013-2020 is 16.57 million cum Average harvestable volume per hectare is 150cum Average C stock in living biomass is 66.80 tC/ha Average C stock in dead organic matter is 7.55 tC/ha
Estimating cost per tCO2eq from protection activities	Total area owned by private individuals that are compensated for protection activities is: 190,744 ha (Natura 2000 only) Compensation (as per the ministerial decree (is approximately € 137 per hectare per year. Unit cost for managing NFA park area can be extrapolated for other areas under protection: The cost for the basic level of management per hectare is: € 4.5 The cost for the optimal level of management per hectare is: € 7.4 Unit cost for managing 22 NFA CNPA park area can be extrapolated for other areas under protection Benefits from total CO2E sequestered for 25 years in business as usual (BAU) is € 14,400,000 Benefits from total CO2E sequestered for 25 years under Sustainable Ecosystem Management (SEM) is € 20,200,000 Amount of tCO2eq sequestered in 25 years is: 3,200,000 for BAU Amount of tCO2eq sequestered in 25 years is: 4,488,889 for SEM

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	Main assumptions*
	(assumptions specific to benefits from protected area involved extrapolations from Popa and Bann, 2012, without including the tourism and CO2 benefits used in their approximations)
Estimating cost per tCO2eq from afforestation	Using distinct values for afforestation of plains, hills and mountains with specific species and soil conditions, the present value of afforestation costs (for 6 years) in the three geographic areas are approximately: € 6227 in the plains € 4870 in the hills € 3509 in the mountains Approximately 40% of the area that is afforested serves as a forest belt For optimal outcomes, 4-6% of agricultural land should be under forest belt Improvements in wheat yields are a valid and representative approximation of benefits from forest belts The improvement in yields are gradual and reach a maximum after 10 years when the forest belt is well established Wheat yield is approximately 4000kg/ha Forest belts result in a maximum 17% increase in yield Average price per kg of wheat is € 0.7
Common assumptions	Average C stock in living biomass is 66.80 tC/ha Average C stock in dead organic matter is 7.55 tC/ha Conversion value from C to CO2 is: 3.6 Discount rate is 10% Exchange rate from RON to US is: 0.3 Exchange rate from US to Euro is: 1.33 Deflator for period 2005-2013: 138.46%

The assumptions presented above were derived from existing studies and models conducted by ICAS and experts on the forest sector of Romania It should be noted that the variability in land size, quality of forests, age of stands and access to infrastructure would change costs of forest management. That said, several non-market benefits associated with forest management are not reflected in the estimations for production areas and afforestation.

RESULTS AND DISCUSSIONS

The estimations of discounted net benefits per tCO2eq are:

- Sustainable management of production forests for timber: approximately € 0.77

This value is estimated using figures for revenue and costs associated with the existing technical measures and limited road access. If the technical measures were modified, access improved and new technologies adopted, the net benefits per tCO2eq could be higher)

- Sustainable management of protection forests (protected areas): range from € 401-€ 512

This value is estimated using information from five of the most established protected areas in the mountains of Romania. The benefits from soil erosion estimated from these five protected areas are likely significantly higher than the soil erosion benefits that would be derived in the

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central or southern parts of the country. Accordingly, the value is considered to be significantly higher than a representative value for the country.

- Afforestation: range from € 5.8 to € 6.1

The lower value is for afforestation in the plains and the higher value is from afforestation in the mountains.

The net benefits indicated above should not be used as absolute values because they are estimated based on several assumptions. The values, instead, should be used to give an indication of whether there are positive discounted net benefits associated with the three management options given their potential to contribute to CO_2 emission reduction. Additional data on management costs, revenues, and information on carbon sequestration and release based on species, age class of stands, soils and harvesting need to be used to generate accurate estimations and provide the basis for developing a marginal cost curve. The National Forest Inventory that is underway, has generated useful information from the first round of data. Without the second round of inventory analysis, however, it is difficult to use these data at this juncture.

There are several benefits from sustainable management of production forests and afforestation that are not reflected in the calculations. For the former, these include positive economic and social externalities (e.g., employment, revenue from trade, social inclusiveness and secure benefits) and partially positive environmental externalities (e.g., flood prevention, erosion control and resilience to climate change). Moreover, increased harvesting of trees allows for greater carbon sequestration as the trees regrow and mature (year 20-40), after an initial decline in carbon sequestration. There are also benefits stemming from the reduced incidence of fires. One of the best ways to lower the incidence of forest fires is to have firebreaks and to reduce the 'fuel' or combustible material found on the floor of forests. This can cause the fire to spread quite rapidly. Forest management activities often include thinning – removing smaller trees, small diameter trees and low value species. Management often also involves removing understory vegetation that can be a source of ladder fuel. For afforestation, these include positive environmental, economic and social externalities (similar to those mentioned above). In addition, the cost of forest management currently is significantly higher than optimal. A 2006-2007 study of Romsilva found that there were ways to reduce the NFAs its operating costs by 58%. Such a reduction in cost complemented with improved road infrastructure would increase the net benefits per tCO_2eq.

CONCLUSIONS

Even in the condition of poor data availability, we can affirm that the forest sector of Romania is a key sector for mitigating climate change. Forests are a major sink of GHGs and can help maintain, and potentially even increase, the level of GHG emissions reduced by the country. Forest based mitigation measures can include conserving existing CO_2 sinks, enhancing carbon sinks and reducing the trade-off between the sinks and tangible and intangible benefits from other land uses.

An advantage of investing in the forest sector for mitigation is the co-benefits from SFM and forest conservation. Improved forest management and management practices that internalize the potential impact of climate change can build the resilience of forests to climate variability, enhance the resilience of other sectors (e.g., agriculture), restore degraded lands, and provide a source of renewable energy for rural areas that has a low carbon footprint. Sustainable management of forests is instrumental for achieving Romania's international obligations and EU directives.

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Assessment of Novel Forest Ecosystems on Post-mining Restoration Site in Aidu, Estonia

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Abstract

Opencast mining creates disturbance to the ecosystem at all ecological scales: species, ecosystem and landscape level. The novel conditions are overwhelming starting from newly established bedrock and habitat distribution for vegetation dynamics. Usually on post-mining restoration sites develop novel ecosystems as soil conditions are completely new and ecosystem assemblage is spontaneous in the beginning. This study is based on long term monitoring and evaluation of afforested oil shale quarry in Estonia. Afforestation for ecological rehabilitation has been used in Aidu oil shale quarry since early 1960s. Scots pine showed the best afforestation results of these new calcareous sites. During the mining the ground- and rainwater has been continuously extracted from the quarry area. Water extraction from abandoned Aidu quarry has been terminated in 2012 and this leaves the area to the gradually changing water table in the next years.
The study is based on chronosequence data of soil and vegetation. After site reclamation soil formation has started and our study shows that soil properties develop towards the common *Hepatica* and *Calamagrostis* forest site types. Vegetation of restoration area differs from common forest sites, there are represented dry and wet site specific species as well as poor and fertile type specific species. Forest stand development is similar to *Hepatica* type forest. Studied novel ecosystems are quite dynamic, changing quickly by disturbances and have not easily predictable development pathways.

Keywords: afforestation / long-term monitoring plot / oil shale / ecosystem restoration

INTRODUCTION

Oil shale mining has been carried out in Northeast Estonia since 1916 (Toomik, 2008). The opencast mining area covers now more than 12,000 ha. Most of the mining area is located in former woodlands and has been rehabilitated as woodlands (Toomik & Liblik, 1998). Reforestation of abandoned mining areas dominated by calcareous detritus has been carried out since 1960 on the area of 10,965 ha (Kaar, 2010). Scots pine (*Pinus sylvestris* L.) has showed the best adaptation ability for afforestation of these novel calcareous sites (Kaar, 2010) and excellent growth results (Korjus et al., 2007). Even on very stony substrate the survival of planted Scots pine has been up to 85-90% (Kaar, 2002). In some areas planted Scots pine has been replaced naturally with Silver birch (*Betula pendula* Roth.).
During the mining on Aidu quarry the ground- and rainwater has been continuously extracted. In 2012, the water extraction has been stopped in the whole area, including afforested area.

This leaves the area to gradually raising water table in the next coming years what will be also monitored in future.
Ecological restoration of post-mining sites aims to direct their development towards a long-term sustainable ecosystem (Lamb & Gilmour, 2003) and to return the degraded system to pre-mining conditions where ecosystem structure, function and processes are restored (Bradshaw, 1997). Afforestation can play a major role in harmonizing long-term reclamation of the ecosystems by restoring productivity, biological diversity, and ecological integrity on these degraded areas (Kaar, 2002). Classical ecological restoration actions follow the principle of moving an ecosystem from undesired state towards the desired, pre-disturbance state that existed historically (Perring et al., 2013). Although, this can be valid up to certain extent in the degraded agricultural, forest or pastoral lands, it is usually not possible to exhausted mining sites (Doley & Audet, 2013). In post-mining sites the inability to achieve ecological restoration goals is due to the radical difference in physiochemical and biological characteristics of these sites as compared to historical environments. The degree of change caused by anthropogenic disturbance is often so severe, that novel ecosystems develop (Hobbs et al., 2006; Mascaro et al., 2013), where combinations but also relative abundance of species arise that have not occurred previously in a given site. This is distinguished from hybrid ecosystems that have the ability to turn back previous or historical conditions (Hobbs et al., 2009).
We set out this study to examine reclamation process on former oil shale mining sites in Northeast Estonia, to see how attempts at restoration that began in the 1960s fared and to compare the forest stands that resulted to native forests on similar sites. Because site and stand factors recover at different rates, we examined stand composition and structure, ground flora diversity, and soil physical and chemical property development over time. An early failure of the reclamation treatment (planted conifers) and subsequent recolonization by silver birch in one area provided an opportunity to examine whether we had a “counterfactual” treatment (Ferraro, 2009), that is, a “no-treatment” or natural succession treatment (Mascia et al., 2014). Prach et al. (2014) have found close relationships between local species pools and success of target species in colonization of restored sites, which among others indicate importance of traditional floristic research in ecological restoration.

MATERIAL AND METHODS

The study area is Aidu quarry (total area 30 km^2) in northeast part of Estonia (59°30’N; 27°07’E). The former land use on this area was woodland, wetland and agricultural land on a smaller scale (Tulchinsky, 2008). The excavation of oil-shale in opencast mining was started in 1974 and stopped in 2012. The oil-shale overburden was 5-30 m deep. After reclaiming the elevation of this area is 41 – 59 m above the sea level. The afforestation started in 1981 (Kaar, 2010). Most of the area has been planted with Scots pine bare root seedlings with initial density 5,300-6,700 plants per hectare.
This study includes complex monitoring of changes in:

1) forest stand level: stand structure and species composition, individual tree competition and height growth;
2) ground layer vegetation: moss and herb layer species and abundance;
3) soil: soil structure, soil organic layer, soil texture, pH, contents of K, P, N organic C and total C;
4) groundwater table: groundwater level fluxes.

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For the study there were established 60 permanent survey plots in different forest stands in 2011 (Figure 1). The method of the Estonian Network of Forest Research Plots (Sims et al., 2009) was used for monitoring of stand dynamics. The sample plots are circular with a radius of 10 and 15 m, which depends on stand density and visibility in stand. On all plots, azimuth and distance from plot centre of each tree (both, live and dead) were recorded. On 54 plots, diameter at breast height (DBH) and condition of each tree were measured. For every fifth tree, tree height and crown base height were measured. In young stands (6 plots) with many trees below 1.3 meter height, height and also DBH (if it was possible) of all trees was measured. Increment cores were taken from 5 trees as minimum in every stand. Vegetation subplots (1 x 1 m plots) are located 5 meters to north, east, south and west from survey plot centre, where all seedlings, vascular plant species and all bryophytes were recorded on Braun-Blanquet scale. All together 240 subplots were described.

On all plots soil properties were characterized. The humus layer and topsoil layer thickness was measured in 13 points by inserting a metal rod through the topsoil to hit the first rock layer. Stoniness of each plot was evaluated according to the method of Laarmann et al. (2010). Topsoil samples were taken from the each plot in depth to 30 cm and analysed in the Laboratory of Biochemistry of the Estonian University of Life Sciences. Total nitrogen and carbon content of oven-dried samples were determined by dry combustion method on a varioMaX CNS elemental analyser (ELEMENTAR, Germany). Soil organic carbon was determined by Tyurin method, the pH values were determined by extraction using potassium chloride (pHK_{Cl}), the concentrations of mineral elements (P, K) were determined by FiaStar5000 (FOSS GmbH, Germany) and soil texture classified into 3 categories: <0.002 mm (clay), 0.002 – 0.063 mm (silt), 0.063 – 2 mm (sand).

The correlations between soil parameters and stand data were analysed using dispersion and regression analysis. Species and communities data were analysed using canonical correspondence analysis (CCA) with the PC-ORD software ver.6. (McCune & Grace, 2002). Species richness was defined as number of different species on plot. Understory plants were divided into four groups by degree of anthropogenic impact. Kukk & Kull (2005) system classification is used, which defines the ability of a species to survive and develop habitats with a specified level of human impact: antropophyte tolerate strong, apophyte moderate, hemeradiaphore little and hemerophobic without any anthropogenic impact. Soil, stand and understory data were ordinated using Detrended Correspondence Analysis (DCA). If the length of a variable's variation gradient was relatively short (<2SD), then Principal Component Analysis (PCA) was used. Differences among the stands of the two main tree species (pine and birch) was tested using the multi-response permutation procedure (MRPP).

For ordination of understory data we used non-metric multidimensional scaling (NMS) for pine stands; there was insufficient age variation in the birch stands to examine understory development over time. NMS is an ordination technique based on ranked similarities of species composition suitable for community data that may not be normally distributed or fit assumptions of linear relationships among variables. We used the Sorensen distance measure with a log transformation on species abundances. We used the "autopilot" option on "slow and thorough" and a Monte Carlo randomisation test was applied on the stress scores. Pearson correlations with ordination axes for all quantitative variables were calculated separately for each.

For comparing tree height and diameter with regular forest types, we use stand-wise forest inventory data from the database of Estonian Forest Registry. Indicator species of three site types (*Hepatica*, *Arctostaphylos*, *Calamagrostis*) were taken from literature (Lõhmus, 2006; Paal et al., 2009). These site types have similar bedrock conditions to the study area. From the database we selected 2140 managed Scots pine stands from *Hepatica* (1111 stands),

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Arctostaphylos (973 stands) and *Calamagrostis* (64 stands) forest site types (Lõhmus, 2006), with stand age ranging from 1 to 39 years.

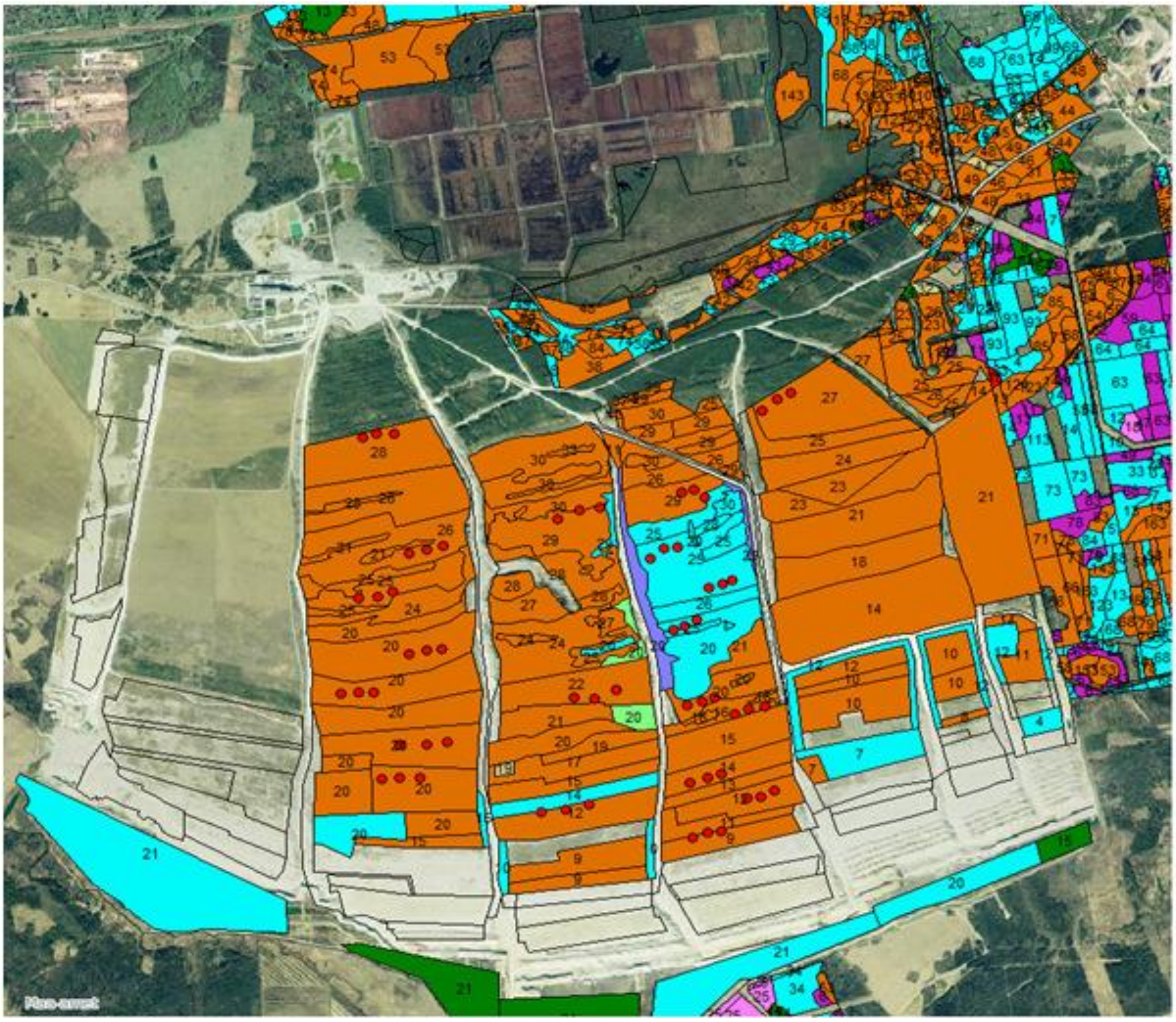

Figure 1. Study area in Aidu quarry, red dots are permanent survey plots, red areas Scots pine stands, light blue areas Silver birch stands. (Base map: Estonian Land Board).

RESULTS

The restoration efficiency on degraded oil-shale mining areas is depending on initial site conditions. Analysis results are presented in the Table 1. The analysis showed that stoniness influences forest growth more than other measured variables. The stoniness is significantly correlated with other soil variables, except with content of potassium. There was significant correlation between stoniness and share of deciduous species on plot ($r = -0.90$, $p<0.001$). Phosphorus content in soil ranged from very low to very high. Regression analysis showed that age has significant effect for P content ($p<0.001$) although this model described only 35% of variation. P content is positively correlated with share of sand in soil and negatively correlated with share of clay in soil. Potassium content varied from low (<50 mg kg^{-1} on 45 plots) to average (51-100 mg kg^{-1} on 15 plots) and is positively correlated with clay content in soil ($p<0.001$). The average nitrogen content in soil was 0.13%. Total C content is higher with

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thinner fine soil depth ($p=0.003$) and with higher clay content ($p<0.001$). The content of organic carbon is related to soil pH ($r=-0.57$, $p<0.001$) and N content ($r=0.65$, $p<0.001$).
On eight sample plots, where Scots pine was initially planted, it has been naturally replaced with silver birch. Topsoil layer thickness is dependent from dominant tree species ($p<0.001$), the average soil depth in pine stands was 6.7 ± 0.6 cm and in birch stands was 37.61 ± 3.0 cm. An increase of the deciduous tree percentage corresponds to a significant increase in average soil thickness ($p<0.001$) soil nitrogen ($p<0.001$), organic carbon ($p=0.01$), phosphorus content ($p<0.001$), organic layer thickness ($p<0.001$) and to a significant decrease in soil pH level ($p<0.001$). There was no significant relationship for carbon ($p=0.09$) and potassium ($p=0.17$) content.
According to the PCA, birch stands are clearly and significantly (MRPP; $t=-11.75$; $p<0.001$) different from pine stands in the ordination plot (Figure 2). The first ordination axis most closely represented a gradient of fine soil thickness ($r=0.92$, $p<0.001$), from a very thin soil layer on the left side of diagram to a thicker layer on the right. The gradient went in the opposite direction for stoniness and pH level. The second ordination axis represented a gradient of stand age, with younger stands at the top of the diagram and older stands at the bottom ($r=-0.86$, $p<0.001$). The increase in soil nitrogen (N) in pine stands over 33 years was statistically significant ($p<0.001$), but still remains lower than the nitrogen level of birch stands (Table 1). The soil phosphorus (P) level increased significantly ($p<0.001$) with stand age, reached up to 40 mg/kg and the mean P level differed significantly between pine and birch stands ($p<0.001$). Soil pH was higher in young pine stands and soil acidity increased with age ($p<0.001$). We did not find significant differences between soil carbon ($p=0.317$) or potassium ($p=0.176$) content among stands of different ages.
There were 100 herbaceous plant and 32 bryophyte species in total on sample plots. Three protected species were found also: *Epipactis helleborine* on 3 plots, *Goodyera repens* on 3 plots and *Dactylorhiza fuchsii* on 2 plots. Most of herbaceous species on the plots tolerate moderate anthropogenic impact, there were found also two species who need strong anthropogenic impact, *Tragopogon pratensis* (on 2 plots) and *Melilotus albus* (70% of plots), and two hemerophobic species *Orthilia secunda* (48% of plots) and *Monotropa hypopitys* (on 2 plots).The average herb richness was 13 species on a plot in pine stands and 10 species in birch stands ($p=0.05$).

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Table 1. Summary of measured environmental variables (p values present the comparison between the pine and birch stands, p-value: * 0.05, ** 0.01, *** 0.001).

Variable	Scots pine stands			Silver birch stands			p-value
	Avg	Min	Max	Avg	Min	Max	
Share of deciduous species (%)	10	0	56	99	94	100	***
Herbs richness	13	6	32	10	6	13	*
Mosses richness	4	1	10	2	1	3	***
Herb cover (%)	26	3	55	59	34	84	***
Moss cover (%)	39	2	99	9	1	27	***
Herbs diversity by Shannon	0.76	0.05	1.79	1.02	0.69	1.36	0.29
Mosses diversity by Shannon	0.49	0	1.30	0.02	0	0.45	***
Organic soil layer thickness (cm)	1.4	0	3.5	3.1	2.1	4.3	***
Fine soil thickness (cm)	6.3	2.5	28.7	38.5	31.3	48	***
N total (%)	0.11	0.05	0.21	0.22	0.12	0.37	***
C total (%)	9.21	1.74	17.72	6.014	3.48	10.04	**
C organic (%)	4.74	2.01	8.47	5.96	3.67	9.50	**
pH KCl	7.6	7.2	7.8	7.0	6.3	7.3	***
P available (mg kg^{-1})	24,91	4.94	103.48	67,23	33.03	124.89	***
K available (mg kg^{-1})	86.47	49.72	153.75	77.94	55.18	102.15	0.28
Share of sand (%)	55	31	85	70	61	78	***
Share of silt (%)	31	10	52	20	13	26	***
Share of clay (%)	13	5	17	11	8	13	**
Stand height (m)	7.5	1.9	13.8	15.3	10.6	18.2	***
Mean stand diameter (cm)	8.5	1.5	15	13.3	8.5	15.6	***
Basal area (m^2 ha^{-1})	13,0	0.4	27.1	16.6	13.5	22.1	0.23
No of trees (ha^{-1})	2304	594	3883	1350	821	3274	**
No of dead trees (ha^{-1})	26	0	255	158	14	269	***

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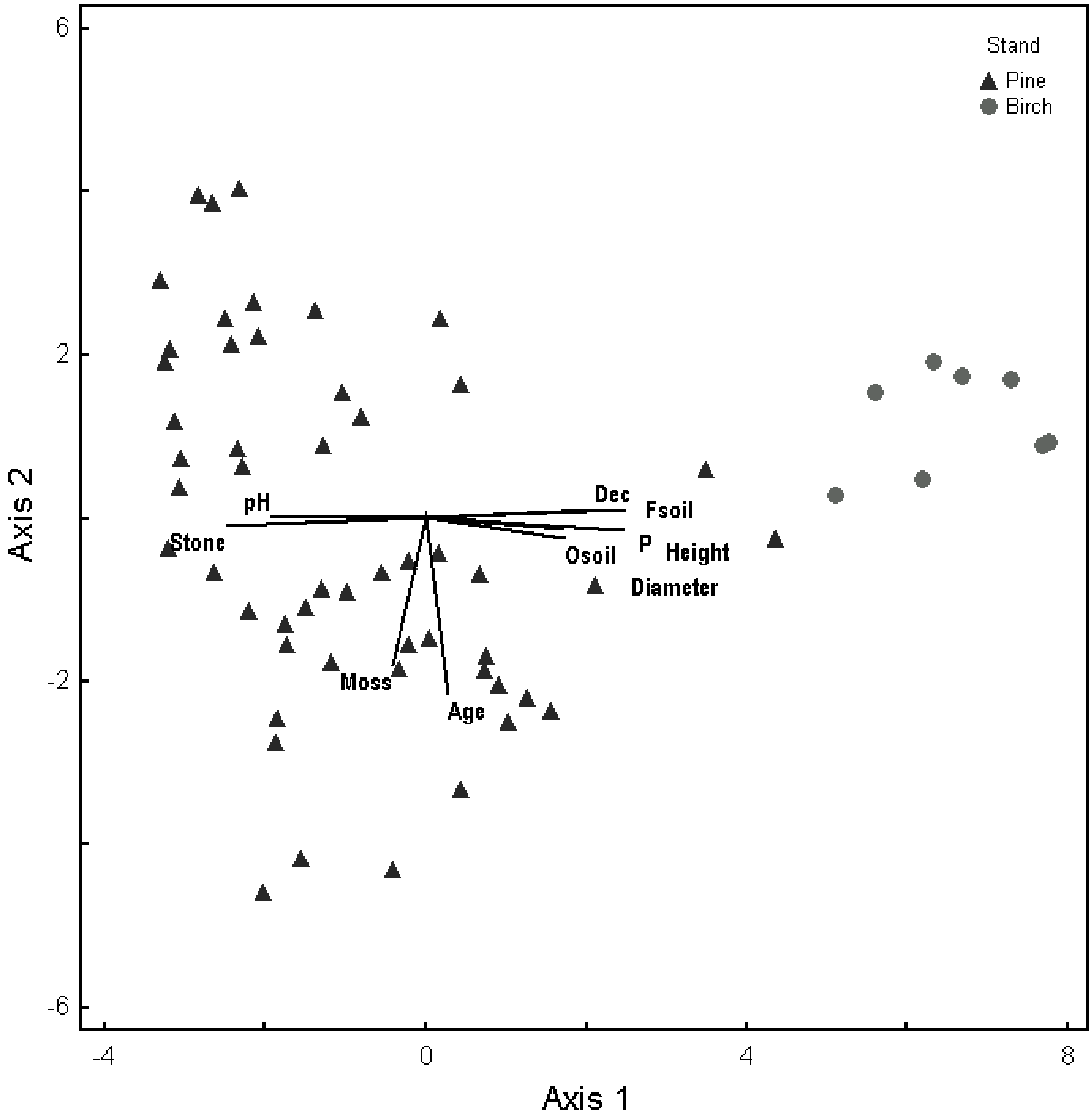

Figure 2. Ordination of plots by soil and stand variables. PC1 (37% of variance, p=0.001) and PC2 (16% of variance, p=0.001). The cut-off for vectors is R^2 of 0.5. Dec = share of deciduous trees in stand, Fsoil = topsoil layer thickness, P = phosphorus, Height = mean stand height, Diameter = mean stand diameter, Osoil = soil organic layer thickness, Age = stand age, Moss = mean richness of bryophytes, Stone = stoniness, pH = pHK_{Cl}. Stands are represented by symbols: triangles = pine stands, circles = birch stands.

DISCUSSION

Our assessment of forest ecosystem and soil properties showed successful restoration of opencast mining area through afforestation with Scots pine before water extraction stopped in Aidu quarry. Collected data is useful for further reference and monitoring after water extraction has stopped. Next measurements on sample plots will be done with 3-year interval.

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Monitoring and evaluation of restoration sites is generally lacking long-term studies and seldom pre-mining conditions are evaluated to use as a reference to guide restoration or as a measure to assess restoration success (Anderson & Dugger, 1998). One way to overcome these limitations is the chronosequence approach where space is substituted with time (Hutto & Belote, 2013). Our study used a quasi-experimental design to evaluate reclamation of spent mined lands in Northeast Estonia. The substrate (calcareous shale) differs considerably from many reclamation studies (Wiegleb & Felinks, 2001; Mudrák et al., 2010) on more acidic material, for example coal mines. Nevertheless, the reclamation approach that began in former Soviet times followed a simple revegetation paradigm (Stanturf et al., 2014) and focused on establishing a forest cover using *Pinus sylvestris*, a species that was easy to propagate, establish, and sell low-quality timber. The extensive use of Scots pine in afforestation of post-mining sites is due to its usually successful survival and establishment under difficult conditions (Kaar, 2002). Nevertheless, young trees may die as a result of frost in winter or drought in summer on such stony and clayey substrate.

An advantage of active restoration is that there is a faster formation of continuous vegetation cover than on spontaneous succession (Prach & Hobbs, 2008). In some cases, however, spontaneous succession may be preferable, especially on smaller disturbed sites surrounded by natural vegetation and if there is no specific restoration goal. Another advantage may be that spontaneous succession promotes natural conditions, which may be more important than the future productivity of the disturbed site (Prach & Hobbs, 2008; Hodačovà & Prach, 2003). Sites of spontaneous succession may act as habitat for endangered species, while reclaimed sites offer habitat for common species with broad ecological amplitudes (Prach et al., 2011). Reclaimed mined land may present heterogeneous substrate conditions and relying on a single planted species may raise the risk of low growth, high mortality, disease or invasive species, especially if the planted species is not adapted to site conditions (Martinez-Ruiz et al., 2007). At the Aidu quarry, high mortality of the newly planted Scots pine resulted in colonization by birch. Since the stands under monitoring are relatively young the results does not indicate, that the birch will achieve commercially valuable timber size, or other more adaptable species may have been planted, that would better achieve restoration goals. It is likely that assemblages will vary naturally across sites during the recovery process (Klötzli & Grootjans, 2001; Wiegleb & Felinks, 2001; Choi, 2004). However, such variation may hide aberrant trends on some sites and/or assemblages amid many others (Wassenaar et al., 2007). On the other hand, continuous tree cover was obtained and a diverse understory, different from that under pine was developed; which has met biodiversity restoration goals.

Restoration of post-mining sites faces completely new substrate conditions in the beginning and usually it is not possible to restore historical conditions in disturbed sites. A common outcome is a novel ecosystem that is characterized by new species combinations as result of human intervention, but does not depend on continuing human activity (Hobbs et al., 2006). Novel ecosystems may be more rich and diverse than natural communities and may offer suitable habitat for threatened and protected species (Richardson et al., 2010). We evaluated whether the ecosystems that develop on restored mined land in Northeast Estonia represent novel communities by comparing them to common forest conditions based on representative Scots pine site types. We compared the soil conditions to three site types found on similar bedrock to our study sites and then compared indicator understory vegetation common to the three sites types. The N, K and organic carbon levels in soil are similar to soil of *Hepatica* site type, whereas P, C and pH are more similar to *Calamagrostis* site type. It shows that soil formation and its content in reclaimed mined land differs from soils of certain forest site types and has formed unique conditions for vegetation development. The vegetation community is also distinctively different from vegetation on common forest sites. Pine growth on the

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reclaimed sites is similar to the growth on *Hepatica* site type (Figure 3) and significantly different from the other two forest site types. Similarly, more understory species are indicators of *Hepatica* site type than the other types.

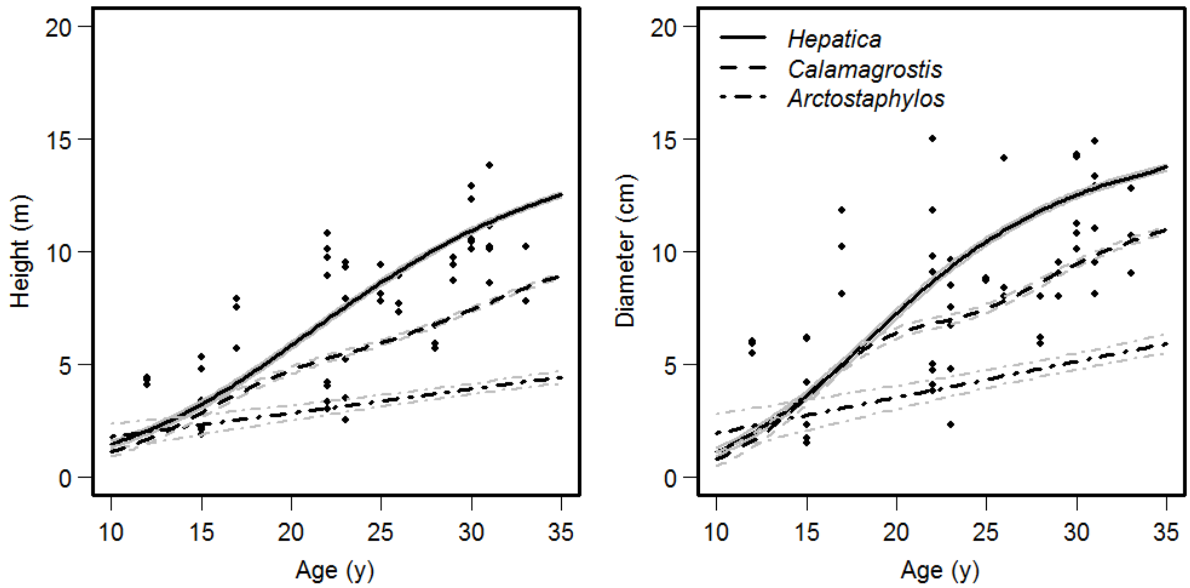

Figure 3. Stand height and diameter on sample plots at post-mining restoration in Aidu compared with dynamics on common forest site types. Dots are plots in the current study, lines show different common forest types presented by the GAM model.

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Tree Height Distribution in Young Naturally Regenerated Forests in Järvselja, Estonia

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Abstract

Height distribution patterns of young, especially naturally regenerated mixed broadleaves stands, have not been extensively studied in Estonia. Still, the percentage of stands left for natural regeneration is increasing and today, 70% of clear-cut stands left for natural afforestation are regenerating by 76% with broadleaved species. Growth assessment of young stands, especially stands before canopy closure, gives possibility to assess forest site potential and to develop realistic predictions for following periods. In Estonia, the growth modelling of young stands is based on tree species abundance and average height estimation. At the same time it is different from for the older stands, where the modelling is based on tree species average basal area and average tree height after canopy closure.
Data was collected from three test stands (final felling year respectively 1996, 2000 and 2002) with 9 study areas where 45 forest regeneration study plots were established and measured in 2005 at Järvselja Training and Experimental Forest Centre. The study plots were re-measured 4–6 times between the years 2006 and 2012. Suitability of Weibull distribution for height distributions on consecutive years was tested and Weibull parameters were analysed. Annual height growth model was created in order to assess yearly dynamics, where the effects of significant model parameters were separately assessed. Analysis indicates that empirical height distributions of young regenerated forests do not fit well to theoretical distributions, but in many cases, distribution configurations resemble. The annual growth analysis showed that annual increment is significantly influenced by particular calendar year.

Keywords: Weibull distribution / height growth / modelling / broadleaves

INTRODUCTION

In Estonia, naturally regenerated forests are dominating on the forested land. Just 90 years ago broadleaved forests covered a quarter of the forest land, but today the share between broadleaved and coniferous forest is almost equal. Over the last half-century, the Estonian forest area has almost doubled. This trend has caused a sharp increase in the proportion of naturally regenerated broadleaved forest. An increase of broadleaved species area and (general) proportion is primarily caused by natural and artificial afforestation of abandoned agricultural land and changes in reforestation policies (Kurm and Tamm 2001).
Today, one of the most important questions in Estonian silviculture is how to develop a young naturally regenerated broadleaved forest to ecologically and economically valuable forest. At the same time the naturally regenerated mixed broadleaved stands have not been extensively

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studied so far in Estonia. Assessing the development of naturally regenerated forests is complicated because the changes are happening rapidly and are affected by a set of several variables. It has been shown before, that the most descriptive and also well suited is to use height growth as the proxy to describe growth and yield potential of a juvenile stand.
The aim of the study was set to examine the height distribution and annual growth dynamics of young forests. We compared consecutive years height distributions to theoretical Weibull distribution (and Weibull probability density function parameters were studied). For finding the most substantial factor affecting the annual height growth of young trees, we used model trees annual increments analyse.

MATERIAL AND METHODS

Forest regeneration study plots were established in 2005 in south-eastern Estonia at the Järvselja Training and Experimental Forest Centre (58°25´N, 27°46´E) for a study the growth dynamics of young naturally regenerated forests. Nine sample areas (M1, M2, M3…M9) are located on three different young stands (*Oxalis*, *Oxalis* drained peatland and *Vaccinium myrtillus* site type) by groups of one, three and five depending on the stand size. Before the establishment of sample areas the study sites were cut in 2000, 1996 and 2002 and left for natural regeneration. Sample areas were distributed within stands with the distance of 50 meters. The sample plots inside the study areas were placed using cluster arrangement as shown in Figure 1.

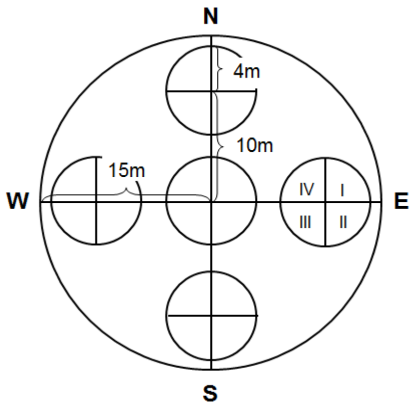

Figure 1. Design of five circular plot cluster on the study areas

Every cluster includes five circular 50 m^2 sample plots. The centre of the middle plot in a cluster was always set in the centre of the study area. The other four plots were placed 10 meters from centre to north, south, east and west directions. The plot centre was marked with a metal rod. Furthermore, all plots were divided into four sectors (each 12.5 m^2). Each sector was numbered (e.g. Figure 1), starting with the northeast quarter. The aim of a small plots cluster is to allow merging these plots into one large plot after the canopy closure. During the first three measurement years the height of all trees higher than 0.8 meters from the ground level were measured. Since 2008, all tree heights were measured starting from the ground level. Also, the intensity of measurements was changed, during the first four years sample areas were measured each year and after that on every second year. In total there were carried out 5 to 7 measurements between the years 2006 and 2012 depending on the sample area. The records of each measurement included a sector number, tree cohort, tree species and a total tree height for each sample tree. Within the sample plot sector, from dominant tree species the

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three highest trees were selected as model trees. In addition, a model tree was selected for every other tree species found in the sector. For each model tree higher than 1.3 meters, was measured breast height diameter in two directions, total height, the height of living crown base and the height of the lowest dead branch (thickness not less than 2 cm, length not less than 10 cm). Also damages were assessed on the model trees, which were classified according to cause and severity. Unique tree number was given to each model tree, which allows to monitor each model tree growth dynamics whole out the study period. The stands were re-measured at the end of the vegetation period or early in next year before new vegetation period started (Padari *et al*. 2009).

More than 14 tree species have been recorded in the sample areas, most common were Silver birch, Norway spruce and Common aspen. Trees from a previous forest generation are growing in some of the sample areas, but in our analysis only measurement data of a newly established tree generation was used. Due to different measuring techniques of sample and model trees the result is two different datasets, which were analysed separately. The sample trees dataset also contained model trees. The total number of measured sample and model trees in each sample area is presented in Table 1. The age of the trees in 2006 was counted by measuring tree rings from the analyse trees felled next to the sample plots.

Table 1. Short description of re-measurements on sample areas

Stand	Sample area	The age of the trees in 2006			Number of sample trees Number of model trees						
		Min	Avg	Max	2005	2006	2007	2008	2009	2010	2012
I	M1	2	4,6	10*	395 86	476 83	592 86	967 90	-	845 89	807 92
	M2	2	4,0	11*	471 94	541 94	680 100	908 98	-	693 89	759 88
	M3	2	3,9	15*	426 89	450 86	645 93	955 94	-	617 90	761 95
	M4	3	5,0	10*	130 43	139 41	221 43	281 45	275 45	268 45	327 47
	M5	3	4,0	7	100 44	149 41	232 53	378 53	417 58	415 58	504 61
II	M6	3	9,3	32*	246 70	285 70	404 78	939 80	-	641 79	972 79
	M7	2	5,4	19*	446 77	439 76	513 81	786 81	-	413 65	-
	M8	2	7,9	18*	169 58	234 58	763 91	1144 89	-	402 81	567 80
III	M9	4	12,4	25*	105 58	120 59	151 61	154 62	150 62	153 61	160 64

*The maximum age of the analyse trees appeared to be older than the regeneration period from final felling due to the sampling of Norway spruce advanced regeneration.

Tree height distribution analysis based on sample trees

We tested the fit of empirical young trees height distribution to three different theoretical distribution (normal, lognormal and Weibull distribution) based single year measurement data. Based on the results, Weibull distribution was selected for this study to test distribution fit to consecutive years height distributions. Weibull distribution has been previously successfully used to describe distribution of breast height diameter (Gulov 2010). We decided

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to use shape and scale parameters that contain the 2-parameters Weibull distribution function, which is not as flexible as the 3-parameter function, but has proven to be more accurate (Maltamo *et al.* 1995). Statistical computing environment R (R Core Team 2014) was used to analyse the data. Consecutive years height distribution of different tree species was the object of the analysis, each sample area data was analysed separately. We used a maximum likelihood method to estimate shape and scale parameters with R function *fitdistr()*. Weibull distribution fit for height distribution was assessed with the Pearson chi-squared test. To use the Pearson test, the data must be grouped into classes (Sachs 1982). We set a criterion that in every sample area, each tree species total measurement count must be higher than 300 and for particular year more than 40. In result 120 empirical distributions met the set requirements (Table 2).

Table 2. Number of height distributions by tree species and sample areas

Sample area \ Tree species	Common aspen	Silver birch	Norway spruce	Rowan	Linden	Others	Total
M1	6	5	-	-	6	-	17
M2	6	6	6	6	-	-	24
M3	6	6	-	-	-	-	12
M4	-	7	4	-	-	-	11
M5	-	7	4	-	-	-	11
M6	-	6	6	-	-	-	12
M7	-	5	5	-	-	-	10
M8	-	6	-	-	6	4	16
M9	-	-	7	-	-	-	7
Total	18	48	32	6	12	4	**120**

We used three methods for grouping tree heights (with one-meter interval classes, with 5 equal frequency classes, with 10 equal frequency classes). Function *pchisq()* was used to calculate probability of significance (p-value). Empirical distribution was considered different from theoretical distribution when p-value was less than 0.05. Shape and scale parameters dependence on each other and on several variables (minimum, maximum, arithmetic and mean square height; tree species; sample area) was assessed. Variation in parameter estimates throughout the study period was analysed for each tree species in each sample area.

Single tree growth analysis based on model trees

The tree species top height was used as a proxy for selecting model trees, it was assumed that these trees would form future stand. By observing growth dynamics of model trees, we can make predictions about the development of the future stand. The model trees were linked to a unique number in each sample area, which allows ranking every model tree height to a particular measurement year. To analyse annual growth dynamics, it was necessary that the height of the model tree be measured on every measurement occasion. The final dataset of the model trees consists of 360 model trees measurement data. The analysis was carried out using data on three most represented species (Common aspen, Silver birch and Norway spruce). To monitor the growth dynamics the time from the regeneration felling for each stand was used as a proxy. This allowed comparing the same species growth dynamics if trees were growing in different sample areas. The annual height growth for each model tree was calculated and top height (average height of one hundred highest trees H100) was calculated for each sample area. The relative height of each model tree was calculated, using the ratio between a model

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tree and H100. The relation between measurement characteristics and annual growth was modelled. The importance of measurement characteristics on an annual growth of a model tree was analysed. The significance of different characteristics was assessed with ANOVA, function *anova()* in program R. A model was created using the results of the analysis to simulate the growth of the model trees.

For modelling the trees species annual growth different dependent variables were used: measurement year; sample area; age of the tree; and relative tree height. For each tree species the model of linear dependence and generalized additive model (GAM) was created. The model of GAM better describes the contribution of different characteristics to annual height growth. GAM allows a generalized linear model to apply a smooth function of an additive model (Crawley 2007). Each factors contribution to the annual growth was tested with ANOVA.

RESULTS AND DISCUSSION

Tree height distribution dynamics

Distribution with five classes showed best fit with the Weibull distribution, the Pearson chi-squared test result probability of significance was 0.05 or higher in 39.17 % of the cases. Respectfully the fit with one-meter interval classes was significant in 31.67 % of the pairs and for 10 classes distribution 30.83 % of the cases. These results confirm that the method for dividing the data in classes plays an important role in the Pearson test results. About half of the analysed empirical distributions rejected fit to the Weibull distribution or to the other used classical distributions. However, visual analysis of these distributions showed the empirical and theoretical distributions general shape similarity.

The fit with empirical distribution depends on the shape and scale peculiarities of the specific distribution on particular measurement year. The changes of the shape and scale parameter values in consecutive years was analysed by tree species in each sample area. In Figures 2 and 3, the values of the parameters dynamics are shown graphically. The Figure 2 shows that the different tree species shape parameter values have a similar dynamics in each sample area. In the temporal scale, the parameter values follow in general declining trend. The reason behind that decline is the reduction of average height of trees during the development of the stand. The average height of young stands is reduced particularly because of ingrowth of new trees in the sample area, this increases the share of small tree heights in the dataset.

The increase of the shape parameter is caused by the increase of average height of trees. In sample area M8, there was a sharp rise in the values of Silver birch shape parameters in comparison of the years 2008 and 2010. This was caused by the death of small trees between the two re-measurements.

The density function curve of the Weibull distribution is determined with the shape parameter being close to normal distribution at the value of 3.6. On studied sample areas the value of the shape parameter is less than 3.6 in case of most of measurement years and most of the tree species, indicating to a positive asymmetry within the distributions. The positive asymmetry is expected with young trees height distribution because of the annual ingrowth of new trees in early stand development. Therefore, the share of small values is high in each year, but at the same time also high height values always exists stretching the distribution to the right. In temporal scale shape parameter have a declining trend, so positive asymmetry of distribution growing during the study period.

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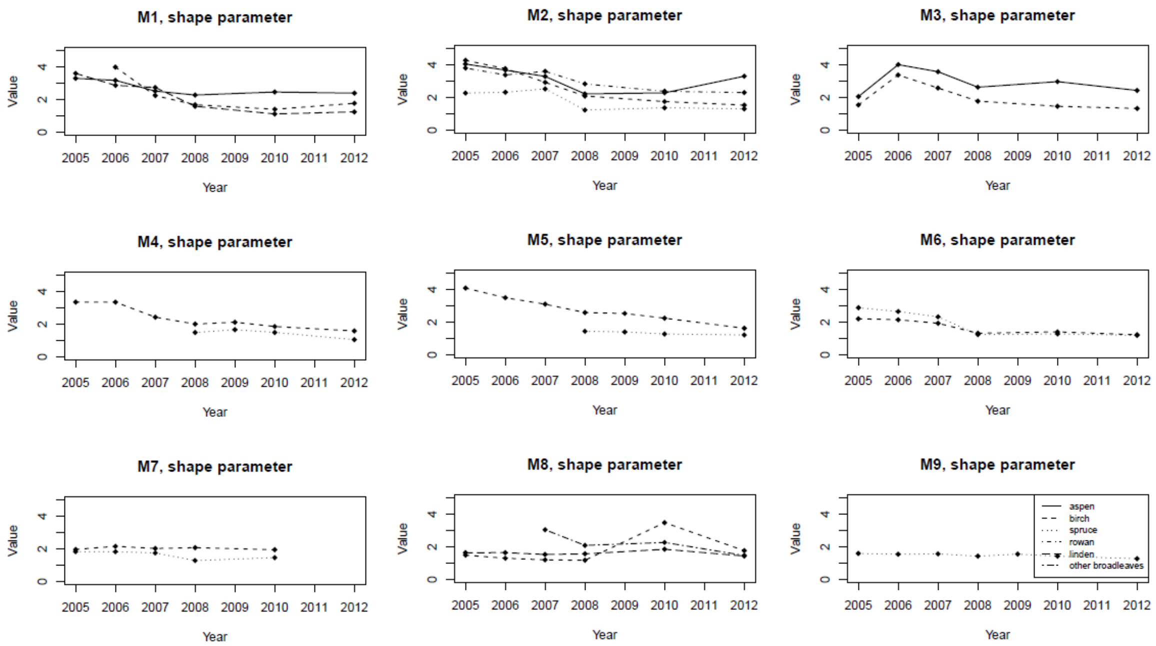

Figure 2. The dynamics of the shape parameter value on each sample area

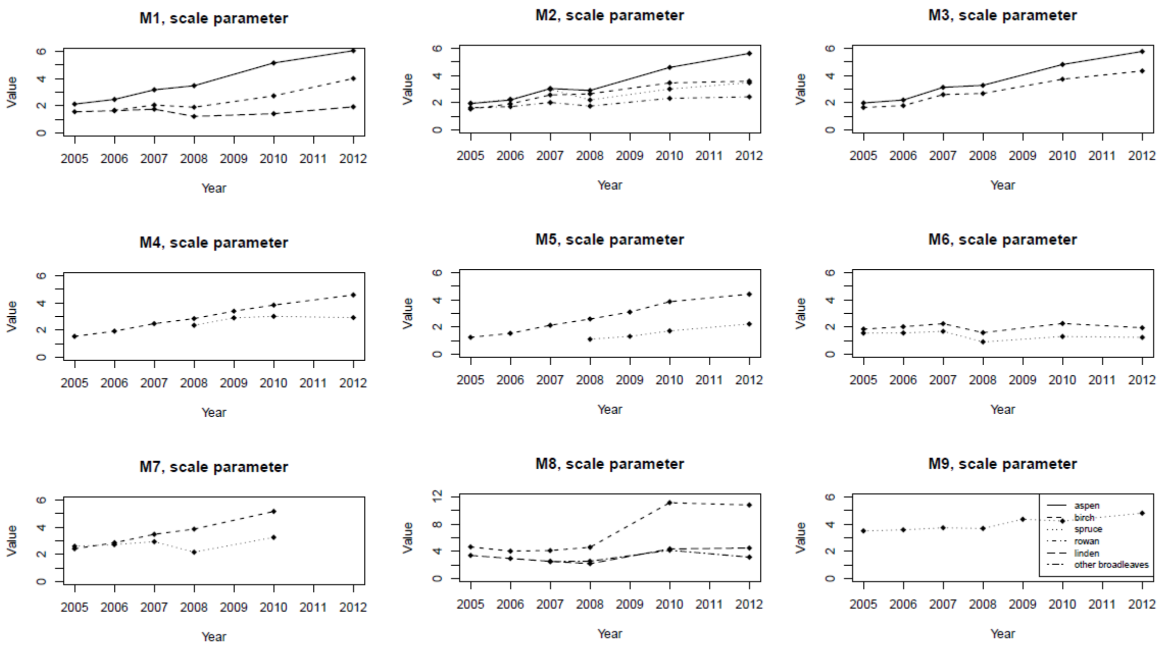

Figure 3. The dynamics of the scale parameter value on each sample area

The scale parameter describes the scope of the observed dataset values. The values of the analysed distributions showed an increasing trend over the study period, describing clearly the young stand peculiarities. The height distributions of young stands always starts with very small values, but the difference between the minimum and maximum value increases annually. A change in parameter value dynamics can be observed in years 2007 and 2008 and was caused by the changes in the method for tree height measurement. The scale parameter trends for different tree species are similar.

The two parameters of the density function of the Weibull distribution dependence on different site and climatic variables were analysed. The shape and the scale parameter showed correlation to each other, but not a good correlation was found between the shape parameter

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value and stand height characteristics. The correlation was found between the scale parameter, maximum height of the distribution and the scope of the heights. A strong linear correlation was between the scale parameter and the mean square height of all studied tree species.

Modelling based on the model trees

In Table 3 is presented the probability of significance of factors in GAM model.

Table 3. Probability of significance of factors

Factor	Probability of significance		
	Common aspen	**Silver birch**	**Norway spruce**
Year	<0,0001	<0,0001	<0,0001
Sample area	0,0020	<0,0001	<0,0001
Age of tree	-	0,00414	0,3580
Relative height	0,0485	0,00724	<0,0001
R^2	0,3050	0,3660	0,2990

The analysis of each factor impact to annual growth showed that, for all the tree species, growth is most dependent on a specific growing year. The importance of the growing year can be foremost connected with the average temperature during the vegetation period. To control this dependence, dynamics of annual growth was compared with the nearest weather station average summer temperature (May to August). Figure 4 shows the predicted annual height growth growths and the 95% confidence intervals.

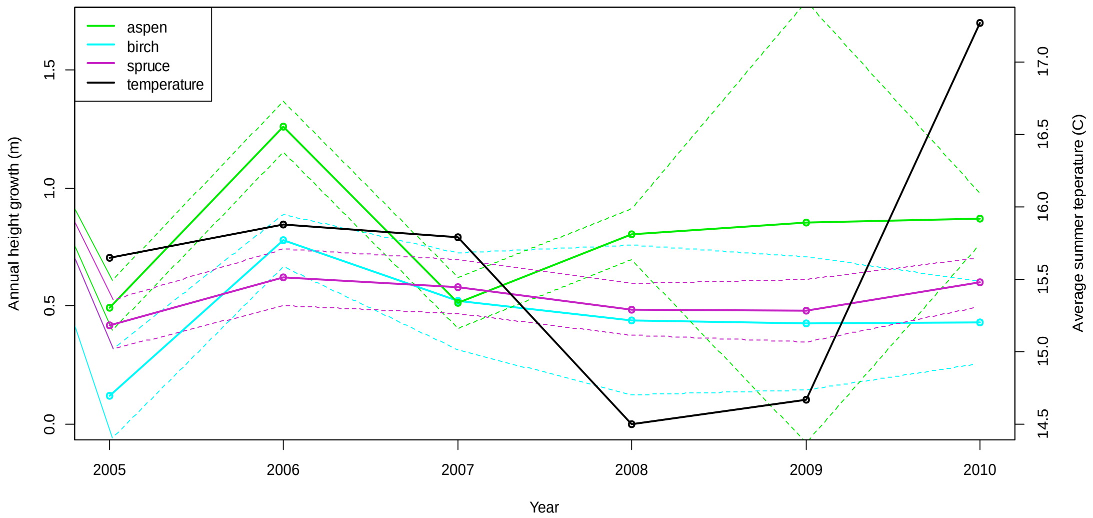

Figure 4. The average temperature of the vegetation period and predicted annual growth

The comparison of growth and the average temperature showed nonlinear relationship. A deviation from the general trend occurs with the growth of Common aspen in 2008.

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Growth Decline Response of Beech to Climate Change

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Abstract

The need to predict the growth response of trees to future climate change is ever growing. Current climate change is altering environmental conditions quickly, and locally adapted populations are likely to experience climate to which they are not well adapted. In order to study this sub-optimal adaptation, common garden experiments provide a powerful tool for studying climate tolerance of trees. Out of the 1998 series of the international beech provenance trials, one experiment was established in Bucsuta, SW Hungary. Because of its ecologically marginal location, this is one of the most suitable site in the experiment to predict responses of populations to sudden climatic changes, simulated by transfer. 15-year diameter data were used as dependent variable. Out of the bioclimatic variables, Ellenberg's drought index (EQ) which has shown the best correlation was selected for the further analysis. The difference in EQ (ΔEQ) between the provenance origin and the test site, and the 15-year diameter data were used to establish a linear transfer function which may be used to predict growth decline caused by future climate change.

Keywords: common garden / increment loss / Ellenberg index / adaptation

INTRODUCTION

According to palaeoecological data, tree species will be unable to adapt to rapid climate change due to their low migration rate (Davis et al. 2005) and highly fragmented landscape (Jump – Penuelas 2005). Ecological tolerance limit of the species are threatened by projected increasing average temperature and increased frequency of extreme events.

European beech (*Fagus sylvatica* L.) is a dominant tree species across Europe with a wide distribution range. In Central and South Europe, the most important factor limiting the occurrence of the tree is the precipitation, therefore marginal population at low-elevation (xeric) limit require special attention. In some studies has been demonstrated the growth decline with the worsening climate conditions at the xeric limit (Mátyás et al. 2009, Jezik et al. 2011, Hlasny et al. 2014). On the other hand, heavy and long drought events weakened the trees and have made them susceptible to diseases causing mass mortality of beech (Jung 2009, Lakatos – Molnár 2009).

Population's gene pool is shaped by macroclimate, beech populations adapted to local climate with different ecological conditions. This difference is also reflected in phenotypic traits like bud burst date, length of vegetation period..etc. Populations from different parts of the distribution area show distinct ecological tolerance which may provide an opportunity to investigate tolerance limit of beech (Mátyás – Yeatman 1987). Common garden experiments provide a powerful tool for studying climate tolerance of trees. These experiments have a long tradition in forest research. Data collected from these trials allow to compare such important

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traits as frost resistance, drought tolerance or other differences in growth between populations. According to the results of common garden experiments we can give recommendations for the use and transfer of forest reproductive material have to be adjusted in the face of climate change.

The International Beech Provenance Trials of IUFRO

In 1995 and 1998 international beech provenance trials were established across Europe, organized by the Institute for Forest Genetics, Grosshandorf, Germany (Wühlisch 2007), (*Figure 1*). Reproductive materials used in the experiments were collected from the whole distribution area and raised at the same place until age two. After two years they were transferred to trial sites across Europe.

The objective of these experiments was to identify intraspecific differences in order to be able to determine the most suitable population at a given site and to make predictions of future distribution range of beech under changing environmental conditions.

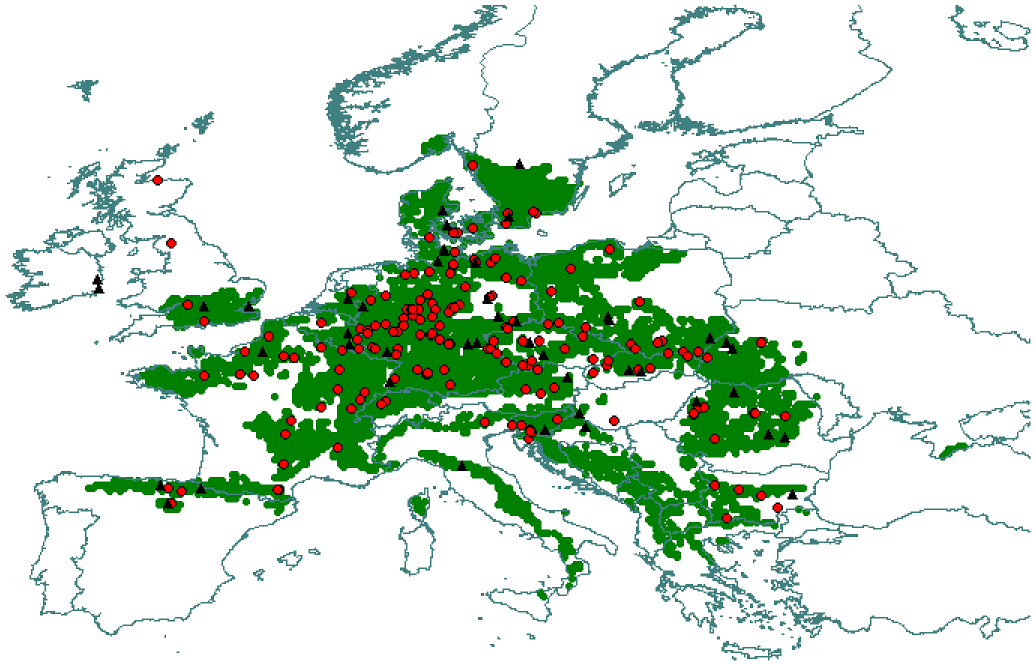

Figure 1. Test sites (▲) and origins of beech provenances (●) of the 1995 and 1998 International Beech Provenance Trial, projected on the distribution map of European beech (source: EUFORGEN)

The Hungarian Trial Site in Bucsuta

Out of the 1998 series of the international beech provenance trials, one experiment was established in Bucsuta, SW Hungary. This trial covered a wide part of the species range, it consists of 36 provenances (*Table 1*). Every provenance was planted in randomized plots and replicated in three blocks across the site which belongs to Zalaerdő Forestry Corporation. Each rectangular plot consists of five rows, each with 10 trees at a spacing of 2 m between rows and 1 m between plants within the rows.

Before planting, the old forest stand was clear-cut, tree stumps were removed and the trial area was fenced. The trial is situated on 220 m a.s.l. under beech forest climate, it has southern exposure with 5-10° slope angle. The soil type is brown forest soil with clay illuviation. The third block is located on the bottom of the hill, it is the most humid part of the trial site.

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Table 1. Geographic data, annual precipitation and July mean temperature of provenances, as well as the ecodistance (ΔEQ) between Bucsuta and the provenance location

ID	Name of provenance	Country	Latitude	Longitude	Altitude (m)	Annual mean precipitation (mm)	July mean temperature (°C)	Δ*EQ*
1	*Perche*	FR	48.42	0.55	205	691	17.6	3.98
2	*Bordure Man.*	FR	49.53	0.77	80	689	17.6	3.90
6	Plateaux Du*	FR	46.80	5.83	600	1097	17.8	13.22
8	*Pyrenees Or.*	FR	42.92	2.32	670	754	21.3	1.20
11	*Heinerscheid*	LU	50.08	6.12	423	844	16.7	9.66
13	*Soignes*	BE	50.83	4.42	110	810	17.4	7.97
14	*Aarnink*	NL	51.93	6.73	45	797	17.1	7.99
17	*Westfield 2002*	GB	57.40	-2.75	10	836	13.2	13.66
21	*Grasten, F.413*	DK	54.92	9.58	45	780	15.8	9.19
23	Torup*	SE	55.57	13.20	40	634	16.6	3.27
26	*Farchau, 72A*	DE	53.65	10.67	55	676	17.3	3.86
27	*Graf Von W.*	DE	51.52	8.78	375	941	15.8	12.66
29	*Dillenburg*	DE	50.70	8.30	520	751	17.4	6.28
31	*Urach, 12A 13*	DE	48.47	9.45	760	894	16.3	11.22
32	*Ebrach*	DE	49.85	10.50	406	701	17.2	4.91
34	*Oberwil*	CH	47.17	7.45	570	923	17.8	10.16
35	Hinterstoder*	AT	47.72	14.10	1250	1539	11.4	22.04
36	Eisenerz*	AT	47.53	14.85	1100	1259	12.2	19.76
39	*Jaworze, 178F*	PL	49.83	19.17	450	950	16.3	12.29
40	*Tarwana, 81C*	PL	49.47	22.33	540	704	16.9	5.44
43	Jawornik, 92B*	PL	49.25	22.82	900	764	16.4	7.98
46	*Domazlice-Vyhl*	CZ	49.40	12.75	760	893	14.5	13.21
48	*Jablonec N.N.*	CZ	50.80	15.23	760	731	13.9	10.43
49	*Brumov Sidonie*	CZ	49.05	18.05	390	799	16.5	8.80
51	Horni Plana-Ce.*	CZ	48.85	14.00	990	1097	14.2	16.50
52	*Magyaregregy 60A*	HU	46.22	18.35	400	707	19.0	2.57
53	Postojna Masun.*	SI	45.63	14.38	1000	1346	16.9	16.89
54	*Idrija-II/2, 14*	SI	46.00	13.90	930	1318	16.8	16.70
59	*Pidkamin*	UA	49.95	25.38		612	18.1	-0.13
64	*Nizbor*	CZ	50.00	14.00	480	541	17.6	-3.08
65	*Koino*	PL	49.92	20.42	400	729	18.2	4.48
67	*Bilowo, 115D116B*	PL	54.33	18.17	250	631	15.6	4.73
70	*Buchlovice*	CZ	49.15	17.32	410	669	17.3	3.59
H1	*Bánokszentgyörgy*	HU	46.60	16.85	200	747	20.0	2.67
H2	*Farkasgyepű*	HU	47.20	17.65		625	19.1	-1.11
H3	Ördöglyuk *	HU	48.49	21.36	450	651	19.0	0.26
Bucsuta (1998-2013)			46.57	16.67	220	707	20.8	

* The marked provenances not included in the analysis.

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Figure 2 shows climate location of Bucsuta and of all provenances which are presented at the site. The average rainfall in Bucsuta is about 700 mm per year and the average yearly air temperature in summer is 21°C. Hungarian test site is located at the margin of the climatic space as shown in *Figure 2*.

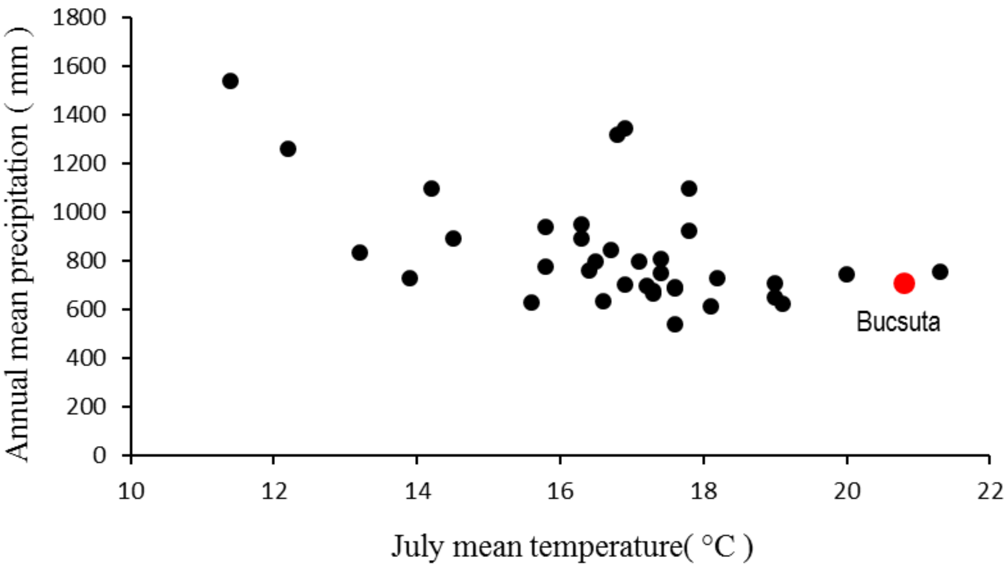

Figure 2. Location of Bucsuta and of the provenances in the climatic niche of annual precipitation and July mean temperature

MATERIAL AND METHODS

Climate data

Climate data for the provenances origin are derived from the WorldClim database (www.worldclim.org), referring to the 1950-2000 period. The database included interpolations of observed data with a spatial resolution of about 1 square kilometer. In the case of trial site, it was needed to get climate data for the period provenances were exposed to (1998-2013), as the outplanted seedlings responded to the climate conditions of this period. Owing to a lack of local meteorological station, the data of the nearest station (in Nagykanizsa) were used for the analysis.

17 bioclimatic factors, two continentality- and three aridity indices computed from monthly averaged temperatures and monthly precipitations were used (*Table 2*). The most significant component was selected by correlation analysis.

Observed data

Plot averages of 15-year diameter, measured on the 5 largest trees per plot at the Hungarian site were analyzed to establish a linear transfer function. All of the diameter data could not be used for the analysis, only the most reliable plots included in the dataset. The Alpine provenances behave quite different probably due to different adaptation, therefore, they also have been removed. Finally, 8 provenances had to be excluded from the analysis. Out of provenances used in the experiment, 16 with two block diameter data and 12 with one block diameter data are presented. In addition, 44 diameter data have been used. The 5 largest trees of each provenance have been selected, these trees may be considered as final crop trees

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which characterize the growth potential of population well. Finally, screening data have been taken into account as pooled dataset.

Working hypothesis

Long-lived organisms such as trees must tolerate relatively broad fluctuations of environmental conditions without the chance of escaping to more favourable habitats. Adaptation is the only way to survive the changing environment, there are several genetic and non-genetic processes operating on the individual, population, species and ecosystem levels, balancing changes in environmental conditions. Despite of the fact, that tree species have successfully survived changing geological periods, it is concern that they may not be able to cope with future environmental changes. Expected temperature increases are far higher than those that occurred during the interglacial periods of the Quaternary. The aim of the study was to determine increment loss of beech due to sub-optimal adaptation to rapid climate change.

Observed changes in growth of a provenance in response to climatic changes experienced by transplanting can be interpreted as simulations of its response to future climate change. The magnitude and direction of changes can be performed with the help of ecodistance variables (Mátyás 1994). The ecodistance is calculated as difference between test site climate and climate of the origin of provenance.

This study is the reformatted version of the article (Horváth – Mátyás 2014) which was submitted to the scientific journal of Erdészettudományi Közlemények in Hungarian language.

Table 2. List of bioclimatic variables used in the correlation analysis with15-year diameter data (significant at p< 0.05 (*) and at p<0.01 (**) are marked)

Bioclimatic variables	Abbreviation	Pearson's correlation coefficient	Significance
Annual Mean Temperature	T_a	0.345	0.190
Mean Diurnal Range	T_{hh}	0.369	0.160
Isothermality	Izoterm	-0.110	0.680
Max Temperature of Warmest Month	T_{max}	0.582	0.018*
Min Temperature of Coldest Month	T_{min}	-0.014	0.960
Temperature Annual Range	T_{ah}	0.430	0.096
Mean Temperature of Wettest Quarter	TQH	0.060	0.826
Mean Temperature of Driest Quarter	TQA	0.014	0.958
Mean Temperature of Warmest Quarter	TQW	0.582	0.018*
Mean Temperature of Coldest Quarter	TQC	0.059	0.828
Annual Precipitation	P_a	-0.405	0.120
Precipitation of Wettest Month	P_{max}	-0.181	0.503
Precipitation of Driest Month	P_{min}	-0.436	0.092
Precipitation of Wettest Quarter	PQH	-0.303	0.254
Precipitation of Driest Quarter	PQA	-0.345	0.191
Precipitation of Warmest Quarter	PQW	-0.298	0.263
Precipitation of Coldest Quarter	PQC	-0.237	0.377
Gorczinski's Continentality Index (Rasztovits et al. 2012)	GCT	0.460	0.073
Continentality Index (Rasztovits et al. 2012)	CONT	0.399	0.126
De Martonne aridity index (Rasztovits et al. 2012)	DMI	-0.540	0.031*
Ellenberg's climate quotient (Rasztovits et al. 2012)	EQ	0.642	0.007**
Forest Aridity Index (Führer – Jagodics 2007)	FAI	0.415	0.110

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RESULTS AND DISCUSSION

In order to select the most significant bioclimatic factor, we performed correlation analysis between bioclimatic variables and 15-year diameter data (*Table 2*). Significant value was obtained by following variables: EQ, $T_{max,}$ TQW, DMI. The most important factor which performed the strongest correlation is Ellenberg's climate quotient (EQ), as shown in *Table 2*. Earlier studies demonstrated that EQ is the most influential predictor which describes the distribution limit of beech (Fang – Lechowicz 2006, Czúcz et al. 2011). After we determined ecodistance (ΔEQ) values, as described in the working hypothesis. Positive value of ΔEQ expresses a simulated warming of the environment through transfer to the site. As shown in *Table 1*, almost all provenances experienced warmer and drier conditions by transplantation.
Instead of absolute value of diameter, all data in percent of maximal value (wich obtained by 0 ΔEQ) were used in the analysis. *Figure 3* shows linear function of increment decline which explains 25% of the total variation between provenances (R^2=0.2472, p=0.0006). The function used to define increment loss caused by sub-optimal adaptedness, in other words, by this function we can predict increment loss of populations caused by projected climate change. For example, increase in EQ value of one site by five units due to climate change means 10% reduction in growth.
Because of the ecologically marginal location of Hungarian trial site, Bucsuta is one of the most suitable site in the international experiment to anticipate negative effect of climate change. Generally accepted that the local population is the best, however, other studies suggested that non-local provenances may exceed the performance of the local ones (Mátyás et al. 2010, Leites et al. 2012). Finding a population which is considered preadapted for future conditions may be decisive for sustainable forest management.

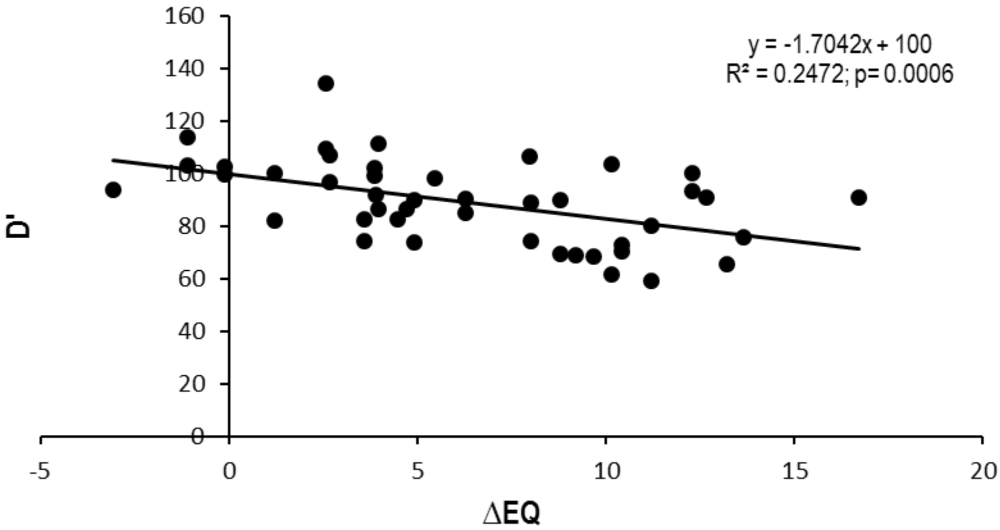

Figure 3. Increment decline caused by sub-optimal adaptedness. The "transfer function" defines the decline in percents of the mean diameter of the locally adapted provenance, in function of the change of the Ellenberg's drought index (ΔEQ)

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CONCLUSION

Planting seedlings adapted to predicted future climates has been suggested as a key forest management strategy to mitigate negative impacts of climate change. Therefore it is important task to recognize adaptive capacity of main tree species. Provenance tests provide sufficient information about the response of population transferred to new environment which interpreted as climate change effect. In our study, we introduce an increment loss describing function which can be used to predict growth decline caused by future climate change.
Our study should assist forest managers in planning reforestation for uncertain future conditions.

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Causes of the Forest Die-off in a Pinus Forest (*Pinus sylvestris*) in Fenyőfő

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Abstract

This paper investigates the causes of a Pinus forest die-off in Fenyőfő. In the research area 20 soil profiles were studied to find the reason of the tree mortality. The characteristic soil type is rusty brown forest soil in the area. The effects of climate change on the Pinus forest were also analyzed. We used gridded station data from the Hungarian Meteorological Service for the time period 1961-2013. It contains daily, monthly and yearly time series for precipitation and temperature means and extremes. The results show that the annual mean temperature and the frequency of extremely high temperatures increased in the last few decades. Soil conditions and climate change together lead to the decrease of the groundwater level that became unavailable for the vegetation.

Keywords: climate change / die-off / groundwater level / *Pinus sylvestris /* soil investigation

INTRODUCTION

Hungary has several places where natural ecosystems are under transformation for example by the effect of climate change. Lack of the adaptation capacity can lead to the mortality of these trees. In our study we try to determine the causes of the forest die-off in a primary Pinus forest in Fenyőfő. The aim of the research is to find the reason of the decay of this old-growth forest– which is growing on protected area – whether it is caused by the soil properties and other abiotic variables or it is the result of the drying climate. On the investigated area there were high human activities (e.g. agriculture, grazing – see below in *table 1*), which may have an effect on the mortality of the forest (*picture 1*).

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Picture 1. Scots pine (Pinus sylvestris) with strong symptoms of health declinde in the Fenyőfő research site

STUDY AREA

The research site belongs to the Trans-Danubian region, and the investigated old Pinus forest is part of the Pápai-Bakonyalja mountains. The average altitude of Fenyőfő 250-300 m. The location of the area is shown in *figure 1* and *picture 2*.

Figure 1. The location of the research site


Picture 2. Investigated forest stand

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On the area of Fenyőfő and its surrounding the typical land use types are forests (47.2%) and agricultural lands (39.4%). Grazing (8.5%) is also characteristic and the territory of settlement takes 863 hectars.

Table 1. Land use types in Fenyőfő

Land use type	ractional coverage (%)	Area (ha)
Residental area	3.5	863.0
Agricultural area	39.4	9621.3
Garden area	0.7	172.0
Viticulture area	0.3	61.5
Grassland	8.5	2087.4
Forested area	47.2	11525.7
Creek and lake areas	0.4	87.8

Soil properties

According to the texture 56 % of soils are sand and 42 % is loam by the physical assessment, therefore soil texture and hidrological factors could be made versatible soil types on the area. Thus we could find rusty brown forest soil (*picture 3*) and brown soil mostly under the subsurface of forests (MAJER 1988). Skeletal soil, quicksand and slithly humic sand soils (*picture 3*) have been created by anthropogenic effects. Rarely we could detect perigon sand because of deposition, next to creeks we could find meadow soil (BABOS 1966). Because of the climate and the forest vegetation the carbonated quicksand were leach out, therefore humic sands, slightly acidic rusty brown and lessivated brown forest soils have been rised. The groundwater level is between 4-6 meters, so for vegetation it is not avaible.

Picture 3. Rusty brown forest soil (left) and humic sand soil (right)

Climate conditions

The climate conditions of the research site are medium wet and medium warm. The average annual temperature is 10.0 °C and the annual precipitation sum is 600-650 mm (HALÁSZ 2006). In the warmest month of the year the average temperature is 19.7 °C and in the coldest month of the year -2.1°C (MAJER 1988). The sunshine duration is above 1980 hours (DÖVÉNYI 2010), so the vegetation is mostly Pinus on sandy soil (*Festuco vaginatae-Pinetum sylvestris*), other types Pinus (*Festuco rupicolae – Pinetum sylvestris*) and mixed sessile oak (*Quercetum petraeae - cerris pannonicum*) (DÖVÉNYI 2010).

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MATERIALS AND METHOD

Soil analysis

Altogether 119 samples from 20 soil profiles have been collected which proved to be substantial for the proper characterization of the territory. After a ground reconnaissance we have been focused on the following properties in the lab: soil pH (potentiometrically in water and KCl), the texture of soils was determined by particle size distribution (MSZ-08-0205-1978). In addition we determined calcium carbonate content (Scheibler calcimeter) and soil organic matter content (FAO 1990). Furthermore the y1 and y2, ammonium lactate/acetic acid extractable (AL) potassium and phosphorus content were measured (BELLÉR 1997). The categorization of the soil samples was carried out as reviewed by BELLÉR (1997) and STEFANOVITS et al. (1999).

Climate dataset

For the time period 1961-2013 we used gridded station data from Hungarian Meteorological Service (www.carpatclim.eu.org). The spatial resolution of the database is 0.1° × 0.1° (~ 10 × 10 km grid). It contains daily, monthly, yearly datasets for temperature and precipitation means and extremes, wind and moisture conditions and drought indices. The selected climate parameters were the monthly and yearly mean temperature, the precipitation sum and the drought indices.

RESULTS AND DISCUSSION

Climate change

In the reference period (1971-2010) the average annual temperature was 10.4 °C and the annual precipitation sum was 667.5 mm in Fenyőfő. *Figure 2* shows clearly the increase of temperature means and the extremes of the precipitation sum.

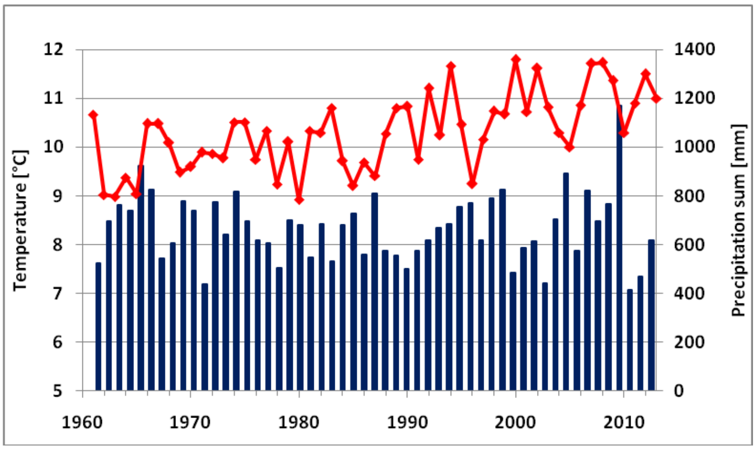

Figure 2. The annual tempreature means and precipitation sums in Fenyőfő (1961-2013)

Analyzing the temperature and precipitation differences of the vegetation period compared to 1971-2010, the data show that the temperature differences increase drasticaly at the last few decades (*figure 3*). The precipitation of the vegetation period had a large influence on Pinus forest, therefore the precipitation differences were essential to find the causes of the tree die-off. Statistically every third-fourth drought event (when the precipitation sum is lower than the average) is followed by a year with extremly high precipitation sum (*figure 3*). Between

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2000-2005 there were several dry periods with high temperature and low precipitation sum. This variablity can cause the drying of the Pinus trees.

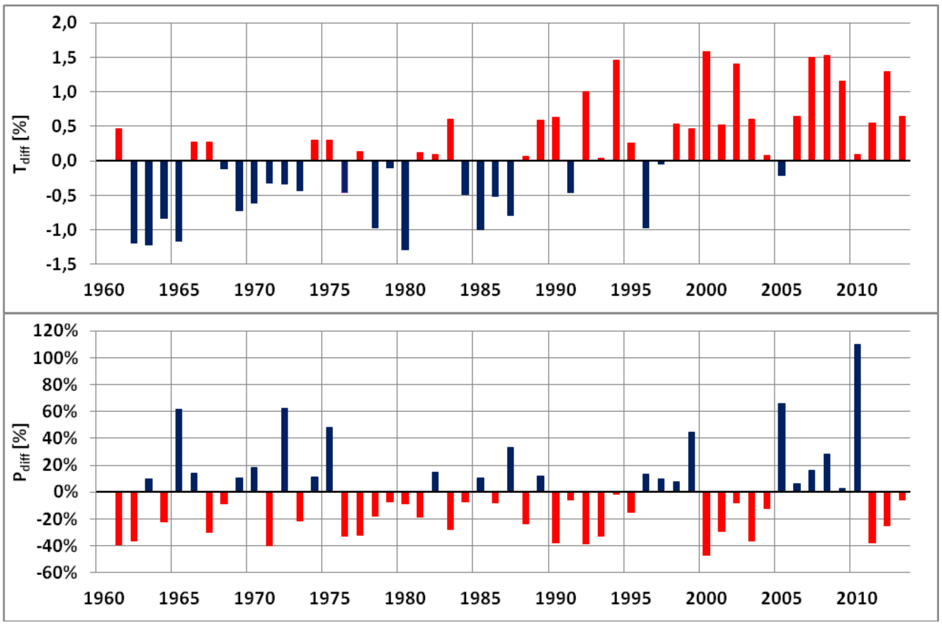

Figure 3. The temperature differences (on top) and the precipitation sum of the vegetation period (below) compare to 1971-2010 in Fenyőfő

The climate database contains also information on extreme temperature indices. For our investigaton we used the maximum temperature (T_{max}) indexes such as the total number of summer days (where T_{max}> 25°C), hot days (where T_{max}> 30°C) and dry days (where T_{max}> 35°C). The average of the number of dry days was 11 days in 1961-1990, and between 1971-2010 it was 17 days, so the frequency of extremly high temperatures increased. The tendency of the number of dry days, hot days and summer days is shown in *figure 4*.

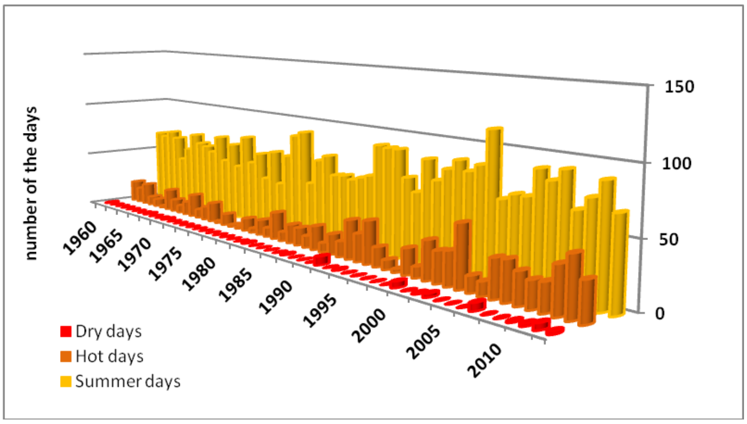

Figure 4. The number of the extrem temperature indicates changes (1961-2013)

The consequens of the increasing mean and extreme temperature and the variability of precipitation could lead to the forest die-off in Fenyőfő, but definitaly these parameters were not the only causes.

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Soil conditions

Soil pH (pH$_{H_2O}$) was between 4.2 and 8.5. The soil pH of upper layers were detected between the mostly acidic and the weakly alkaline category (*figure 5*), but the most of the soil samples were acidic. The soil pH of lower layers were dominantly alkaline. In the soil profiles the leaching was characteristic, therefore we could measure the acidic values in upper layers. The results of pH$_{KCl}$ were followed the values of pH$_{H_2O}$. Soil pH (pH$_{KCl}$) was between 3.5 and 8.3.

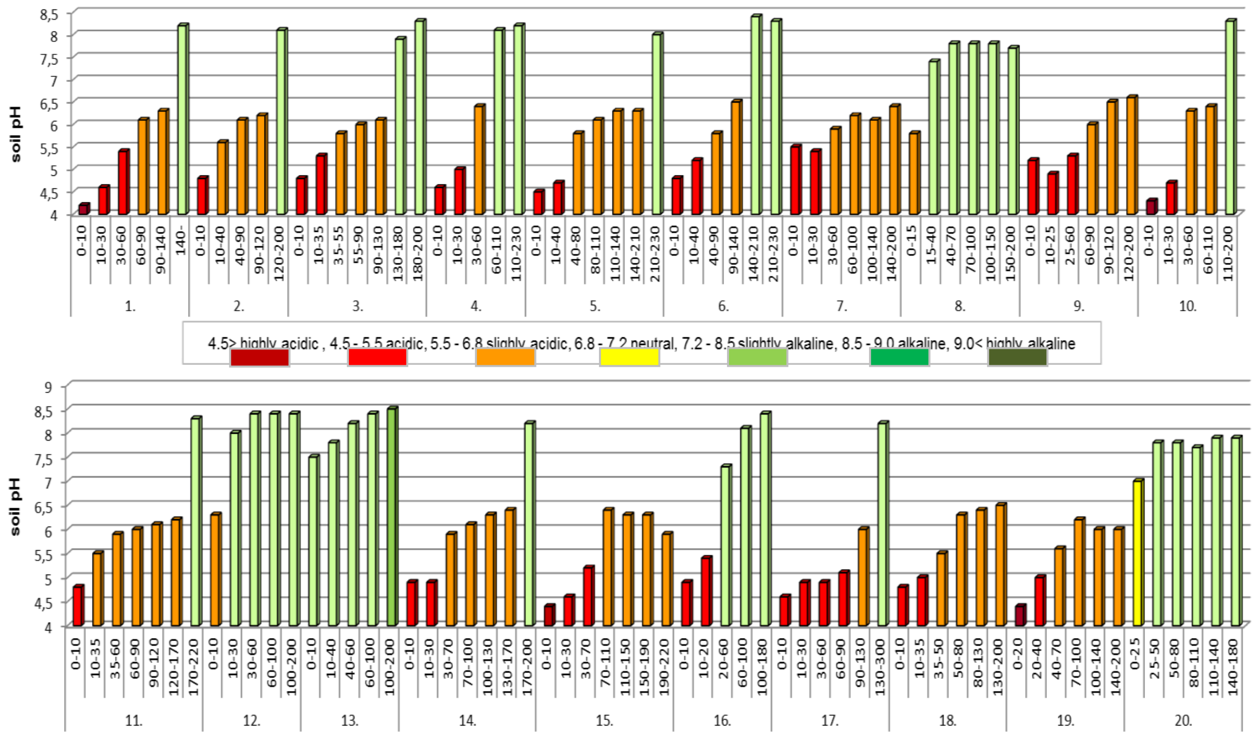

Figure 5. Distribution of soil pH (pH$_{H_2O}$) in all soil profile

The acidic pH of topsoil (0-20 cm depths) is favourable for the most of tree species, altrought the appear of calcium carbonate content in alkaline lower layers are unfavourable for the vegetation. The reason for it is that the calcium carbonate have an influence on drying, which hinders the water uptake of the vegetation.

The $CaCO_3$ content of the soils was between 2% and 19% in below of 20 cm depths layers, which is not favorable to each species. We found a few saline soil in lower layers.

The conclusion is that the chemical properties of soils are suitable to the vegetation, beside of the higher $CaCO_3$ content and salinity of soils decreased the productivity of these soils.

The texture of soils was determined by particle size distribution (MSZ-08-0205-1978). The ratio of clay% and silt% was between 3% and 11% in the samples, thus based on these values the physical assessment was coarse sand. These types of soils can be characterized with unfavourable absorbing capacity; although they can not store water quite well and the water escapes from the upper layers very fast. So this water is hardly available for the vegetation (Stefanovits 1992), because the available waterstock is exhausted easily during a longer dry period.

The humus content of the soil was between 0.01% and 8.8%. High values were detected close to the surface, but figure *figure 6* shows, that the highest values were mostly in the lower layers. We found buried humus layer in a few cases (*picture 4*), which improve the water and nutrient supply of soils.

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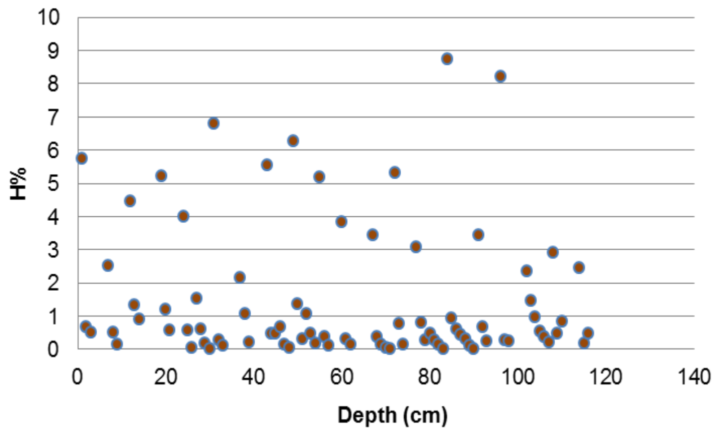

Figure 6. Distribution of humus content in all soil profile

The total nitrogen supply was medium (0.01 – 0.25 N%). AL-extractable phosphorus content of soils was few (3.4 – 15.9 P_2O_5 mg/100g soil) and AL-extractable potassium content showed the same amount (1.5 – 9.1 K_2O mg/100g soil). The low amount of these nutrients mean that there is no part of this soil, which can store the colloids.

Picture 4. Rusty brown forest soil with buried humus layer

CONCLUSIONS

The aim of this study was to find the reasons of an old Pinus forest die-off in Fenyőfő. On the investigated area we analyzed the climate conditions and studied 20 soil sites.

The meteorological data clearly show, that the mean annual temperature of the research plot increased drastically (~1°C). The annual precipitation sum decreased in the last few decades, but its not significant, because the precipitation in the vegetation period shows high variability. We analytzed also the frequency of extreme high temperatures. The number of summer days (when the maximum temperature T_{max}>25°C), hot days (T_{max}>30°C) and dry days (T_{max}>30°C) increased in Fenyőfő, which caused higher water utilization and water deficiency. The main conclusion is, that the higher temperature and the variability of the precipitation sum caused the forest decay.

Firsly, the area seems to be homogenic, but based on our research, we found a lot of diffencies (e.g. genetic soil type, tilth or humic layer) on several plots of the investigated area.

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On most of the area the caracteristic soil type is the rusty brown forest soil, but humic sand soils have been also found. In several cases buried humus layer has been detected, which improve the water and nutrient supply of soils. Due these favorable properties the calcium carbonate content appeared near to the surface, which hinder the vegetation in water utilization or water uptake. Coarse sand is the typical physhical assessment, which has unfavourable absorbing capacity; they can not store water, thus it leach trought of soil profile. Where $CaCO_3$ content is still in soil and there is a thin humus layer above the coarse sand, the soils properties are mostly favourable. The water is hardly available for the tree species, water storage is impossible in sand soil.

Summarized, the previously unfavourable conditions of soil (low watercapacity, sandy soils with calcium carbonate content in the topsoil) occurred together with high temperature values in the last years. It causes continuously water utilization. Both climate extrems of the summer period and the unfavourable soil properties have an effect on the stands. The forest stand have no avaible water, that can protect it from extreme warm conditions.

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Local and Regional Challenges of Climate Change Adaptation and Green Technologies, H-Sopron, 2014
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How is Water Balance Affected by Climate Change? An Example Based on Spatial Data of Zala County

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Abstract

In Hungary about 90% of the precipitation evaporates and only 10% runs off (goes to streams, soil and groundwater storage). It is essential to determine more accurate the amount of evapotranspiration for better knowledge of hydrological cycle. Water balance of Zala county (west-southwest Hungary) was analysed using remote-sensing based actual evapotranspiration (Szilágyi & Kovács, 2011) and runoff spatially distributed maps (1 km^2) over the 1999-2008 period. For evaluating the effects of climate change on water balance we used the Budyko-type model (α-parameter), moreover a linear model with β-parameter was introduced for the extra-water affected pixels. By using the two parameter maps and future data of climate models (mean annual temperature and precipitation) evapotranspiration and runoff predictions have been done by the end of the 21st century, in spatially distributed mode.

Keywords: evapotranspiration / runoff / climate change

INTRODUCTION

Generally, on the land surface more precipitation evaporates than runs off (goes to streams, soil and groundwater storage). In Hungary about 90% of the precipitation evaporates and only 10% runs off. Evapotranspiration (ET) is a very effective vehicle for mass and energy (due to the high latent heat of vaporization value of water) transfer between the land- or vegetation surface and the ambient atmosphere (Szilágyi & Józsa, 2009). Therefore, it is essential to determine more accurate the amount of ET for better knowledge of energy balance and hydrological cycle.

Obtaining spatially distributed ET estimates is crucial in most water balance calculations for identifying mass and energy fluxes across the area of interest (Szilágyi & Kovács, 2011). Monthly actual evapotranspiration (ET_A) has been mapped for Hungary by Kovács (2011) over the 2000-2008 period.

MATERIAL AND METHODS

Description of the ET_A and runoff mapping technique

Spatially distributed (1 km^2) monthly actual evapotranspiration (ET_A) rates over Hungary for 2000–2008 are mapped by Kovács (2011), with the help of MODIS daytime land surface temperature as well as sunshine duration, air temperature and humidity data Mapping by the

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CREMAP-model (Szilágyi & Kovács, 2011) is achieved by a linear transformation of MODIS daytime land surface temperature values employing the complementary relationship (Bouchet, 1963) of evaporation.
The monthly ET_A maps have been prepared from March till November each year, because in the winter-time with possible patchy snow cover on the ground the quasi-constant surface net energy assumption of the surface temperature versus ET_A transformations break down (due to the snow cover's vastly different albedo from that of the land) (Szilágyi & Józsa, 2009). ET_A in Hungary is small from December through February, the sum total is about 20 mm (Kovács, 2011). We made calculations for total water years (from November 1. to October 31.), so 20 mm correction was added for all pixels of each mean annual ET_A maps (1999 November was prepared as the average of the other Novembers). The mean annual ET_A maps were averaged for the examined period (1999-2008).
On annual scale - using ET_A and precipitation data - the spatially distributed runoff can be calculated using long-term water-balance equation:

$$R = P - ET_A \tag{1}$$

where P is the precipitation, ET_A is the evapotranspiration and R is the runoff (each members in mm/period).

The Budyko-Type Model

The Budyko-model (Budyko, 1974) is often used to estimate the actual evaporation as a function of the aridity index. According to Nováky (1985, 2002) the spatially distributed version of Budyko-model is applicable to analyze the climatic impacts. For evaluating the effects of climate change on evapotranspiration we used a Budyko-type parameter (α), furthermore a linear model with β-parameter was introduced.
The Budyko-type α was calculated to each pixels (1 km^2) according to the next equation (Csáki et al., 2013):

$$\alpha = -\frac{ET_0}{ET_{pan}} = -\frac{P\left(\ln\left(\frac{R}{P}\right)\right)}{\left(36400\frac{T}{P}+104\right)} = -\frac{P\left(\ln\left(\frac{P-ET_A}{P}\right)\right)}{\left(36400\frac{T}{P}+104\right)} \tag{2}$$

where α is a calibration parameter, which aggregates all of the factors affecting the evapotranspiration (dominantly the surface cover) (Keve & Nováky, 2010), ET_0 the potential evapotranspiration (mm/year), ET_{pan} the pan-evaporation (mm/year), ET_A the actual evapotranspiration (mm/year), R the runoff (mm/year), T the mean annual temperature (℃), and P is the precipitation (mm/year).
In that case if ET_A value was higher than P value of the pixel, so R becomes negative, the α parameter could not be determined, because the natural logarithm of a negative number is undefined (*Eq. (2)*). For these pixels another calibration parameter (β) was calculated, which gives the relationship between ET_{pan} and ET_A (Csáki et al., 2013):

$$\beta = \frac{ET_A}{ET_{pan}} = \frac{ET_A}{\left(36400\frac{T}{P}+104\right)} \tag{3}$$

The spatially distributed parameter maps (α and β) can be used for evaluating future ET_A and R in spatially-distributed mode, for that only temperature and precipitation predictions are required. The calculations were done with the help of DigiTerra Map software, the

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temperature and precipitation data were available in the TÁMOP-4.2.2.A-11/1/ KONV-2012-0013 project.

STUDY-SITE DESCRIPTION

Zala county is situated in the south-western part of Hungary (*Figure 1.*). It is bordered by the Vas county from the north, by the Veszprém county from the east, by the Somogy county from the south, and by the state border in the west. It is one of the smallest counties of Hungary, it has an extent of 3784 km^2.

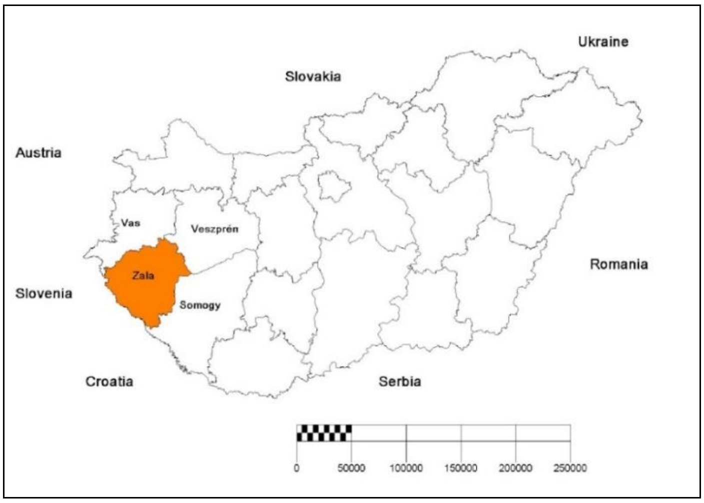

Figure 1. Location of Zala county within Hungary

The climate is moderated by atlantic effects, so the mean annual temperature was about 11.6 °C between 1999 and 2008. Winters are relatively mild and summers tend to be cooler than the norm for the Carpathian Basin. It is one of the wettest part of the country, the average annual rainfall in the examined period was about 700 mm in the west, and 600 mm in the east.

Dominant land use in the county is agricultural (54%), with a significant presence of forests and semi natural areas, which cover more than 37% of the total area (*Figure 2.*).

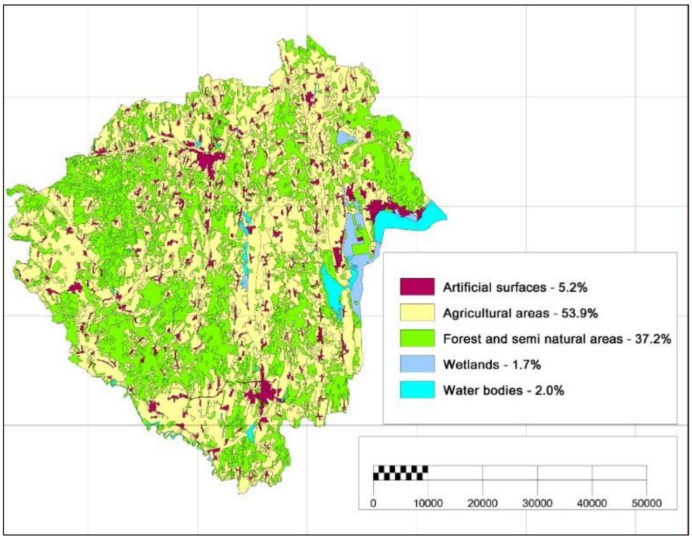

Figure 2. Land cover of Zala county (CLC, 2006)

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RESULTS

Evaluation of evapotranspiration and runoff

The mean annual actual evapotranspiration over Zala county (1999-2008) is displayed in *Figure 3*. The average ET_A of Zala county was 577 mm/year, the 88% of the mean annual precipitation (655.7 mm/year). The blue pixels show lower rates on the map, the bigger cities are distinctly visible (blue patches: Zalaegerszeg in the North, Nagykanizsa in the South, Keszthely in the East). Higher ET_A values (red and orange pixels) belong to water bodies and wetlands, as well as in the southwestern part of the county.

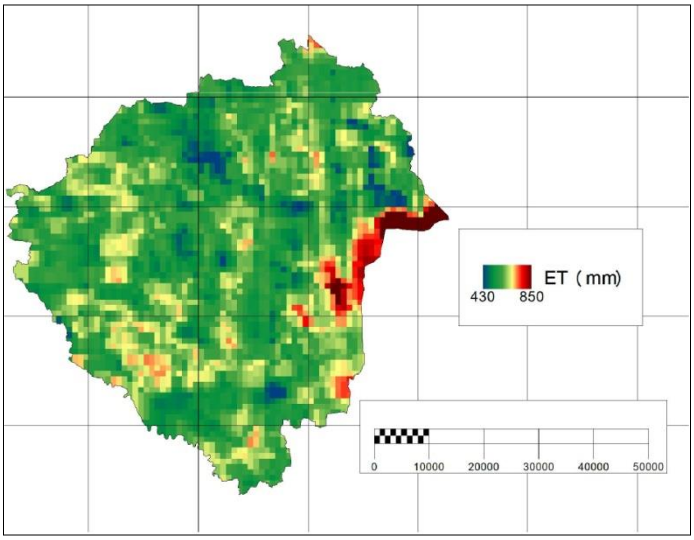

Figure 3. Mean annual ET_A rates over Zala county (1999-2008)

Mean annual runoff (R, 1999-2008) was calculated from the water-balance equation, as the difference of annual precipitation and mean annual actual evapotranspiration ($R = P - ET_A$). The average runoff was 78 mm/year (the 12% of the mean annual precipitation). In the northeastern part of the county, water bodies and wetlands have the lower runoff rates (blue pixels, *Figure 4.*). Higher values (red and orange pixels) belong to the cities, moreover to the middle, the south and to the southwestern part of the county.

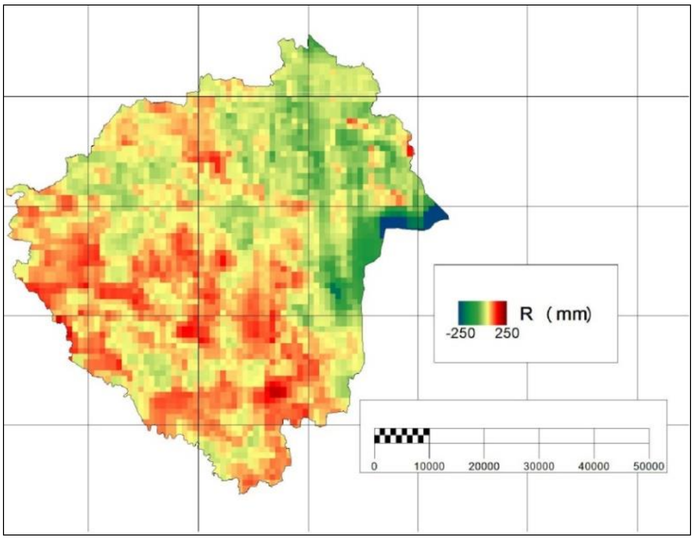

Figure 4. Mean annual R rates over Zala county (1999-2008)

Evaluation of α and β parameters

The Budyko-type α parameter was calculated, according to the *Eq. (2)*. The spatially distributed map of the parameter can be seen in *Figure 5*.

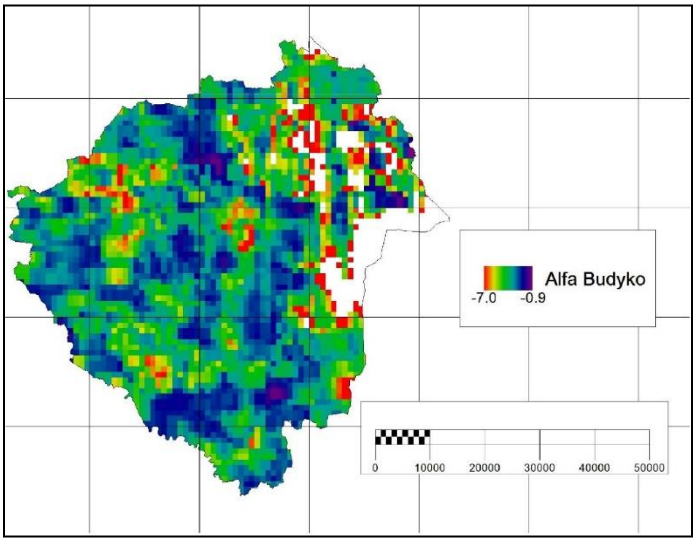

Figure 5. The calculated Budyko-type α parameter rates in Zala county

β parameter was calculated (with the help of *Eq. (3)*) for that pixels, where the ET_A value was higher than the P value (the Budyko-type model for such type of pixels is not valid). Typically this is the case for wetlands and water bodies. The β parameter map is displayed in *Figure 6*.

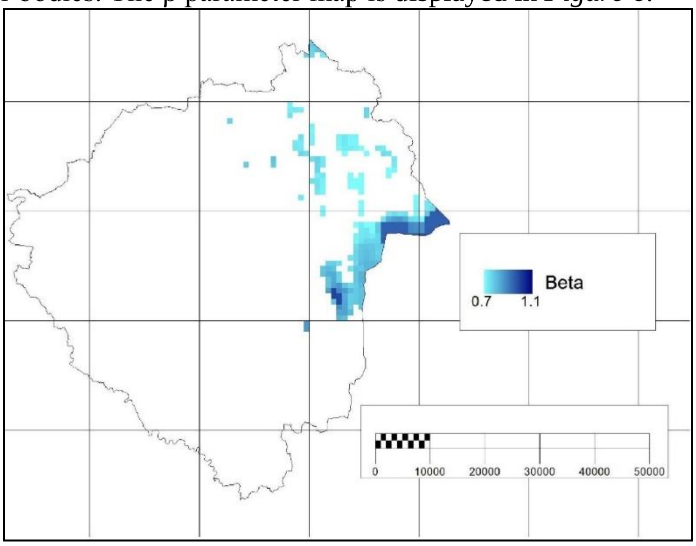

Figure 6. β parameter pixels and rates in Zala county

EVAPOTRANSPIRATION AND RUNOFF PREDICTIONS

For estimating future ET_A and runoff of Zala county, besides the prepared Budyko-α and β parameter maps, temperature and precipitation data were required. They were obtained for three periods (2011-2040, 2041-2070, 2071-2100) by averaging of 12 Regional Climate Models data (Csóka, 2013). The *Eq. (2)* and *(3)* were applied for calculating spatially distributed future ET_A. The runoff data were counted as the difference of precipitation and ET_A.

The estimated mean annual ET_A values belong to the examined (1999-2008) and the predicted three periods (2011-2040, 2041-2070, 2071-2100) in the context of climatic index (100·T/P, Nováky, 1985) can be seen in *Figure 7*. According to the predictions about 3 Celsius mean annual temperature

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increase (from 11.6 °C to 14.6 °C) and 25 mm precipitation decrease can be expected to the end of the century. The mean annual evapotranspiration may increase about 27 mm, from 577 mm to 604 mm (from 88 to 96 percent of the precipitation).

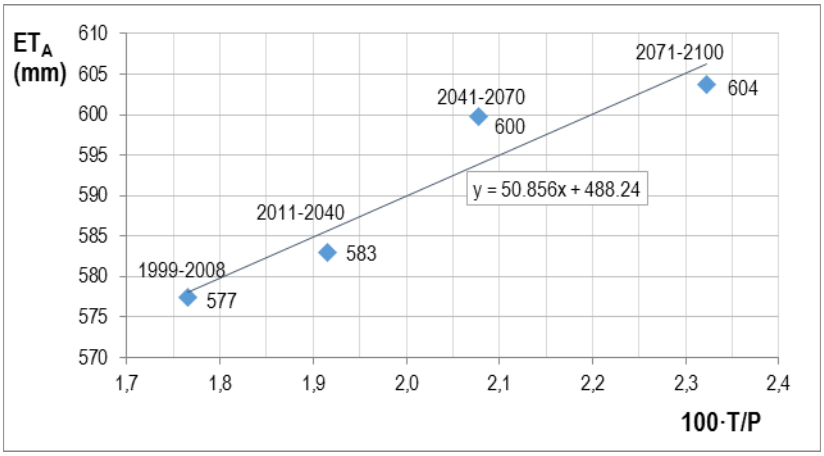

Figure 7. The trend of mean annual evapotranspiration in the context of climatic index

Figure 8. shows the mean annual runoff values belong to the examined (1999-2008) and the predicted three periods in the context of climatic index. The mean annual runoff may significantly decrease (from 78 mm/year to 27 mm/year, from 12 to 4 percent of the precipitation) to the end of the 21st century.

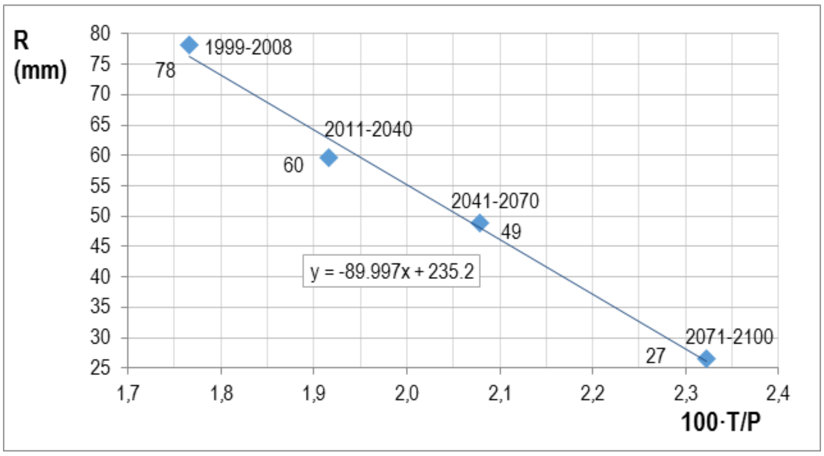

Figure 8. The trend of mean annual runoff in the context of climatic index

CONCLUSIONS

Water balance of Zala county was analysed using spatially distributed actual evapotranspiration (Szilágyi & Kovács, 2011) and runoff maps (1 km^2) over the 1999-2008 period. The average ET_A of the county (1999-2008) was 577 mm/year, the 88%, while the runoff was 12% of the mean annual precipitation.

For evaluating the effects of climate change on evapotranspiration we used the Budyko-type model (α-parameter), moreover a linear model with β-parameter was introduced for the extra-water affected pixels. By using the two parameter maps and future data of climate models (mean annual temperature and precipitation) evapotranspiration and runoff predictions have been done by the end of the 21st century. According to the predictions, the mean annual evapotranspiration may increase about 27 mm while the runoff may decrease to the one third to the end of the century.

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Surface Hydrology and Soil Conservation in Volcanic Islands; Strategies Against Climate Change

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Abstract

The present study describes the hydrologic characteristics of volcanic islands erosion and identifies problems that occur in them. In order to manage and mitigate climate change is necessary watershed management of the islands, including the management of natural hazards through its analysis, flood estimation and stability of slopes and embankments because the torrential rain regime, and finally erosion control and soil conservation, one of the main problems of oceanic islands that directly and indirectly affect its hydrological cycle.

Keywords: hydrology / oceanic islands / climate change / water erosion

INTRODUCTION

The islands are isolated systems, this has meant to evolve as different environmental units with respect to the continental land in several aspects (Santamarta, 2013); on one hand plant diversity -including endemism- that in most of the islands is present, this effect is greater the more distant to continent, all resulting from a combination of evolution and geographical isolation. The other aspect to consider is the origin of volcanic islands, produced by a volcanic eruption located on the seabed. The islands have a short life cycle compared with the continental land and from the beginning, go through the following stages: (i) seamount formation, (ii) growth, (iii) collapse building due to large gravitational landslides and erosion processes, and finally (iv) sinking under the sea.

They also share common environmental, economic and social characteristics such as: (i) unique forest ecosystems and highly sensitive species to small perturbations in habitats, (ii) botanical singularity, (iii) high presence of the primary sector, (iv) dependence on tourism as an industry, (v) high energy dependence but can integrate renewable energies, (vi) high population density -an illustrative example is Hawaii that has the highest population density in the United States. Even edafologic levels between the volcanic soils in the islands are more similarities than differences.

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HYDROLOGY OF VOLCANIC ISLANDS

Watersheds in the islands show a morphology bounded by ravines, when there have been conditions of precipitation and significant erosion over time (Fig. 2), these are very pronounced in the highlands of the islands -greater concentration of precipitation in the rift zone-, also they are smaller than in continental areas, the terrain is steeper, especially in young islands, when the ravines are close to the coast lines and become more stretched and widths. It is necessary to take certain precautions while technical projects are drafted, specially related to the estimation of surface runoff, because the formulas used to continental terrains tend to overestimate the runoff amount, according to some studies carried out (Santamarta, 2013).

Except very specific archipelagos, such as Hawaii, volcanic islands tend to not have continuous rivers, but small streams especially after heavy rainfall episodes can occur. This means that only a small percentage of the surface water resources are used (mainly in agriculture). In some cases, these waters are mixed with groundwater of lower quality -with high content Sales- to improve the final characteristics of the waters. It may seem that the volcanic islands with heavy precipitation rates such as the island of Terceira in the Azores with 1,300 mm on average per year or Jeju Island in South Korea with a rainfall of 1,975 mm per year may have rivers throughout the year, which does not occur due to the permeability of the volcanic terrains in the islands (Jong-Ho et al., 2005).

The surface exploitation is based on use of water that flows through the ravines when they are perennial -occasionally-, or temporary when there is significant rain amount. Conventional water dams are used to collect the water in the ravine itself if geological conditions are possible; in other cases, indirect methods as channels in ravine (known as "tomaderos" in local terminology) are used. After that, surface water is led to other dams or water basins waterproofed artificially. It is desirable that the water collected come with fewer sediments in order to not decrease the ability of storage both dams and basins.

Numerous water harvesting systems are described in which forestry engineering, historical tradition and specific strategies in semiarid land are combined, often of Arab origin, in order to increase the availability of water resources in crops.

STRATEGIES FOR SOIL CONSERVATION AND WATER HARVESTING

Erosion occurs when conditions are favorable for detachment and transport of soil particles. Both sheet erosion and rill erosion are caused by the impact of falling raindrops, the shear surface runoff and concentrated flow channels, and the combination of both processes. Factors such as climate, soil erodibility, tilt and length slope and vegetation cover conditions determine the magnitude of the erosion rate.

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Figure 1. Rill erosion on the island of La Gomera

To reduce erosion many practices have developed, not all of them universally applicable; however, wherever the erosion phenomenon occurs, there are three basic principles for effective control, not only of water erosion, but also wind erosion:

- Increase the resistance of the soil to erosive forces
- Reduce the erosive force of flow
- Reduce the impact of falling raindrops on the ground

Soil resistance to erosive forces is increased by improving the structure and stability of the soil, through measures such as addition of organic matter or other chemicals (lime, gypsum or fertilizer), and certain farming (topographic contours, terraces).Maintaining a permanent cover to protect the soil surface mainly reduces the impact of falling raindrops on the soil. The reduction of the erosive force of the flow is achieved by reducing the runoff amount and flow rate. The resistance to flow velocity can be increased by several practical applications, such as building of barriers or terraces. It is also possible to use hydraulic retention structures, piping and control of water and storage (Santamarta, 2011):

Figure 2. Construction of a sediment retention dam

One of the biggest problems facing soils in the volcanic islands are forest fires. The effect of fire alters the physical and hydrological properties.

DISCUSSION AND CONCLUSIONS

The origin, geology and the formation of volcanic islands significantly determine the development, use and both positive and negative effects of water resources in the island environment.

Water and natural resources must be managed in a special way and jointly, taking into account the peculiarities of the volcanic island systems and its water resources; this means that sometimes the strategies and methodologies used in continental land need not be valid for limited and heterogeneous spaces as the islands.

Part of the solution to the shortage of water resources and erosion control is in sustainable forestry in addition to the construction and maintenance of aquifer protection areas corresponding to natural spaces.

Finally the following actions are necessary: i) surface water sources uses and control of associated natural hazards, (ii) reduction of surface runoff are necessary and therefore erosion rates, (iii) planning and management of natural areas for mitigating the effects of torrential rains, (iv) improving the processes of infiltration and groundwater recharge by increasing and

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treatments of the vegetation cover, and (v) soil conservation by water infrastructure and mitigating of its effects by immediate post fire hydraulic performances (Santamarta, 2013b).

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The Impact of Land Use Types on Urban Soils

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Abstract

In order to investigate the land use types of the soils we have collected samples from the topsoil of sampling sites in the following Hungarian towns: Sopron, Szombathely. In these towns there are significant differences in land use: as besides the old downtown there are also younger suburbs and suburban forests, vineyards, pastures, gardens and agricultural areas. Samples were collected from soil spots from 0-10 and 10-20 cm depth as well as from soil profiles, where samples were taken from each of the profile layers. Differences between the previously results can be explained by the effects of the vegetation and land use. Land use is also significantly determined by ecological conditions and now the whole ecological system depends on effect of climate change. The location of towns is another determining factor in this case. Based on our experiments the unique character of the cities are fading away, the qualification of the peripheral areas are changing, the usage of the land is condensing, which lead to a declining quality of urban soil.

Keywords: land use change / Sopron / Szombathely / urban soil investigation

INTRODUCTION

Land use change has a very significant role in nowadays. During our investigation we tried to determine the condition of urban soils, which based on the different land use types in Sopron and on area of Szombathely town (HORVÁTH et al. 2013). After the previously research it has a point, that there is a strong connection between the contamination of technosols and land use types.But how to detect this connection in case of towns, which are derived from different geologic circumstances and from different developments? What kind of impact has the local environmental factors, when the anthropogenic loadings are mostly the same? Our aim was to identify the main feedback effects between the town and its environment.

ABOUT STUDIED AREAS

The studied area was the township of Sopron and of Szombathely. These cities are located in the north-western part of Hungary at the western border of the country.
SOPRON **-** The area of the city has been inhabited since the prehistoric age. In 1676 a conflagration destroyed most of the city and during World War II it survived many air raids (TÓTH 2011). Most of the city is located in the Sopron-Basin, which is situated between the Fertőside Hills and the Sopron Hills. The city is covered by Neogene deposits (DÖVÉNYI ed. 2010). The Sopron Hills were formed 580-520 million years ago during the Cambrian period and probably consist of the oldest rocks in Hungary (gneiss and mica-schist). Luvisols

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typically evolved in the Sopron Hills and in the suburb. In the Sopron Basin, where most of the city is located, the characteristic types of soil are Fluvisols, but in the downtown they turn to Technosols (calcic) (IUSS Working Group WRB 2007). The climate of the city is temperate cold with an annual precipitation of 500-600 millimetres. In the Sopron Hills the amount of annual precipitation exceeds 750 millimetres (DÖVÉNYI ed. 2010). Nowadays the largest anthropogenic effects appear in the areas of city construction and in the soils of the city centre.

SZOMBATHELY - The investigated area was the township of Szombathely, which has got nearly 85.000 inhabitants. It is the oldest founded town in Hungary that was destroyed already by an earthquake in 456. The most important water courses of Szombathely are the Gyöngyös and the Perint, which are running through the area. The characteristic type of soil is Fluvisols in the low carbonaceous and non-calcareous valleys of the Gyöngyös and Perint creeks. There are Umbrisols on the suburb, but in the downtown they turn to Technosols (calcic) (NOVÁK 2013). The climate is temperate cold and dry. The average annual temperature is 9.0–9.5°C. The average amount of the annual precipitation is 630-650 mm. The locations of cities are shown by Figure 1.

Figure 1. The location of cities in Hungary

METHODS AND MATERIALS

Sample collection was carried out during the spring of 2011, after the period of ground frosts at the beginning of sprouting when intense agricultural work had already commenced. We collect soil samples on the studied areas (Sopron - 104 sampling point - *(Figure 2)*, Szombathely - 88 plots - *(Figure 3)*). The sampling was applied on a random roaming method to focusing all at the problematic places in towns.The studied areas have been characterized by land use types, therefore the number of samples were quite different in each category. It was typical both of the cities, that the areas occurred mosaic, so the contamination of these land use categories are dissimilar.

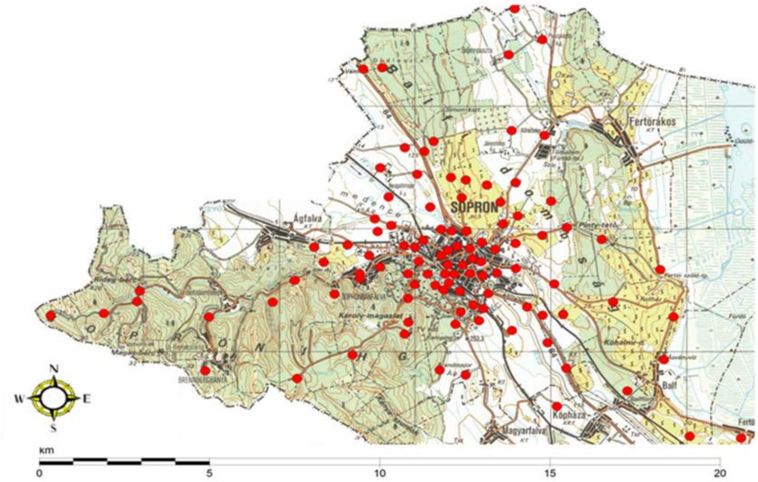

Figure 2. Sampling points on studied area of Sopron

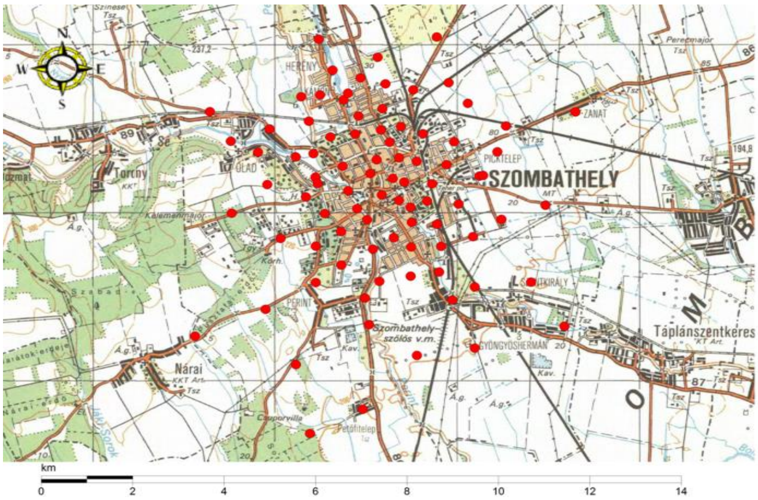

Figure 3. Sampling points on studied area of Szombathely

The samples of Sopron belong dominantly to forestlandcategory*(Figure 4)* and soil samples of Szombathelyare originated from creek and lake banks *(Figure 5)*.

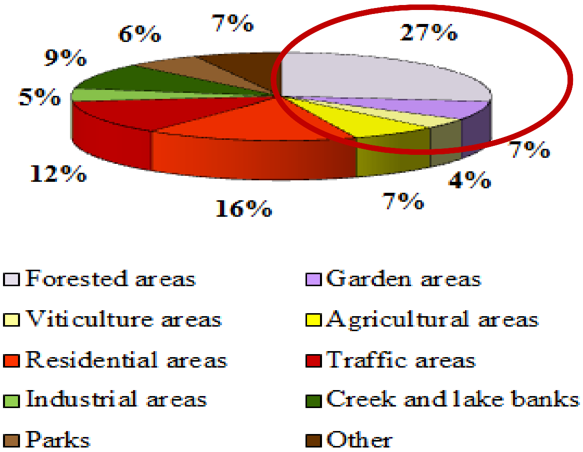

Figure 4. Distribution of land use types on studied area of Sopron

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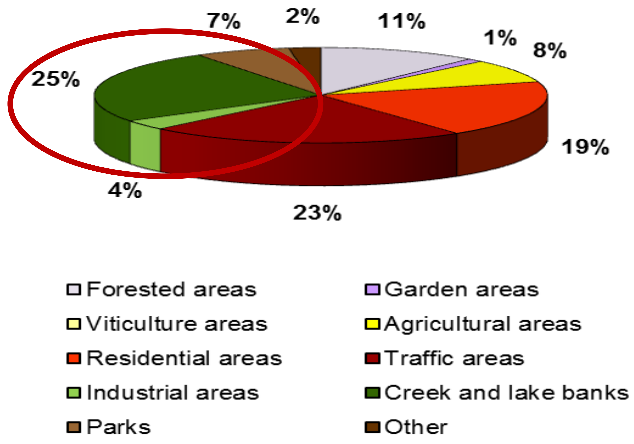

Figure 5. Distribution of land use types on studied area of Szombathely

PREVIOUSLY RESULTS

While increasing of area of Sopron the forest of surroundings became to part of the city. That is why the “Lőverek” – it is the traditional name of forest gardens in Sopron – will disappear in the future. The soils of forest are acidic, so if there are anthropogenic effects, than the extractable toxic element will be available easily for vegetation. Gyöngyös and Perint creeks are acrossed Szombathely. Perint is the reservoir of the cleaned sewage. According to soil analysis soil pH was dominantly neutral, but it was acidic soil pH in several cases. On these plots the contaminations could be mobilized and they could leach in the groundwater. The cause of deficiency of water supply has been completed by the infiltrating waters.

Table 1. Distribution of average values of land use in Sopron

Sopron								
Land use types	**pH**		**$CaCO_3$**		**KA**		**H%**	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
Forested areas	5,5	5,3	7	6	55	46	8,08	4,63
Garden areas	7,5	7,6	13	12	47	43	4,77	3,43
Viticulture areas	7,5	7,0	11	10	53	53	6,46	4,90
Agricultural areas	7,3	7,5	8	7	52	47	5,74	4,39
Residential areas	7,6	7,8	13	13	49	44	5,72	3,8
Traffic areas	7,7	7,9	16	16	52	45	7,07	4,11
Industrial areas	7,8	8	19	18	46	43	5,55	3,85
Creek and lake banks	7,7	7,8	14	14	57	51	6,64	5,63
Parks	7,7	7,9	14	13	56	50	6,79	5,21
Other	7,5	7,7	20	20	55	50	4,19	4,23

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Table 2. Distribution of average values of land use in Szombathely

Szombathely								
Land use types	**pH**		**$CaCO_3$**		**KA**		**H%**	
	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm	0-10 cm	10-20 cm
Forested areas	5,5	5,4	0	0	46	38	4,94	2,67
Garden areas	7,7	7,7	10	6	53	43	5,85	3,07
Viticulture areas	-	-	-	-	-	-	-	-
Agricultural areas	6,7	6,8	4	3	44	44	3,76	2,97
Residential areas	6,9	7,1	4	5	51	43	5,78	3,51
Traffic areas	7,2	7,3	5	6	49	42	6,20	4,52
Industrial areas	7,9	7,9	6	8	49	54	3,92	4,29
Creek and lake banks	6,9	6,8	4	4	57	58	3,79	3,64
Parks	6,5	6,8	5	5	54	45	5,96	3,88
Other	7,0	7,3	3	5	54	49	6,64	5,73

The summary of the result are able to localize local pollution plots and to access problems for the further investigations. In all of the three towns there are significant differences in the land use, as besides the old downtown there are also younger suburbs and suburban forests, vineyards, pastures, gardens and agricultural areas. In our further research we would like to understand the functioning of the ecosystem and its elements on these areas in case of climate change or man-made effects.

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Role of Agroforestry in Climate Change Adaptation of Hungary

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Abstract

Agroforestry is a method of land use helping to mitigate climate change impacts and providing several ecological services. In the last century agroforestry was a widespread technology in Hungary. During the last decades it has regressed and disappeared from large areas of the Hungarian countryside. The paper introduces in short the role of agroforestry in the past and its potential role in cimate adaptation of the Hungarian countryside.

Keywords: climate change / agroforestry / rural development

AGROFORESTRY - PAST AND PRESENT

Hungary is an agricultural country, therefore the traditonal agroforestry technologies like windbreaks, shelter-belts, hedgerows, wooded pastures were applied in large scale in the past centuries. The conscious afforestation of pastures, croplands, and waysides started disparately on state or private lands in the 18th-19th centuries (Gál, 1961). This tendency continued in the cooperative large-scale monoculture farming systems during the 1950-60s, as a result of which the volume of wooded buffer strips increased significantly up to a total length of 2500 kms (Gál, 1961). Thanks to a large-scale state financed program on protective wood lands, the extension of the windbreak system significantly increased in the period of 60s'-70s'. The aims of the program were to increase the domestic agricultural productivity and wood production basis and decrease the national wood import dependency. The aims of the research were to identify the effects of wooded buffer strips on the production sites (soil, microflora, microfauna) and on the agricultural productivity, so as to justify their positive effects observed or measured only in fragments up to the sixties (Gál, 1961;1963). As a result of that multi-annual research and development activities the area of forest belts increased further until the 80's.

However, after a while, aerial pest management made it necessary to eliminate shelterbelts from the large-scale farms. As the outcome of the privatization, the landscape of the Great Plain had undergone a structural transformation, resulting in more diversified land use, a lot of small parcels together with new large estates. The significant decrease of forest belt territories was the outcome also of the widening of roads and the logging of shelter-belts or rarified snow protection forest belts. After harvesting, these protective woodlands have not been rehabilitated. In this way the positive trend of increasing area of protective forest belts first stopped, then reversed. As a result, the former area of forest belts (35 000 hectares) has decreased by 50% by the beginning of the 21st century (see Table 1.).

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Table 1. Forest belts of Hungary in terms of numbers and decades (Frank and Takács, 2012)

Date	Source	Volume	Location/ status	Note
1960	Gál (1961)	1500 km	Alföld	shelter-belts
		1000 km	Kisalföld	
1970	Danszky (1972)	34977 ha	nation-wide	protective forest strips
1975	Gál and Káldy (1977)	9891 ha	realized	shelter-belts
1976 -1990		4091 ha	planned	
1975		22600 ha	realized	sum of forest belts
1975	Keresztesi (1991)	8800 ha	realized	green belts
1975 -1990		20600 ha	planned	
1990		29400 ha	planned	
1990	Danzsky (1972)	33400 ha	planned	wooded buffer strips
2001	ÁESZ* (2001)	16417 ha	registered	shelter-belts

THE POTENTIAL ROLE OF AGROFORESTRY IN CLIMATE ADAPTATION

Nowadays the effects of climate change are already felt. It manifests in enduring hot spells along with long terms of droughts in summer mainly in the central, southern and eastern parts of the country. Floods and drainage waters are expected to occur more frequently. Maintainance of high level and good quality of agricultural productivity under these circumstances has become a great challenge for the present-day Hungarian agriculture.

In Hungary the total ratio of agricultiural territories - croplands, pastures, plantations, grasslands - is 60% of the territory. 85% of these are classified agro-environmentally sensitive areas. The high ratio of "risky" territories demonstrates the strong need for development in rural areas, among others the implementation of innovative agricultural technologies able to mitigate climate effects and increase social-economical sustainability. As a consequence rural development has become one of the hot issues in the last years in Hungary.

A research project supported by the Hungarian Academy of Sciences and Ministry of Environment called "VAHAVA" targeted at analysing the **effects of climate change**, identifing the best practices, and increasing the resilience of the Hungarian rural areas against the climate change effects. According to the VAHAVA report, the most endangered territory is the Great Plain, the main area of the Hungarian agriculture (Láng et al., 2007).

According to the Hungarian Rural Development Strategy (2012-2020), rural regions need to find new paths of development with the following basic features:

- preserving the integrity of the landscapes (landscape protection)
- high quality food production
- sustainable natural resource management
- protection of water, soil, and living resources.

* ÁESZ: State *Forestry* Service

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Agroforestry has been seen as an option to work at the interface of these challenges. International studies have shown that this land use system has the potential to maintain productivity and improve ecological functions in agricultural landscapes, while helping to mitigate climate change impacts.(Alam et al., 2014)

Hungary has a leading position in the implementation of the EU Measure 222 (First Establishment of Agroforestry on Agricultural Land) in Europe. (Agroforestry in the past CAP..) This measure was inteded to contribute to the objectives of sustainable and environmentally sound land management by establishing new land use systems combining extensive agricultural and forestry systems. In Hungary more than 900 ha of newly established agroforestry areas – wooded grasslands - have been resulted from the implementation of this measure.
There is also a growing interest of farmers and conservationists in the traditional silvopastoral systems. This highlights the importance of traditional ecological knowledge of the agroforestry systems.
Furthermore, by recognising the important role of protective forest belts/windbreaks and the potentials of alley-cropping systems new initiatives and research projects started in the last years.
The aim of these programs are:

- to develop a model for the designing and construction of forest belts by the combination of digital modelling and field sampling with analytical methods
- the examination and development of windbreaks and shelter belt system
- to study and develop agroforestry technologies under domestic circumstances in cooperation with local farmers. (This cooperation will also contribute to the „AGFORWARD" international research project on agroforestry.)

These initiatives are also supported by the fact that agroforestry is among the "determinative research and development subjects" of the Ministry of Rural Development. (Vityi et al., 2014)

CONCLUSION

The **use of modern agroforestry technologies and re-adaptation of traditional ones** could become a new path of the development of Hungarian rural lands, since it meets the objectives of the national rural strategy while facing the challenges of the agricultural sector.

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A klímaváltozás helyi és regionális kihívásai, zöld technológiák, H-Sopron, 2014
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Szántóföldi növénytermesztési technológiák vizsgálata életciklus szemléletben

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Kivonat

Munkánk során kifejlesztettük az előrevetített klímaváltozás okozta földhasználat-változások technológiai aspektusának környezetvédelmi elemzési modelljét. Kutatásunk során az agrár-földhasználatok művelési technológiáinak környezeti vonatkozásait vizsgáltuk. A jellemző mezőgazdasági/erdészeti technológiákról, azonos funkcionális egységre (referenciaegységre) vetítve, folyamat- és életciklus szemléletben létrehozott környezeti leltáradatbázisban öko-mérleget (input-output anyag- és energiamérleget) állítottunk fel. Az egyes technológiák mérleg eredményei - a környezeti problémakörökhöz kapcsolódó környezeti hatáskategóriák segítségével jellemezve - értékelhetővé és összehasonlíthatóvá válnak. A földhasználatokhoz kötődő művelési technológiák, klímaszcenáriók szerinti, környezeti hatásminősítése és környezeti kockázatossága megállapítható.

Kulcsszavak: földhasználati technológia / életciklus-elemzés / életciklus-hatásértékelés / szénlábnyom / életciklus szemlélet

BEVEZETÉS

Az időjárás átlagos állapotát, melyet az egyes meteorológiai paraméterek várható értékeivel jellemezhetünk, az adott terület és időszak klímájának nevezzük. A Földünk éghajlatában bekövetkező változás mára a kutatók számára vitathatatlan tény. A változás általános mikéntjének alapelveiről nagyjából megegyeznek az elképzelések, viszont a kisebb részletek már annyira hely-specifikusak, hogy újabb kutatásokat igényelnek (Ladányi 2006).
A környezeti elemek és rendszerek jellemzőiben az emberi tevékenység következtében bekövetkező változás a környezeti hatás (Pájer 1998). A környezeti hatás értékelése a változás jelentőségének kifejezését célozza, és ezzel egyúttal intézkedéseket, döntéseket készít elő. A környezeti hatások értékelése alapot adhat ahhoz is, hogy különböző tevékenységek környezeti szempontból összehasonlíthatók legyenek (Polgár 2012).
A komplex környezeti rendszer kölcsönös kapcsolataiból kifolyólag a klímaváltozással összefüggésbe hozható környezeti hatásokat is e rendszer szerves részeként kell vizsgálnunk.
Az agrár-földhasználatokból adódó erdő- és mezőgazdálkodási műveléssel a vegetáció alakulását, ezzel a felszínborítást befolyásoljuk.
Drüszler (2011) nyomán megállapíthatjuk, hogy a csapadékon, hőmérsékleten, fényen és széndioxidon keresztül elsősorban az éghajlat alakítja a vegetáció fejlődését (Budyko 1974; Prentice 2001; Nemani et al. 2003).
Újabb kutatások szerint azonban a vegetáció is visszahat az éghajlatra, méghozzá az albedón, a hő-, víz- és momentum forgalmon keresztül direkt módon az energia mérlegre, illetve indirekt módon a CO_2 koncentráció megváltoztatásán keresztül is (Pielke et al. 1998; Betts 2001; Bonan 2004; Matthews et al. 2004; Pitman et al. 2009; Pongratz et al. 2009).

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A Föld felszínének jelentős területét használjuk növénytermesztésre, s az emberiség direkt beavatkozása (erdőirtás, városodás, mezőgazdaság, túllegeltetés) bolygónk szárazföldi területeinek közel 50%-án változtatta meg a természetes növénytakarót (Crutzen 2002).
Az arid, szemi-arid területeken a mezőgazdasági területek terjedése, a túllegeltetés és a tüzelőfa kitermelés képes módosítani a felszín energia egyensúlyát, valamint a hidrológiai ciklust, s ezáltal az éghajlatot (Charney 1975; Charney et al. 1977).
A nagy területen bekövetkezett felszínborítás-változás képes jelentősen módosítani a biomasszában tárolt, illetve a légkörbe kerülő szén mennyiségét, az N_2O illetve CH_4 légköri koncentrációját, ezáltal a felszínborítás-változás az üvegházhatáson keresztül is indirekt hatással van a klímára (Drüszler 2011).
Földünk felszínének csupán 11-13% esik mezőgazdasági művelés alá, mely területek nagy részén a művelés nem intenzív. Magyarország viszont különleges helyzetben van, ugyanis területének 50%-a intenzíven művelt, valamint 20%-át közel intenzív módon kezelt erdőterület borítja (Neményi - Milics 2010).
Magyarország felszínének ca. háromnegyedét foglalja el elsődlegesen klímafüggő, azaz nem öntözött terület: szántó, rét, erdő.
Mátyás (2006) idézi Rumpf (2011) szerint a légköri szénmegkötés jelentőségének felismerése kedvező helyzetbe hozta az erdőgazdálkodást. Az erdőgazdálkodás az egyetlen olyan gazdasági tevékenység, amely azon túl, hogy szénsemleges, jelentős mennyiségű atmoszférikus szén tartós kivonását is lehetővé teszi.
Az általánosan elfogadott előrejelzések szerint az európai erdőövezetek pólusirányú eltolódása fog bekövetkezni. A várható éghajlatváltozás okán az erdőterületek észak felé bővülni fognak, míg déli irányból visszahúzódnak. A biodiverzitásban és a tájban okozott hatásai miatt, az eltolódás széles körben kiváltja nyilvánosság érdeklődését a probléma iránt. (Mátyás 2010).
A gazdasági szféra és nyitott technológiai folyamatai eltérő intenzitásukból adódóan más-más környezeti hatást fejtenek ki. Ebből adódóan a hozzájuk tartozó anyag- és energia elvonások és kibocsátások alapján a globális környezeti problémákhoz is eltérő módon járulhatnak hozzá. A technológiák folyamat- és életciklus szemléletben történő környezeti vizsgálata lehetővé teszi a részletes elemzést és a klímaváltozáshoz történő hozzájárulás megállapítását is.
A földhasználatok során a művelési technológiákkal átalakított vegetációs viszonyok és a felszínborítás hatásai mellett, az egyes technológiák sajátos környezeti vonatkozásait is figyelembe kell venni. A földhasználat technológiai aspektusának vizsgálata fontos kiegészítést jelent az eddigi klímakutatásokhoz.

CÉLKITŰZÉS

Az agrár ökoszisztéma kutatások egyik célja, hogy felderítse, a jelenlegi földhasználatok és az alkalmazott technológiák mennyire vannak összhangban a klímaváltozással járó, megváltozott környezeti adottságokkal. A kutatások eredményei alapján, néhány környezeti tényező hatásának ismeretében, már tanácsot lehetett adni egy-egy földhasználat módosítására, a kisebb környezeti kockázattal bíró technológiák használtára.
„Az előrevetített klímaváltozás hatáselemzése és az alkalmazkodás lehetőségei az erdészeti és agrárszektorban" (TÁMOP 4.2.2.A-11/1/KONV-2012-0013) projekt kutatói csoportunkhoz kapcsolódó résztémájában végzett munkánk fő célkitűzése az előrevetített klímaváltozás okozta földhasználat-változások környezetvédelmi elemzésére alkalmas módszer kifejlesztése technológiai aspektusban. Az elemzési modell a földhasználatokhoz kötődő művelési

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technológiák - klímaszcenáriók szerinti - környezeti hatásminősítését és környezeti kockázatosság megállapítását célozza életciklus szemléletben.

ANYAG ÉS MÓDSZER

A vizsgálataink erdészeti vonatkozásban Magyarországon, Zala megye mintaterületére koncentráltak, míg a szántóföldi növénytermesztési technológiák esetén Győr-Moson-Sopron megyei adatokkal dolgoztunk. Jelen összefoglaló a szántóföldi növénytermesztési technológiák vizsgálatára tér ki.

Első lépésben a jellemző szántóföldi növénytermesztési technológiák feltárására és kiválasztására volt szükség.
A számos felmerülő művelési technológia közötti kategorizálás könnyebb kezelhetőséget és egyszerűsítést tesz lehetővé.
Szántóföldi növénytermesztés esetén szakértői javaslatra (Gergely 2014) a kukorica (elővetemény: őszi búza), őszi búza 1. (elővetemény: káposztarepce) és őszi búza 2. (elővetemény: kukorica) termesztés-technológiai műveleti sorát vizsgáltuk.

Következő lépésben az elemzésre kiválasztott technológiák életciklus-elemzését (LCA) végeztük el, a hatásaik szénlábnyom (carbon footprint – CF, IPCC 2007 tanulmány) alapú rangsorolása érdekében.
Az LCA elkészítéséhez alkalmazott módszertan megfelel az ISO 14040:2006 és ISO 14044:2006 szabvány követelményeinek.

Az LCA lépései a következők voltak:
1. Cél és tárgykör meghatározása:
Az LCA módszerével a vizsgált technológiák összehasonlító környezeti hatáselemzését kívántuk elvégezni, mely rangsorolást tett köztük lehetővé. Erre alapozva környezeti kockázatuk - a felhasznált klímaszcenáriókkal összefüggésben – azonosítható volt.
A szántóföldi növénytermesztési technológiák rendszerhatárait azok műveleti sora adta, amely haszonnövényenként a következőképp alakult:
Kukorica (elővetemény: őszi búza): tarlóhántás nehéztárcsával, hengerezés, hántás, hengerezés; műtrágyaszórás és kiszolgáló szállítás; őszi mélyszántás; talajlezárás; műtrágyaszórás és kiszolgáló szállítás; ásóborona, vetőágy nyitás; vetés; vegyszeres gyomirtás és kiszolgáló szállítás; betakarítás; terményszállítás (10 tkm).
Őszi búza 1. (elővetemény: káposztarepce): tarlóhántás nehéztárcsával, hengerezés; műtrágyaszórás és kiszolgáló szállítás; magágy készítés, szántóföldi kultivátor; vetés; fejtrágyázás és kiszolgáló szállítás; vegyszeres gyomirtás és kiszolgáló szállítás; fejtrágyázás és kiszolgáló szállítás; betakarítás; terményszállítás (10 tkm).
Őszi búza 2. (elővetemény: kukorica): tarlóhántás nehéztárcsával; műtrágyaszórás és kiszolgáló szállítás; őszi mélyszántás; talajlezárás; vetés; fejtrágyázás és kiszolgáló szállítás; vegyszeres gyomirtás és kiszolgáló szállítás; fejtrágyázás és kiszolgáló szállítás; betakarítás; terményszállítás (10 tkm).
Kiszolgáló szállítás esetén 5-5 km-es közúti megközelítési távolságot vettünk alapul. Kukorica esetén a terményszárítás és betárolás, őszi búza 1. és őszi búza 2. esetén a betárolás lépései már nem kerültek az elemzésbe.
Funkcióegységnek 1 ha művelési területet vettünk alapul, referenciaáramokként a következőket vettük figyelembe: kukorica: 8 t/ha, őszi búza 1-2.: 5,6 t/h.

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Az elemzésbe nem vontuk be a technológiákhoz szükséges gépek és eszközök előállításának környezeti paramétereit.

2. Leltárelemzés:
A vizsgált technológiákról szakértői adatok, számítások segítségével környezeti leltáradatbázist (input-output, elemi áramok) hoztunk létre (Gergely 2014). Gockler (2014) nyomán átlagadatokkal dolgoztunk, melyek megállapítása sokszor hibával terhelt, ám alkalmazásuk elengedhetetlen az elemzéshez.
A szántóföldi növénytermesztési adatok vonatkoztatási időszaka 2012/2013. Földrajzi érvényességét tekintve az adatok az NYME MÉK Növénytermesztési Intézet Tangazdaságának területéről származtak.

Az adatok forrásai saját adatok, szakértői becslés, publikált adatok voltak.
Ezután felépítettük a vizsgált a szántóföldi növénytermesztési (kukorica, őszi búza 1-2.) technológiák életciklus-modelljét.

3. Hatásértékelés:
A hatásértékelés módszertani lépéseit az ISO 14044:2006 szabvány írja le. A szabvány szerinti hatásértékelésnél a leltáreredményeket először – az LCA tanulmány céljainak és kereteinek megfelelő – a hatáskategóriákhoz rendeltük. A hatáskategóriák nem mások, mint a környezeti problémaköröket képviselő osztályok, amelyekhez a leltár eredményei hozzárendelhetők. Egy leltáradat, akár több hatáskategóriához is kapcsolható. Minden egyes hatáskategóriára vonatkoztatva a módszer szerzői meghatároztak egy referencia egységet. Pl. 1 kg CO_2 globális felmelegedésre gyakorolt hatása 1, de például a metán emissziók globális felmelegedéshez (GWP) való hozzájárulását [kg CO_2-egyenérték]-ben kifejezett érték adja meg (21, 25 az alkalmazott módszertől függően) (Bodnárné Sándor – Molnárné Sípos 2010).
Simon (2012) nyomán megállapítottuk, hogy a CML 2001 módszer GWP 100 years értéket meghatározó főbb emissziókhoz tartozó karakterizációs faktora jól illeszkedik az IPCC 2007 tanulmányhoz. Hasonló a megfelelés az Eco-indicator 99 módszert illetően is. A módszerek alkalmasak a szénlábnyom (CF) számítására.
Számos hatásértékelési módszer áll rendelkezésre, az elemzést a fenti okokból:

- a CML 2001 (2010. novemberi) hatásorientált (midpoint) módszerrel és
- az Eco-indicator 99 (EI 99) károrientált (endpoint) módszerrel végeztük el.

Az alábbi környezeti hatáskategóriákkal jellemeztük a vizsgált technológiákat Polgár – Wachter (2014) munkája nyomán.

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1. táblázat. Környezeti hatáskategóriák, CML2001 - Nov. 2010 (Guinée et al. 2002)

CML2001 - Nov. 2010 hatáskategóriák	Egyenérték
Abiotikus kimerülő források (ADP)	[kg Sb-ekv.]
Abiotikus kimerülő fosszilis források (ADP foss.)	[MJ]
Savasodási potenciál (AP)	[kg SO_2-ekv.]
Eutrofizásiós potenciál (EP)	[kg foszfát-ekv.]
Édesvízi ökotoxicitási potenciál (FAETP inf.)	[kg DCB-ekv.]
Globális felmelegedési potenciál (GWP 100 years)	[kg CO_2-ekv.]
Globális felmelegedési potenciál, kizárólag biogén eredetű szén (GWP 100 years)	[kg CO_2-ekv.]
Humán toxicitási potenciál (HTP inf.)	[kg DCB-ekv.]
Tengervízi ökotoxicitási potenciál (MAETP inf.)	[kg DCB-ekv.]
Ózonréteg elvékonyodási potenciál (ODP, steady state)	[kg R11-ekv.]
Fotokémiai ózonképződési potenciál (POCP)	[kg etilén-ekv.]
Földi ökotoxicitási potenciál (TETP inf.)	[kg DCB-ekv.]

A jellemzési folyamat során az Eco-indicator 99 (EI 99) módszertanban három különböző értékelési megközelítést használnak: hierarchista (HA), individualista (IA) and egalitariánus (EA),

Az EI 99 módszertan öko-indikátor pontokat használ (mPt), melyek alapján három fő hatáskategóriában hivatott kifejezni a környezeti hatások által okozott károkat:

- Emberi egészség károsodása: kifejezve az elvesztett és fogyatékkal élt életévekkel. Ezen értékeket kombinálja a „Disability Adjusted Life Years" (DALY) mutatóban, amelyet a Világbank (World Bank) és az Egészségügyi Világszervezet (World Health Organization) is használ.
- Ökoszisztéma minőségének károsodása, kifejezve a fajok adott területről, adott idő alatti eltűnésével.
- Erőforrások károsodása: kifejezve az ásványok és fosszilis energiahordozók jövőbeli kitermelésének többlet energiájával. (Eco-indicator 99 2000).

2. táblázat. Környezeti hatáskategóriák, EI 99 (Eco-indicator 99 2000)

Eco-indicator 99 hatáskategóriák	Egyenérték
Ökoszisztéma minősége, savasodás	[PDF*m^2*a]
Ökoszisztéma minősége, ökotoxicitás	[PDF*m^2*a]
Ökoszisztéma minősége, földhasználat	[PDF*m^2*a]
Emberi egészség, karcinogén hatások	[DALY]
Emberi egészség, klímaváltozás	[DALY]
Emberi egészség, ózonréteg csökkenés	[DALY]
Emberi egészség, sugárzás	[DALY]
Emberi egészség, légúti megbetegedés (szervetlen anyagok)	[DALY]
Emberi egészség, légúti megbetegedés (szerves anyagok)	[DALY]
Erőforrások, fosszilis energiahordozók	[MJ többlet tenergia]
Erőforrások, ásványok	[MJ többlet energia]

4. Értelmezés, interpretáció:

Az LCA utolsó fázisában a leltár- és hatáselemzési eredmények ellenőrzése történt meg. Elvégeztük az összehasonlító elemzést, következtetéseket fogalmaztunk meg.

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Az aktuális technológia, mint stresszor, a klímaváltozásra meghatározott kockázati értékkel bír. A megfigyelt változó a környezeti kockázat szempontjából lehet az adott technológia is, hiszen a felhasznált gépek, anyagok, vegyszerek stb. veszélyként is értelmezhetőek, károsodást okozhatnak az egyes környezeti elemekben, receptorokban.
Az LCA eredményei közül a vizsgált technológiák CML 2001 – Globális felmelegedési potenciál (GWP 100 years) [kg CO_2-ekv.] és EI 99 – Emberi egészség, klímaváltozás [DALY] értékeit használtuk fel a továbbiakhoz. Az értékek alapján technológiai rangsort állítottunk fel. Ezáltal megadtuk a technológiák egyfajta környezeti összehasonlító hatásminősítését.

A GWP 100 years hatáskategória indikátor eredménye [kg CO_2-ekv.] értékben kifejezve a technológia szénlábnyomának (carbon footprint, CF) tekinthető, mely összhangban van az IPCC 2007 tanulmánnyal.

Végső lépésben a technológiák hatásainak minősített rangsorát klímaszcenáriókkal (Gálos et al. 2014) hoztuk összefüggésbe.
A globális felmelegedési potenciál értékek (GWP 100 years) alapján rangsorolt technológiákat, a klímaváltozási forgatókönyvek átlaghőmérséklet változásával (dT [°C]) összefüggésben, szakértői mátrixban helyeztük el. A környezeti kockázatok meghatározása szöveges formában történt.

EREDMÉNYEK

A leltárelemzés során a technológia folyamatára jellemző input-output adatokat, elemi áramokat határoztuk meg. Bementi és kimeneti oldalon egyaránt elvégeztük az adatok összesítését.

3. táblázat. Összesített bemeneti és kimeneti környezeti leltáradatok a vizsgált szántóföldi növénytermesztési technológiákban, 1 ha-ra vetítve (Magyarország, GYMS megye) (Polgár – Wachter 2014)

Tényező	Egység	Haszonnövény		
		Kukorica	**Őszi búza 1.**	**Őszi búza 2.**
Vonatkoztatási időszak	év	2012-2013	2012-2013	2012-2013
Referencia áram (szem)	t	8	5,6	5,6
Input				
Dízel	kg	134	128	128
Kenőolaj	kg	4,42	4,83	4,7
Kevert műtrágya (MAP, mono-ammonium-foszfát)	kg	200	0	0
Karbamid műtrágya	kg	200	0	0
Komplex műtrágya (NPK)	kg	0	300	300
Mész-ammon-salétrom műtrágya (MAS)	kg	0	450	450
Gyomirtószer	l	200	200	200
Output				
Szén-dioxid (fosszilis)	kg	423	404	402
Fáradtolaj (reciklált)	kg	4,42	4,83	4,7

Bementi oldalon főként a gépek üzemanyag igénye és kenőolaj felhasználása jelent meg. Felhasználásuk fosszilis eredetű CO_2 kibocsátást eredményezett.

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Szántóföldi növénytermesztés esetén a műtrágyázás (pl. mono-ammonium-foszfát, karbamid, NPK) és gyomirtás vegyszereivel is számolni kellett.
A munkagépek üzemeltetése során a kenőolaj fáradt olajként hasznosításra került.
A szántóföldi növénytermesztés gépei az egyes haszonnövények esetén többnyire azonosak voltak, eltérés a használatuk intenzitásában volt néhol megfigyelhető (pl. eltérés a talaj előkészítésben, ahol előveteményként őszi búzával, vagy kukoricával kellett számolni). Jelen munkában nem számoltunk a területen maradt szár/szalma bálázásával kapcsolatos folyamatokkal.

A vizsgálataink során a munkarendszerek és technológiák primér energia-igényét is megjelenítettük, melyet az alábbi táblázatban mutatunk be. Az adatok jól tükrözik technológiánként pl. a felhasznált anyagokból, gépigényből és fogyasztásból adódó különbségeket.

4. táblázat. Primér energia igények különböző forrásokból (Polgár – Wachter 2014)

Energiaigény	**Haszonnövény**		
	Kukorica	**Őszi búza 1.**	**Őszi búza 2.**
Primér energia nem megújuló forrásokból (br. cal. érték) [MJ]	7023,557943	6738,915673	6707,078325
Primér energia nem megújuló forrásokból (net. cal. érték) [MJ]	6546,103077	6280,790488	6251,121375
Primér energia megújuló nyersanyagokból (br. cal. érték) [MJ]	375,5609199	358,7477535	357,3603443
Primér energia megújuló nyersanyagokból (net. cal. érték) [MJ]	375,5609199	358,7477535	357,3603443

A munkarendszerek CML 2001 (2010. novemberi) környezeti életciklus-hatásértékelése során a következő eredményeket kaptuk.

5. táblázat. Vizsgált technológiák környezeti hatásai CML 2001 (2010. novemberi) értékelési módszer alapján (Polgár – Wachter 2014)

Környezeti hatáskategóriák, CML2001 - Nov. 2010	**Egyenérték**	**Haszonnövény**		
		Kukorica	**Őszi búza 1.**	**Őszi búza 2.**
Abiotikus kimerülő források (ADP)	[kg Sb-ekv.]	2,18E-05	2,09E-05	2,08E-05
Abiotikus kimerülő fosszilis források (ADP foss.)	[MJ]	6546,086641	6280,774697	6251,105662
Savasodási potenciál (AP)	[kg SO_2-ekv.]	0,443553655	0,425779948	0,423729383
Eutrofizásiós potenciál (EP)	[kg foszfát-ekv.]	0,06994391	0,066897078	0,066621994
Édesvízi ökotoxicitási potenciál (FAETP inf.)	[kg DCB-ekv.]	1,481099598	1,416316312	1,410543661
Globális felmelegedési potenciál (GWP 100 years)	[kg CO_2-ekv.]	461,1663339	440,8882628	439,1164061
Globális felmelegedési potenciál, kizárólag biogén eredetű szén (GWP 100 years)	[kg CO_2-ekv.]	491,5926241	469,9362901	468,0552221
Humán toxicitási potenciál (HTP inf.)	[kg DCB-ekv.]	11,27740992	10,79399099	10,74808803
Tengervízi ökotoxicitási potenciál (MAETP inf.)	[kg DCB-ekv.]	4763,867695	4578,725278	4555,56446
Ózonréteg elvékonyodási potenciál (ODP, steady state)	[kg R11-ekv.]	9,96E-09	9,56E-09	9,51E-09
Fotokémiai ózonképződési potenciál (POCP)	[kg etilén-ekv.]	0,043900713	0,042184044	0,041972689
Földi ökotoxicitási potenciál (TETP inf.)	[kg DCB-ekv.]	4,996996125	4,771130755	4,753097645

A szántóföldi növénytermesztési technológiák esetén a legnagyobb hatás az abiotikus kimerülő fosszilis erőforrások (ADP foss.) esetén jelentkezett, majd a tengervízi ökotoxicitás (MAETP) kategóriában. A technológiák a globális felmelegedésre (GWP 100) ezután voltak

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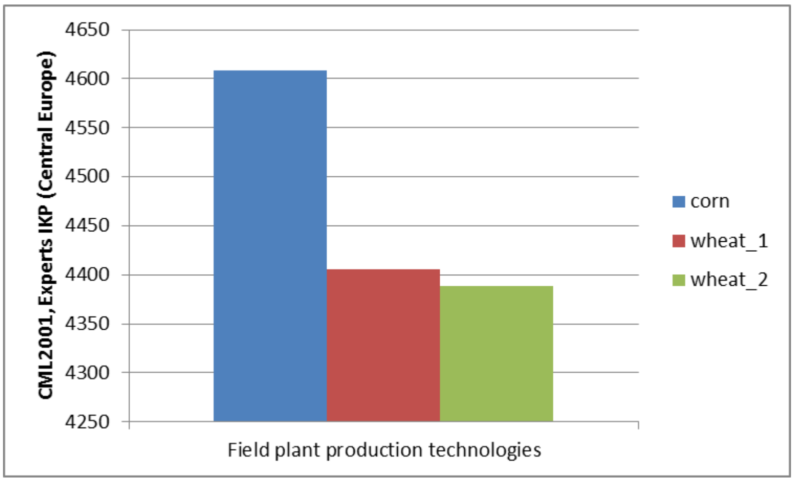
csak hatással. A technológiák életciklus részesedése közel azonosnak tekinthető. A kukorica esetén 34% körüli, az őszi búza 1. esetén 33%, míg az őszi búza 2 esetén alig 33% volt.
A technológiák rangsorolása, ha kis eltéréssel is, azonban mindegyik esetben az *„őszi búza 2.- őszi búza 1.-kukorica"* növekvő sorrendet adta.

Abban az esetben, ha egy grafikonon akarjuk megjeleníteni az összes környezeti hatást, akkor alkalmaznunk kell a normalizáció és súlyozás eszközét. Ez a módszer alkalmas arra, hogy egymás mellett lássuk az összes hatáskategória eredményeit.

Az alábbi ábra alapján elmondható volt, hogy a vizsgált szántóföldi haszonnövényeknél alkalmazott termesztési technológiák teljes környezeti hatása (Közép-Európára normalizálva) esetén is felállítható az *„őszi búza 2.- őszi búza 1.-kukorica*" növekvő sorrend.



Megj.: 'corn' – kukorica; 'wheat_1' – őszi búza 1.; 'wheat_2' – őszi búza 2.
1. ábra. A szántóföldi növénytermesztési technológiák teljes életciklusának környezeti hatásai (Közép-Európára normalizált, súlyozott értékekkel) (Polgár – Wachter 2014)

A leltáradatokat az Eco-indicator 99 módszer szerint is értékeltük. Az eredményeket egyenértékben az alábbi táblázat mutatja be egalitariánus, hierarchista és individualista megközelítésben.

6. táblázat. Vizsgált technológiák környezeti hatásai Eco-Indicator 99 (EA-Egalitáriánus, HA-Hierarhista, IA-Individualista; Emberi egészség, klímaváltozás) értékelési módszer alapján (részlet) (Polgár – Wachter 2014)

Hatáskategória	Egyenérték	Haszonnövény		
		Kukorica	Őszi búza 1.	Őszi búza 2.
EA – Emberi egészség, klímaváltozás	[DALY]	9,66E-05	9,23E-05	9,19E-05
HA – Emberi egészség, klímaváltozás	[DALY]	9,66E-05	9,23E-05	9,19E-05
IA - Emberi egészség, klímaváltozás	[DALY]	9,21E-05	8,80E-05	8,77E-05

Kiemelve az EI99, Emberi egészség, klímaváltozás [DALY] értékeket, a munkarendszerek teljes környezeti hatása esetén mindhárom megközelítésben: az *"őszi búza 2.- őszi búza 1.- kukorica"* növekvő sorrendet kaptuk.

A felhasznált környezeti hatásértékelési módszerek alapján megerősített, azonos eredményre jutottunk.

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KÖVETKEZTETÉSEK

A globális felmelegedési potenciál értékek (GWP 100 years) alapján rangsorolt technológiákat a klímaváltozási forgatókönyvek (Gálos et al. 2014) átlaghőmérséklet változásával (dT [°C]) összefüggésben szakértői mátrixban helyeztük el.
Jelen (1980-2010), 2025 (2010-2040), 2055 (2040-2070), 2085 (2070-2100) időszakokban ezáltal megadhatóvá vált a technológiák környezeti kockázata. A környezeti kockázatok meghatározása szöveges formában történt:

- I. osztály: magas
- II. osztály: közepes
- III. osztály: alacsony.

7. táblázat. Szakértői matrix. A szántóföldi növénytermesztési technológiák környezeti kockázati osztályai a klímaszcenáriókkal összefüggésben (saját szerkesztés)

Klíma	Változó	Jelen (1980-2010)	2025 (2010-2040)	2055 (2040-2070)	2085 (2070-2100)
		mérsékelt	meleg	melegebb	melegebb, szárazabb
Hőmérséklet	**Átlagos változás (dC°) (tenyészidőszaki)**	mérsékelt	gyenge emelkedés	emelkedés	erős emelkedés
		0	1,0	2,1	3,3
Technológia	**Jellemző**				
Őszi búza 2. (elővetemény: kukorica)	Technológia környezeti kockázata a globális GWP 100 years [kg CO_2-egyenérték] alapján	**III. osztály**	**III. osztály**	**II. osztály**	**II. osztály**
Őszi búza 1. (elővetemény: káposztarepce)	Technológia környezeti kockázata a globális GWP 100 years [kg CO_2-egyenérték] alapján	**III. osztály**	**II. osztály**	**II. osztály**	**I. osztály**
Kukorica (elővetemény: őszi búza)	Technológia környezeti kockázata a globális GWP 100 years [kg CO_2-egyenérték] alapján	**II. osztály**	**II. osztály**	**I. osztály**	**I. osztály**

A létrehozott kockázati mátrix alkalmazása fontos kiegészítést jelent a klímaváltozással kapcsolatos döntéshozatalban a technológiák megválasztását illetően. Iránymutatásként szolgál a gazdálkodóknak és a döntéshozóknak egyaránt. A megközelítés alkalmazható más technológiákra is, a közel azonos technológiák között is lehetőséget teremt a rangsorolásra és összehasonlításra.

ÖSSZEGZÉS

Munkánk során kifejlesztettük az előrevetített klímaváltozás okozta földhasználat-változások környezetvédelmi elemzésére alkalmas módszert technológiai megközelítésben. Álláspontunk szerint a földhasználat technológiai aspektusának vizsgálata fontos kiegészítést jelenthet az eddigi klímakutatásokhoz.
A környezetvédelmi elemzés során a szántóföldi növénytermesztési technológiák közül az „kukorica (elővetemény: őszi búza)", „őszi búza 1. (elővetemény: káposztarepce)" és „őszi

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búza 2. (elővetemény: kukorica)" haszonnövények műveleti sorára koncentráltunk. Szakértők bevonásával előállítottuk a vizsgált munkarendszerek környezeti leltárát.
Életciklus-elemzés segítségével elvégeztük a munkarendszerek környezeti hatásainak szénlábnyom alapú rangsorolását, mely az „őszi búza 2. (elővetemény: kukorica)" – „őszi búza 1. (elővetemény: káposztarepce)" - „kukorica (elővetemény: őszi búza)" növekvő sorrendet adta.
A globális felmelegedési potenciál értékek (GWP 100 years) alapján rangsorolt technológiákat a klímaváltozási forgatókönyvek átlaghőmérséklet változásával (dT [°C], tenyészidőszaki) összefüggésben szakértői mátrixban helyeztük el.
A technológiák környezeti kockázatát osztályokba soroltuk (I. osztály: magas, II. osztály: közepes, III. osztály: alacsony). A besorolás figyelembe vétele iránymutatásként szolgálhat a gazdálkodóknak és a döntéshozóknak egyaránt a technológiák megválasztásakor.

Köszönetnyilvánítás: Köszönetünket fejezzük ki „Az előrevetített klímaváltozás hatáselemzése és az alkalmazkodás lehetőségei az erdészeti és agrárszektorban" (TÁMOP 4.2.2.A-11/1/KONV-2012-0013) projekt támogatásáért.

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Három lámpatípussal végzett fénycsapdázás két mintaterületen

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Kivonat

A fénycsapdázás célja a mesterséges fényforrások rovarokra gyakorolt hatásainak vizsgálata. A tanulmány 2012 és 2013 nyarán Jermy-típusú fénycsapdával három különböző fényforrással (Na lámpa, kevert HMLI lámpa, kompakt fénycső) végzett fénycsapdázás eredményeit mutatja be megvilágítottság szempontjából két különböző mintaterületen. A természetes helyszín fényszennyezéstől gyakorlatilag mentes, a mesterséges helyszín jelentős háttérmegvilágítással rendelkezik. A fénycsapdával befogott rovarok értékelése rend szerinti besorolással és dominancia vizsgálattal történt. Természetes területen a Na lámpa a lepkék (*Lepidoptera*), a kétszárnyúak (*Diptera*) és a kabócák (*Hemiptera*) rendjébe tartozó egyedeket vonzotta legnagyobb számban. Mesterséges területen csak a kétszárnyúak (*Diptera*) repültek a Na lámpával üzemeltetett fénycsapdára. A kompakt fénycső felé a természetes területen a lepkék (*Lepidoptera*), kétszárnyúak (*Diptera*), kabócák (*Hemiptera*) és bogarak (*Coleoptera*) rendjébe tartozó egyedek repültek. A mesterséges mintaterületen a kompakt fénycső a kétszárnyúakat (*Diptera*) vonzotta nagymértékben. A kevert HMLI lámpa a természetes területen a kabócák (*Hemipetra*) rendjébe tartozó egydeket fogta be nagy számban, a mesterséges területen pedig a kétszárnyúak (*Diptera*) rendjébe tartozókat. A dominancia értékelés relatív abundancia vizsgálattal történt a fénycsapdával befogott egyedszámok alapján.

Kulcsszavak: fénycsapda / fényszennyezés / rovarok

BEVEZETÉS

A Föld népességének száma egyre gyorsabb ütemben nő és ennek következtében a települések száma is gyarapodik. A nagyvárosokban élők számára nagy biztonságot jelentenek az éjjel kivilágított utcák, terek, amelyek pozitív hatásuk mellett negatív következményekkel is járnak. A mesterséges fényforrások túlzott mértékű használata egy új környezeti problémát okoz, a fényszennyezést, amelyre az űrhajósok hívták fel először a figyelmet. Fényszennyezés során megváltozik az éjszakai égbolt természetes fényessége és az ember tevékenysége következtében az égbolt háttérfényessége megnövekszik (Nowinszky 2007). A kutatók az éjjel repülő rovarok fényhez való vonzódását fénycsapdázással vizsgálják. A fénycsapda alkalmazható faunisztikai, taxonómiai, állatföldrajzi vizsgálatokra, továbbá rovarpopulációk hosszú távú monitorozására, kártevők előrejelzésére. Az első kezdetleges fénycsapdákat a XIX. század második felétől a rovargyűjtők alkalmazták. Magyarországon Jermy Tibor kezdeményezésére 1952-től megkezdődött a világviszonylatban is egyedülálló fénycsapda hálózat kiépítése.1961-ben Tallós és Szontagh irányításával az

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erdészeti fénycsapdák telepítése kezdődött meg, majd az erdészeti fénycsapda hálózat kialakítása (Szontagh 1962), amely napjainkban már 25 fénycsapdával működik (Hirka 2006).

ANYAG ÉS MÓDSZER

Vizsgálataimat Sopronban és környékén végeztem 2012 és 2013 nyarán. A mintaterületeket a megvilágítottság mértéke szerint választottam ki. A térképen „A" jelű mintaterület a fényszennyezettségtől lényegében mentes, a „B" jelű jelentős háttér megvilágítással rendelkezik (1. ábra). Az „A" mintaterület a Soproni hegyvidék területén lévő Ágfalva 1 erdőtag M erdőrészletében található (Hidegvíz-völgy) . A „ B" mintaterület a város központi részén , a meteorológiai állomás területén helyezkedik el (Kuruc-domb) . Az „A" mintaterület a Soproni hegyvidék fokozottan védett természeti területén lévő erdő egy részlete, amely egy gyertyános-tölgyes klímájú, hidrológiai viszonyát tekintve szivárgó vízű és 400 m tengerszint feletti magasságú. Fő állományalkotó fafaja a mézgás éger, de szórtan előfordul a lombos fafajok közül a hegyi juhar, kislevelű hárs és a törékeny fűz. A „B" mintaterület egy mesterségesen létrehozott dombon helyezkedik el, telepített fafajokkal és cserjékkel. A két mintaterületen a rovarok befogásához Jermy-típusú fénycsapdákat használtam, amelyek nagy teljesítményű fényforrások működtetésére is alkalmasak. Három típusú fényforrást használtam, amelyek Sopron közterületein (utcákon, tereken) gyakoriak. Ennek megfelelően Na lámpát (150 W), HMLI kevert lámpát (160 W) és kompakt fénycsövet (36 W) használtam. A fénycsapdázás időpontjait a holdfázisokhoz igazítva három napos ciklusokban választottam ki, június, július és augusztus hónapban, melyre a Na lámpa esetében látható példa (1. táblázat). A fényforrásokat minden nap és mintaterületen cseréltem, hogy minél nagyobb számú mintavételem legyen.

1. ábra: A vizsgált mintaterületek

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1.táblázat: A fénycsapdázás időpontjai Na lámpa esetében

Hónap/év	2012.	2013.	2012.	2013.
	Természetes terület		Mesterséges terület	
június	12.	7.	12.	9.
	20.	15.	20.	17.
	28.	22.	28.	24.
július	4.	7.	4.	1.
	12.	15.	12.	9.
	19.	28.	19.	17.
augusztus	9.	5.	9.	7.
	18.	13.	18.	15.
	25.	21.	25.	23.

EREDMÉNYEK

A vizsgált időszak alatt a két mintaterületen az értékelést azonos számú napok kiválasztása alapján végeztem. Ennek megfelelően minden évben 55 db csapdázási napot hasonlítottam össze. Jelen tanulmányban nem vettem figyelembe az eltérő időjárási körülményeket, csak a fényforrás típusokat és a mintaterületek eltérő megvilágítottságát. Az alábbi ábrán (2. ábra) lévő grafikon azt mutatja, hogy természetes területen a lepkék (*Lepidoptera*) (2309 db),a kétszárnyúak (*Diptera*) (1888 db) és a kabócák (*Hemiptera*) (2714 db) rendjébe tartozó rovaregyedeket vonzotta legnagyobb számban a Na lámpa, a mesterséges területen pedig csak a kétszárnyúakat (*Diptera*) (7336 db). A kevert lámpa a természetes területen kiemelkedően nagy számban vonzotta a kabócák (*Hemiptera*) (104087db) rendjébe tartozó egyedeket, a többi rendbe tartozó befogott egyed száma között nincs kiugró eltérés (3. ábra). A kompakt fénycső a természetes területen a lepkéket *(Lepidoptera*) (1582 db), a kétszárnyúakat (*Diptera*) (780 db) a kabócákat (*Hemiptera*) (1810 db) és a bogarakat (*Coleoptera*) (1377 db) vonzotta a legnagyobb mértékben, a mesterséges területen kiemelkedő mértékben csak a kétszárnyúakat (*Diptera*) (1618 db) (4. ábra).

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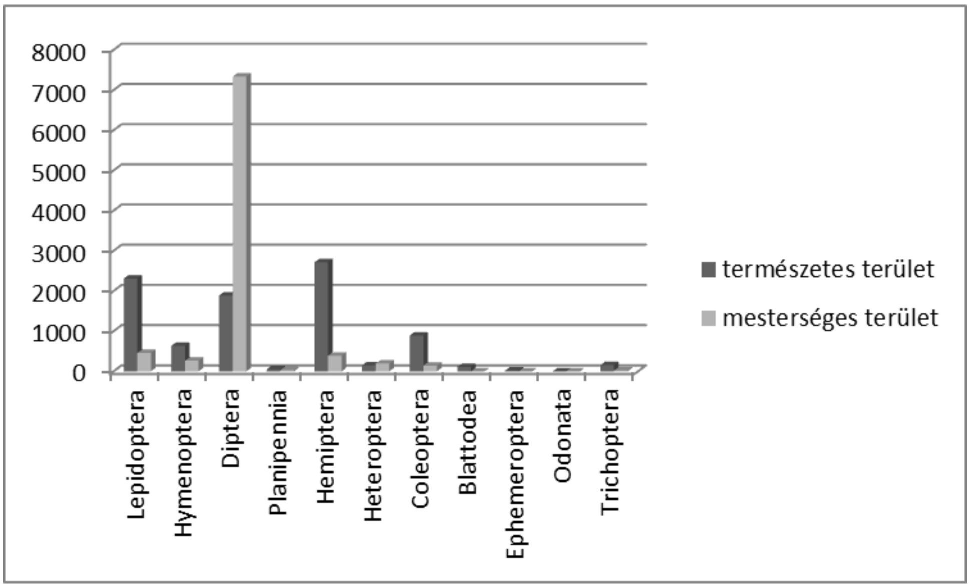
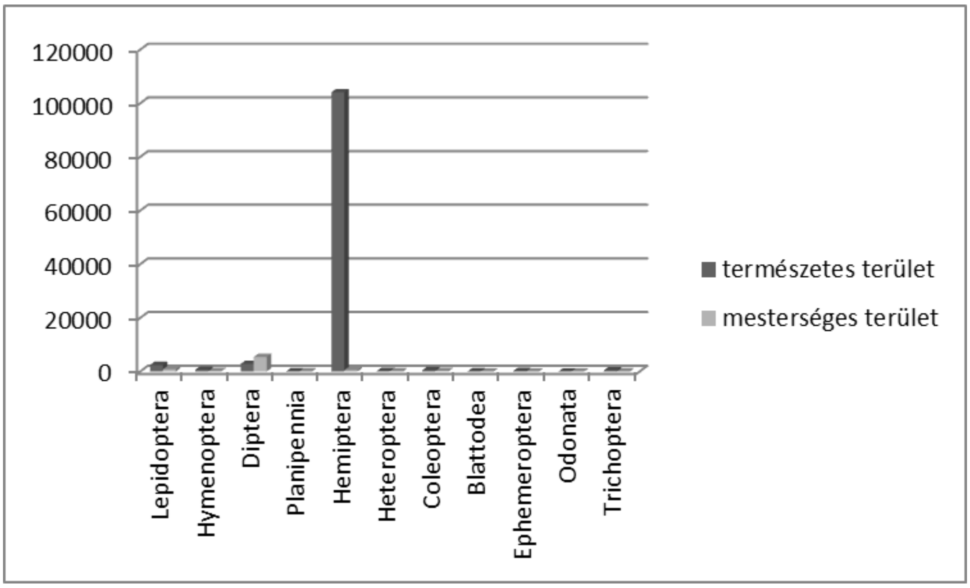
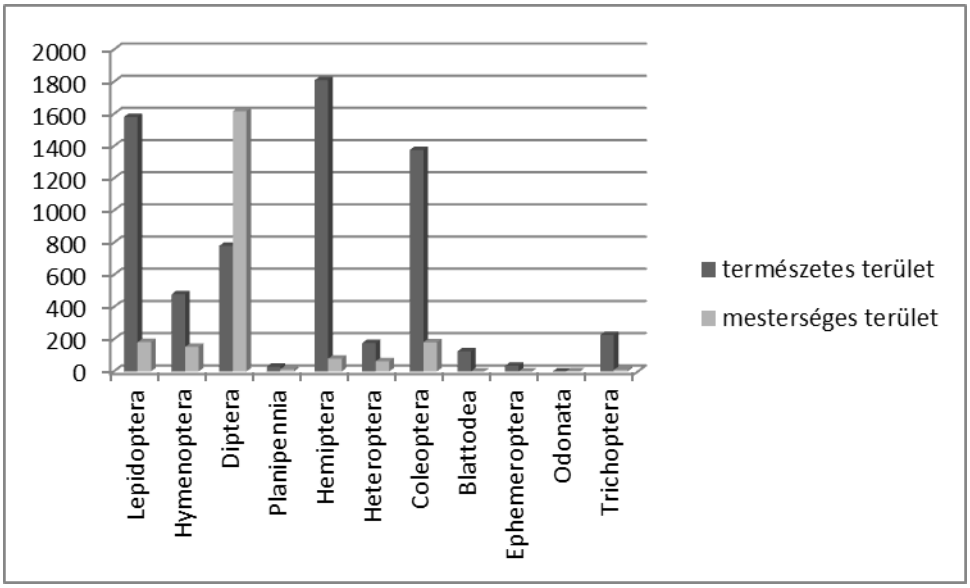


2. ábra: A Na lámpa által befogott rovarok egyedszáma a két mintaterületen

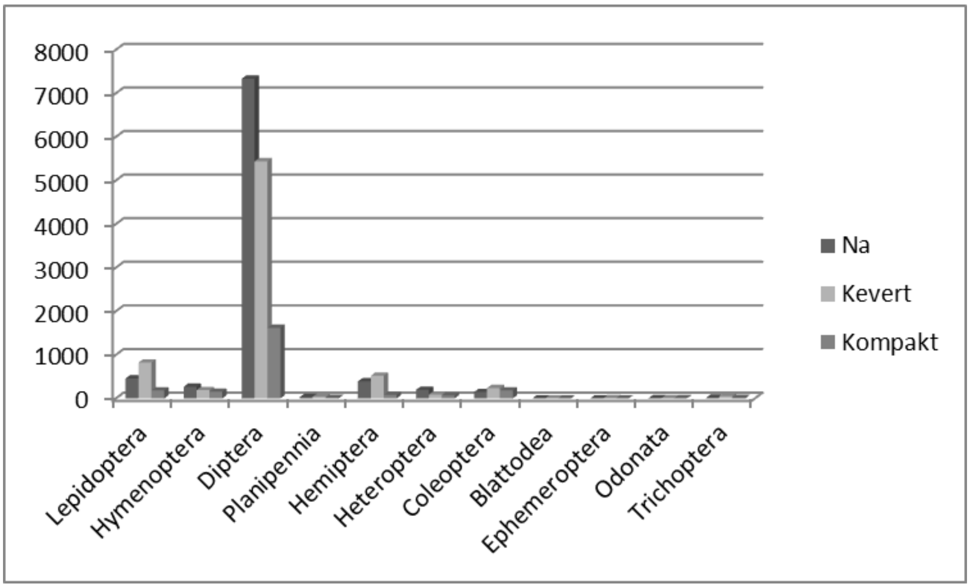


3. ábra: A kevert HMLI lámpa által befogott rovarok egyedszáma a két mintaterületen



4. ábra: A kompakt lámpa által befogott rovarok egyedszáma a két mintaterületen

A következő két ábrán (5. ábra és a 6. ábra) látható a két év alatt befogott egyedek száma rendenként a három fényforrás típus mellett. A mesterséges területen mind a három lámpatípus a kétszárnyúakat (*Diptera)* vonzotta legnagyobb mértékben, a természetes területen pedig a kabócákat (*Hemiptera)*.



5. ábra: A három fényforrás típus által befogott egyedek száma rendenként a mesterséges területen

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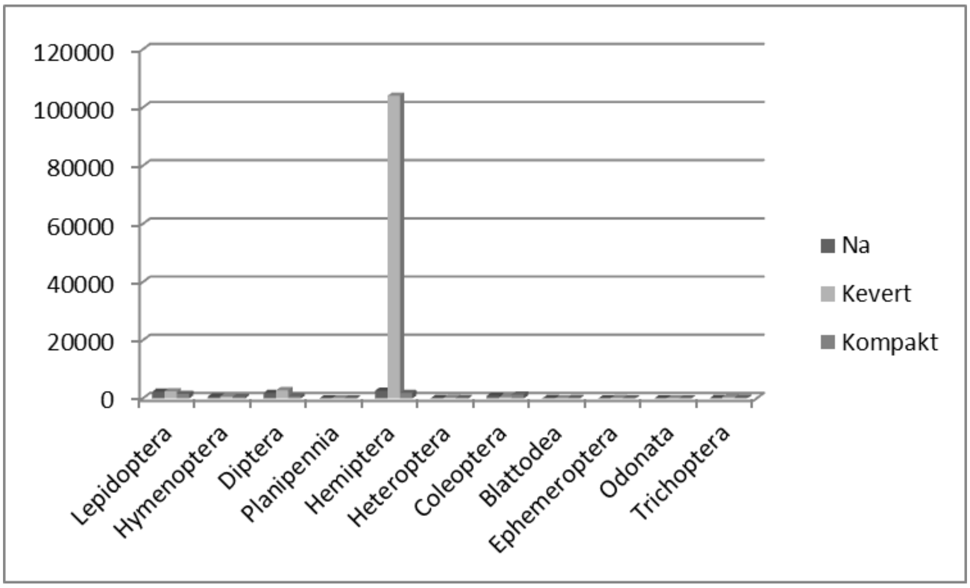

6. ábra: A három fényforrás típus által befogott egyedek száma rendenként a természetes területen

A dominancia vizsgálatot relatív abundancia vizsgálattal végeztem, amely kifejezi, hogy az adott rend egyedszáma hány százalékát teszi ki a vizsgált rend összes egyedszámának (Kovács 2008). Az alábbi képletet használtam:

D = (n/N) 100, ahol

n = a vizsgált rend egyedszáma

N = az összes rend egyedszáma

A besorolás az alábbi módon történt:

kategória	**D(%)**
eudomináns	10%felett
domináns	5-10%
szubdomináns	2-5%
recens	1-2%
szubrecens	1%alatt

A természetes területen a lepkék (*Lepidoptera*), a kétszárnyúak (*Diptera*) a kabócák (*Hemiptera*) bizonyultak eudomináns rendeknek (2. táblázat). A három lámpa fogási eredményeit a Na és a kompakt lámpa által begyűjtött rovarok esetében 5 dominancia csoportba, a kevert lámpánál 3 dominancia csoportba lehetett besorolni. A mesterséges területen a csótányok (*Blattodea*) és a kérészek (*Ephemeroptera*) rendjébe tartozó egyedek kisszámú befogási arányuk miatt kimaradtak a dominancia vizsgálatból.

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2. táblázat: Dominancia értékek rovarrendek szerint a három fényforrás típusnál a természetes területen

Rend	Kategória Na	D(%)	Kategória Kevert	D(%)	Kategória Kompakt	D(%)
Lepidoptera	eudomináns	25,8	szubdomináns	2,1	eudomináns	23,8
Hymenoptera	domináns	7,1	szubrecens	0,6	domináns	7,2
Diptera	eudomináns	21,1	szubdomináns	2,4	eudomináns	11,7
Planipennia	szubrecens	0,5	szubrecens	0	szubrecens	0,4
Hemiptera	eudomináns	30,3	eudomináns	90,1	eudomináns	27,3
Heteroptera	szubdomináns	1,68	szubrecens	0,1	szubdomináns	2,6
Coleoptera	domináns	9,9	szubrecens	0,4	eudomináns	20,7
Blattodea	szubdomináns	1,2	szubrecens	0	recens	1,8
Ephemeroptera	szubrecens	0,2	szubrecens	0,1	szubrecens	0,5
Trichoptera	recens	1,7	szubrecens	0,3	szubdomináns	3,4

A mesterséges területen a Na által vonzott rovarokat 8 rendbe és 5 dominancia kategóriába lehetett sorolni hasonlóan a természetes területhez (3. táblázat). A kétszárnyúak (*Diptera*) kiemelkedő arányban bizonyultak eudomináns rendnek. A kevert lámpa esetében 9 rendbe és szintén 5 dominancia kategóriába lehetett a befogott rovaregyedeket osztályozni, melynél szintén a kétszárnyúak (*Diptera*) voltak eudominánsak. A kompakt lámpa által befogott rovaregyedeket 8 rendbe és 4 dominancia kategóriába soroltam, ahol szintén a kétszárnyúak (*Diptera*) rendje az eudomináns.

3. táblázat: Dominancia értékek rovarrendek szerint a három fényforrás típusnál a mesterséges területen

Rend	Kategória Na	D(%)	Kategória Kevert	D(%)	Kategória Kompakt	D(%)
Lepidoptera	domináns	5,1	eudomináns	11	domináns	7,9
Hymenoptera	szubdomináns	2,9	szubdomináns	2,5	domináns	6,6
Diptera	eudomináns	82,9	eudomináns	73,6	eudomináns	70,2
Planipennia	szubrecens	0,3	szubrecens	0,4	szubrecens	0,6
Hemiptera	szubdomináns	4,4	domináns	7,0	szubdomináns	3,4
Heteroptera	szubdomináns	2,2	recens	1,1	szubdomináns	2,7
Coleoptera	recens	1,6	szubdomináns	3,1	domináns	7,8
Trichoptera	szubrecens	0,2	szubrecens	0,7	szubrecens	0,4
Odonata			szubrecens	0,1		

KÖVETKEZTETÉSEK

Az eredmények alapján megállapítható, hogy mind a természetes, mind a mesterséges mintaterületen a három különböző lámpatípus a négy rovarrendbe (lepkék (*Lepidoptera*), kétszárnyúak (*Diptera*), kabócák (*Hemiptera*), bogarak (*Coleoptera*)) tartozó egyedeket fogta be legnagyobb számban. Az egyes lámpatípusok és területek között voltak eltérések , amely a dominancia értékelésnél került kimutatásra.

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