https://doi.org/10.15414/2022.9788055225029

SLOVAK UNIVERSITY OF AGRICULTURE IN NITRA
FACULTY OF HORTICULTURE AND LANDSCAPE ENGINEERING

VEDA MLADÝCH 2022 - SCIENCE OF YOUTH 2022

proceedings

ISBN 978-80-552-2502-9
ISSN 2585-7398

June, 1st - 3rd 2022

Partner of the conference

Veda mladých 2022 - Science of Youth 2022

PROCEEDINGS OF REVIEWED CONTRIBUTIONS

Banská Štianvica, Slovakia
01.- 03.06.2022

Reviewers

doc. Ing. Elena Aydin, PhD.
Ing. Marek Kovár, PhD.
MSc. Samuel Adamec, PhD.
Ing. Peter Ivan, PhD.
Ing. Miroslav Čibik, PhD.
doc. Ing. Simona Kunová, PhD.
prof. Ing Ľuboš Jurík, PhD.
doc. Ing. Ján Horák, PhD
prof. Ing. Peter Halaj, CSc.
Ing. Kristína Candráková, PhD.
Ing. Veronika Soldánová, PhD.
Ing. Martin Manina, PhD.
Ing. Marek Hus, PhD.
doc. Ing. Miroslav Šlosár, PhD.
doc. Ing. Lenka Lackóová, PhD.
Ing. Viktor Varga, PhD.
Dr. inž. Łukasz Borek
Ing. Marcel Golian, PhD.
Ing. Róbert Lenárt, PhD.

Editors: Ing. Vladimír Kišš, PhD., Ing. Andrej Tárník, PhD.

Schválila rektorka Slovenskej poľnohospodárskej univerzity v Nitre
dňa 15. 07. 2022 ako online proceedings of scientific papers.

This work is published under the license of the Creative Commons Attribution
NonCommercial 4.0 International Public License (CC BY-NC 4.0).
https://creativecommons.org/licenses/by-nc/4.0/

ISBN 978-80-552-2502-9

 https://doi.org/10.15414/2022.9788055225029

Partner of the conference

CONTENT

POSTER SECTION

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 13.05.2022
Received in revised form 31.05.2022
Accepted 01.06.2022

THE PROBLEM OF CREATING LPIS LAND BLOCKS AS A SUPPORT FOR APPLICATIONS FOR DIRECT PAYMENTS

Petra PIPÍŠKOVÁ[1], Peter MICHAL[1,2], Dávid DEŽERICKÝ[1]

[1]Slovak Agriculture University in Nitra, SLOVAKIA

[2]Agricultural Paying Agency, SLOVAKIA

Abstract

The Land Parcel Identification System (LPIS) is a key control mechanism under the Common Agricultural Policy, playing a very important role in verifying qualification for area-based subsidies, monitoring farmers' cross-compliance with selected environmental rules and the rural development programme. LPIS is based on aerial or satellite imagery recording all agricultural parcels. The aim of this paper is to present the tasks, basic steps and outline the problems in creating LPIS blocks as a support for applications for direct payments. The basis for the processing of the article are the basic legislative and methodological regulations defining the frameworks for updating and using LPIS in subsidy schemes. Based on the input data, we found that the area of LPIS in Slovakia is being reduced due to the presence of ineligible areas. Over the period from 2017 to 2021, there has been a steady decline in the acreage of LPIS blocks in Slovakia. Compared to 2017, the first decrease in LPIS block area has already occurred in 2019, by 14.62 %, which amounts to 545 028 ha of land. However, the LPIS block areas continued to decrease in the following years. Currently, there is a further decrease in area of 4.23 % from 2019, which amounts to 157 792 ha of land. We expect that the area of LPIS blocks in Slovakia will continue to decline.

Keywords: Common Agricultural Policy (CAP), Land Parcel Identification System (LPIS), Direct payments, The Agricultural Paying Agency

 https://doi.org/10.15414/2022.9788055225029

Introduction

Since the 2003 reform, the Common Agricultural Policy (CAP) has aimed to ensure a stable income for farmers, decoupled from production, within a framework of sustainable development of rural areas while respecting environmental and other societal needs. There are three main categories of actors in the CAP direct payment process: the European Union (EU) institutions, Member State administrations (including some Member State regions) and farmers (Sagris, Devos, 2008). The Agricultural Information System (AIS) is an information technology system that manages information on agricultural data. The main subcomponents of the AIS include the Integrated Administrative Control System (IACS) and the Land Parcel Identification System (LPIS) (Počivavšek et al., 2011). IACS is the most important system for managing and controlling payments to farmers made by Member States in the application of the CAP. LPIS is one of the most important elements of IACS.

The Land Parcel Identification System (LPIS) is a key control mechanism under the Common Agricultural Policy, playing a very important role in verifying qualification for area-based subsidies, monitoring farmers' cross-compliance with selected environmental rules and the rural development programme (agri-environment schemes, support for areas with unfavourable soil conditions, farming practices with environmental and climatic benefits, ecological commitments). The Member States of the European Union have followed different principles in the process of developing their LPIS. The basic unit in the LIPS database is the reference parcel, which has been defined on the basis of different criteria in the EU countries (cadastral parcels, agricultural parcels, farmer blocks or physical blocks). The implementation of the Common Agricultural Policy (CAP) and area payments in the European Union has necessitated the development of a system for the identification of agricultural parcels characterised by different types of land cover and land use. According to Kay and Milenov (2008) LPIS is based on aerial or satellite imagery recording all agricultural parcels (reference parcels) in the Member States of the European Union. LPIS is a key control mechanism under the CAP and was introduced to verify eligibility for area subsidies (Zimmermann et al., 2016). There are currently 44 national and regional LPIS blocks covering more than 135 million reference parcels in 28 Member States.

LPIS represents the vector boundaries of the agricultural landscape and carries information on the unique code, area, crop/land use, ANC (areas with natural or other special constraints), which are used as a reference for farmers' applications, for administrative and cross-checks, as well as for on-the-spot and remote sensing (RS) inspections. In the Slovak Republic, the LPIS land register is based on land parcels, which represent agricultural areas with more or less stable natural or artificial boundaries and a single crop. This type of reference parcel may contain several crops, groups of

 https://doi.org/10.15414/2022.9788055225029

crops and constitutes the basis for the use of direct payments for one or more applicants. Within the GSAA subsidy information system, LPIS contains information on the identification number of the square (clade) under which the LPIS block in a given area falls, map sheet number, location, work code, total work area, type of ANC (natural constraints) areas, work culture, declared work area, declared ANC area, code of support requested (e.g. sugar beet, vegetable, fruit), crop code and name, and age of the crop (VÚPOP, 2018).

The aim of this paper is to present the tasks, basic steps and outline the problems in creating LPIS blocks as a support for applications for direct payments.

Material and methods

The basis for the processing of the article are the basic legislative and methodological regulations defining the frameworks for updating and using LPIS in subsidy schemes. The following materials were used:

- Regulation (EU) No 1306/2013 of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy.
- Commission Delegated Regulation (EU) No 640/2014 supplementing Regulation (EU) No 1306/2013 of the European Parliament and of the Council as regards the integrated administration and control system, the conditions for refusal or withdrawal of payments and administrative sanctions applicable to direct payments, rural development support regulations and cross-compliance.
- Government Regulation No. 75/2015 Coll., laying down rules for the provision of support in connection with measures under the rural development programme.
- Slovak Government Regulation No 342/2014 Coll. laying down rules for the provision of support in agriculture in connection with decoupled direct payment schemes.
- Slovak Government Regulation No 36/2015 Coll. laying down rules for granting support in agriculture in connection with coupled direct payment schemes, as amended.
- Act No. 280/2017 Coll. on the provision of support and subsidies in agriculture and rural development and on amendment of Act No. 292/2014 Coll. on the contribution provided from the European Structural and Investment Funds and on amendment and supplementation of certain acts, as amended.

- Methodology for updating and maintaining the LPIS register in cooperation with the National Agricultural and Food Centre and the Research Institute of Soil Science and Soil Conservation 2018.

We have targeted the methodological steps to the main tasks that can significantly influence/complicate the applications of the different actors. We have addressed the processes outlined in Figure 1.

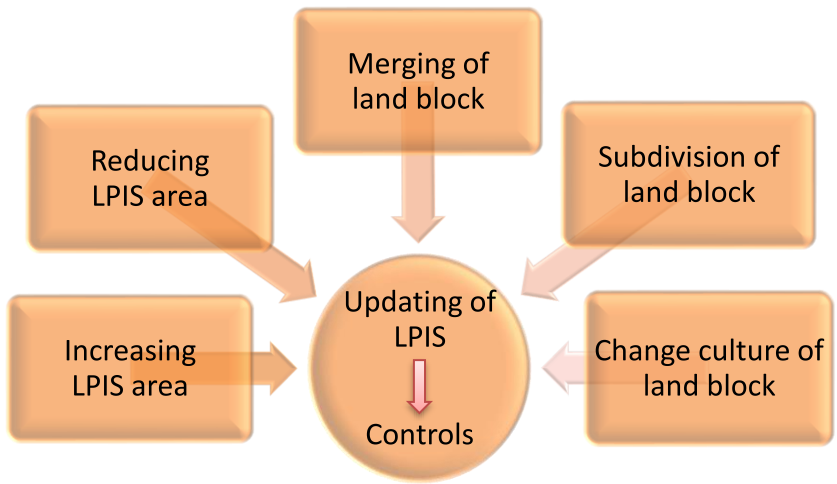


Figure 1 Methodological steps for the creation of LPIS land blocks

Results and discussion

The LPIS, as a set of reference areas forming the basis for applications for direct payments, needs to be changed in accordance with the current state of land use. According to the Slovak Government Regulation No. 280/2017 Coll. on the provision of support and subsidies in agriculture and rural development, it is necessary to carry out regular reassessment of LPIS on the basis of various documents. The process of updating geographic databases is a very important element of system maintenance and should be adapted to the type of data stored. The role of the farmer in updating the LPIS is clearly defined in Commission Regulation No 1122/2009, Article 12(4), which states that he has to correct the pre-printed graphic material at the time of application if there are any changes to his parcel or if any of the information in the graphic material is incorrect or out of date. In moreover, if the correction concerns the area of a reference parcel, then the farmer must declare the actual area of each agricultural parcel concerned and, if necessary, provide the new boundaries of the reference parcel. LPIS systems are now expanding their scope towards the second pillar of the CAP - sustainable rural development that respects environmental and social needs. However, the domain is not very well known to the general geoinformation community, and there are few scientific publications dealing with geoinformatic aspects in this sector (Milenov a Kay, 2006; Sagris et al., 2008).

The LPIS is updated according to the real use of agricultural areas so as to maintain the basic definition of a part of a land block as a polygon defined by natural or artificial boundaries with a single crop. Areas not used for agricultural purposes are not eligible for direct payments. Following the cyclical update of the LPIS, the PPA is registering increased requests for LPIS adjustment due to the reduction of the area of a part of a land block below 0,30 ha, as such parts of land blocks do not meet the condition of minimum continuous area for granting direct payments. When updating the LPIS, the PPA based on the current orthophotos, which were taken during the growing season of 2021, therefore it is necessary for applicants for direct payments to check and evaluate their areas on the new basis. In this context, it is also necessary for applicants to check their areas in the field to ensure that they meet all eligibility conditions. If applicants, after checking their boundaries of use on the current orthophotos and in the field, find a discrepancy, they can contact the relevant PPA unit, which will check the request and provide an opinion on the facts.

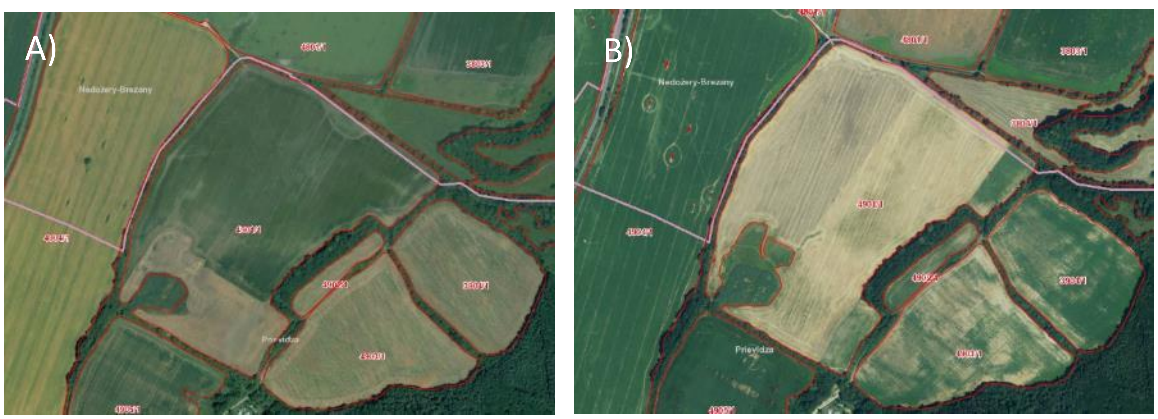


Figure 2 Changes to LPIS blocks A) Campaign year 2020, B) Campaign year 2022 (GSAA, 2022)

In Figures 2 and 3, we can see the change in LPIS boundaries, which are supported by an orthophotograph current for the 2020 campaign (Figure A) and the 2022 campaign (Figure B). In Figure 2 B), the LPIS update of the land block reduced the area by 1.31 ha. We assume that the applicant did not farm that part of the land block between 2017 and 2020 due to periodic waterlogging, and based on this, he adjusted the boundary of use for which he claimed a subsidy each year (Figure 2 A). Consequently, the LPIS block area was reduced for the 2022 campaign based on actual orthophotos that were taken during the 2021 growing season.

In Figure 3 B), there was a subdivision of the LPIS block into two separate land blocks in the 2022 campaign. Between land blocks 3606/1 and 3601/1, a parcel of land registered in Register C has been created and is currently being developed with houses. Compared to Figure 3 A), we can see that there is an embankment of soil added to the lower edge of land block 3601/1, which was left there by the adjacent landowner. However, a situation arose that when the area was surveyed and the LPIS blocks subsequently updated, this part was excluded. The applicant for direct payments lost 1,08 ha of agricultural land.

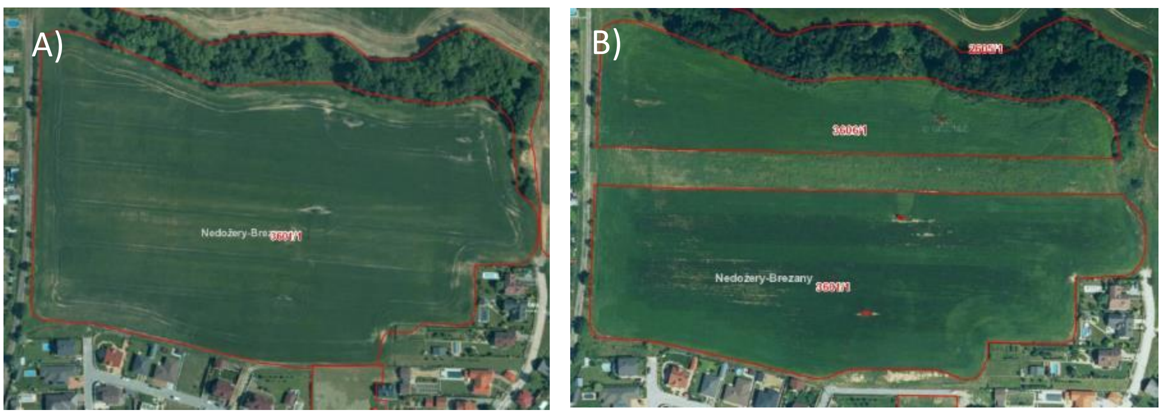


Figure 3 Changes to LPIS blocks A) Campaign year 2020, B) Campaign year 2022 (GSAA, 2022)

Among the primary changes in the area of LPIS land blocks is an increase due to the presence of new eligible areas. This happens when a cultivated area is identified which is not included in the LPIS, whereby either a new part of the land block is created, or an existing land block is increased to include the part that is currently cultivated.

The LPIS area is being reduced due to the presence of unsuitable areas. The removal of unsuitable area from the LPIS is preceded by a check on its duration. All areas that are not used for agricultural purposes and have a duration of more than 1 year are removed from the LPIS. In practice, these areas have a duration of 3 years in most cases, as they are mainly removed during the cyclical update of the LPIS based on orthophoto maps, which is carried out every three years. Exceptions are structures that are removed from land blocks regardless of their duration. When updating the LPIS, consideration must also be given to the maximum tree density rule, which must not exceed 100 trees per hectare. Groups of trees that impede agricultural activity (mowing or grazing) and

 https://doi.org/10.15414/2022.9788055225029

have an area larger than 100 m^2 are considered unsuitable, even if their density in relation to the total area is less than 100 trees per hectare. Exceptions are landscape features delineated on arable land (PPA, 2022).

The merging of land blocks occurs when the same crop is found on adjacent land blocks or when the obstacle that formed the boundary of the land block has disappeared. The division of land blocks occurs where an unsuitable area is found crossing the whole block and its exclusion results in the division of the part. The second reason is the detection of two or more cultures located on a land block. The plot is divided, and the culture of the new land block is determined. At the same time, a change of culture on a block of land occurs when a culture other than the one specified for the block of land is found, taking into account the actual use and the culture indicated by the applicant in the application. A change of culture also occurs on a block of land with arable land on which grass and other forage crops and fallow land have been declared for 5 years. The change to arable crops occurs if they have been used and declared in the above way for 5 years without interruption and do not fall within areas of ecological interest.

In Table 1 we can see that there has been a steady decline in the area of LPIS blocks in Slovakia from 2017 to 2021. In Table 1 we can notice that compared to 2017, the first decrease in LPIS block area has already occurred in 2019, by 14.62 %, which amounts to 545 028 ha of land. However, the reduction of LPIS block areas also occurred in the next years. Currently, there is a further decrease in area of 4.23 % as of 2019, which amounts to 157 792 ha of land. We anticipate that the area of LPIS blocks in Slovakia will continue to trend decline.

Table 1 Area of LPIS blocks for the years 2017 to 2021

Year	Area (ha)	Area (%)
2017	3 727 021,28	100,00
2018	3 727 021,42	99,99
2019	3 181 993,31	85,38
2020	3 171 705,83	85,10
2021	3 024 201,45	81,14

Quality control of the LPIS is carried out continuously throughout the campaign as part of the LPIS management and data submission. In case of differences between the plotted LPIS in the GSSA system and the real LPIS, it can be reported to the Agricultural Payment Agency (APA). These are primarily reported by the users of the LPIS blocks themselves who apply for subsidies. The applicant may not apply for a payment for an area which is outside the LPIS blocks. If there is a situation where an applicant is using an area outside the LPIS, he can also apply for an extension of the LPIS when applying for direct payments in the GSAA. NPPC - VÚPOP (National Soil and Food Research Centre - Research Institute of Soil Science and Soil Protection) will examine the possibility of extending the LPIS on the basis of available orthophoto maps and satellite scenes. If the photointerpretation is able to identify these areas as suitable and to identify the required crop, the NPPC-VÚPOP will update the LPIS for the current campaign. The extension of the LPIS shall be carried out either by increasing the area of the existing part of the land block or by creating a new part of the land block. Otherwise, it shall reject the update. The NPPC - VÚPOP shall keep a list of these parts. It then forwards the list to the Agricultural Payments Agency (APA), which verifies the area and suitability of the plots during an on-the-spot controls. A reduction in the area of a part of a land block may also be made when unsuitable areas of more than 100 m^2 are removed. In the case where the entire area of the land block is unsuitable, it shall be cancelled. The NPPC - VÚPOP shall make an update to the current campaign, maintaining a list of the land blocks this extinguished.

<u>On – site controls</u>

This is the integration of changes identified during the campaign by on-the-spot controls carried out by the staff of the Agricultural Payment Agency (APA) or by external entities entrusted with on-the-spot controls. The results of the on-the-spot checks (measurements made by GPS) shall be provided by the APA Control Section to NPPC - VÚPOP in .shp format and the supporting form in .xlsm format. The results of the on-the-spot controls shall contain the areas in ha to two decimal places. Updating can be done as necessary for the current campaign or for the next application campaign as specified in the document. The most frequent checks are carried out in the case of an increase in the area of the LPIS block or the creation of a new LPIS block by the user making an application to the APA. Before approving the application, the APA sends a staff member to carry out a field reconnaissance and to find out more about the reasons for making the changes.

The most common problems that occur during on-site control of LPIS blocks include:

- Loss of precision (GPS signal failure) - Incorrect plotting of the actual boundary.
- Time consuming.
- In the case of a large number of permanent exclusions, there is a risk of missing the exclusion.
- Non-availability (invisibility) of permanent exclusions (column, concrete manhole) e.g. in corn stands.

 https://doi.org/10.15414/2022.9788055225029

- Non-availability of LPIS - fencing e.g. in orchad, loss of orientation in the terrain.

Remote sensing controls

This is to incorporate changes identified during the check on the eligibility of the area support using the remote sensing (RS) method. The RS is carried out by NPPC - VÚPOP as a delegated activity for the PPA.

The most common problems that occur during the control of LPIS blocks by remote sensing include:

- Low precision in determining the real boundary, especially for blocks bounded by forest cover.
- Ambiguity of the LPIS division for different crops (grasses on arable land - permanent grassland).
- Ambiguity in the exclusion of temporary and permanent exclusions (e.g. mobile apiary).
- Ambiguity in the identification of ineligible areas (unmown permanent grassland, waterlogged areas).
- Ambiguity in the exclusion of roads on arable land and permanent grassland.

Conclusions

The aim of this paper is to present the tasks, basic steps and outline the problems in creating LPIS blocks as a support for applications for direct payments. The main steps in the creation of LPIS blocks include cyclical updating, which takes place in three-year cycles, every year on approximately one third of the territory of the Slovak Republic. The base is orthophoto maps taken during the growing season. The information from orthophoto maps is complemented by information from satellite imagery (satellite scenes), which is supplied annually for selected areas for inspection by remote sensing. The update of the LPIS is the incorporation of changes in agricultural land use identified from the new layer of orthophoto maps and satellite scenes. These include in particular the exclusion of areas that are no longer agricultural land; the current correction of the boundaries of the parcels and the extension of the LPIS; the subdivision of the parcels according to the current culture. If there is a situation where it is not possible to determine the LPIS boundary on the basis of the orthophotos, in this case an employee of the Agricultural Payments Agency (APA) will be sent to carry out an on-the-spot control. The most common problems that arise when checking LPIS blocks using remote sensing include low accuracy of determining the real boundary, especially for parts that are bounded by forest cover, as well as ambiguity of LPIS division for different crops and ineligible areas. When checking LPIS boundaries on the spot, APA employees are often confronted with loss of accuracy and loss of GPS signal, which results in inaccurate drawings of the real boundaries. Reconnaissance of the terrain is time consuming and many LPIS blocks are unavailable due to fencing. We expect that the problems outlined and the method of updating LPIS blocks have contributed to a significant decrease in the area of LPIS blocks. Since 2017, there has been an 18.86 % decrease in the area of LPIS blocks in Slovakia, representing 702 820 ha of land.

Acknowledgement

Work was supported under the Integrated Infrastructure Operational Program for the project: "Data and knowledge support for decision-making and strategic planning systems for adapting agricultural land to climate change and minimizing agricultural land degradation" (code ITMS2014 + 313011W580), co-financed by the European Parliament's Regional Development Fund.

References

GSAA. 2022. Available on internet: https://gsaa.mpsr.sk/2022/.

KAY, S. – MILENOV, P. 2008. Status of the Implementation of LPIS in the EU Member States. Technical Report, European Commission – JRC.

POČIVAVŠEK, G. – LJUŠA, M. 2011. Characteristics of Main Components of the Agricultural Information System, Publisher: Hambrook Publishing Company, London. ISBN 978-0-907833-05-5.

PPA - The Agricultural Paying Agency. 2022. Slovakia. [cit. 2022-04-29]. Available on internet: https://www.apa.sk/aktuality/oznmenie-iadateom-o-priame-podpory-vsvislosti-s-aktualizciou-lpis/11443.

SAGRIS, V. et al. 2008. New Evidence of Land Management in the Frame of Common Agricultural Policy: needs for Standardization. Peer reviewed paper in Conference Proceedings: FIG Working Week – Integrating Generations; Stockholm (Sweden). International Federation of Surveyors, ISBN 978-87-90907- 67-9.

VÚPOP - Research Institute the State of Soil Science and Soil Conservation. 2018. Methodology of LPIS. Slovakia. [cit. 2022-04-30]. Available on internet: https://www.vupop.sk/data/metodika-LPIS-2018.pdf.

ZIMMERMANN, J. et al. 2016. Assessing land-use history for reporting on cropland dynamics a comparison between the Land-Parcel Identification System and traditional inter-annual approaches. Land Use Policy , vol. 52, pp. 30-40. [cit. 2022-05-01]. Available on internet: https://doi.org/10.1016/j.landusepol.2015.11.027.

Act No. 280/2017 Coll. on the provision of support and subsidies in agriculture and rural development and on amendment of Act No. 292/2014 Coll. on the contribution provided from the European Structural and Investment Funds and on amendment and supplementation of certain acts, as amended.

Commission Delegated Regulation (EU) No 640/2014 supplementing Regulation (EU) No 1306/2013 of the European Parliament and of the Council as regards the integrated administration and control system, the conditions for refusal or withdrawal of payments and administrative sanctions applicable to direct payments, rural development support regulations and cross-compliance.

Government Regulation No. 75/2015 Coll., laying down rules for the provision of support in connection with measures under the rural development programme

Regulation (EU) No 1306/2013 of the European Parliament and of the Council on the financing, management and monitoring of the common agricultural policy.

Slovak Government Regulation No 342/2014 Coll. laying down rules for the provision of support in agriculture in connection with decoupled direct payment schemes.

Slovak Government Regulation No 36/2015 Coll. laying down rules for granting support in agriculture in connection with coupled direct payment schemes, as amended.

Contact address: Ing. Petra Pipíšková, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Institute of Landscape Engineering, Hospodárska 7, 949 76 Nitra, Slovakia, pipiskova.petra@gmail.com.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 16.05.2022
Received in revised form 31.05.2022
Accepted 01.06.2022

AN INTEGRATED APPROACH TO ASSESSING THE CONTEMPORARY USE OF AGRICULTURAL LAND BLOCK

Dávid DEŽERICKÝ[1], Petra PIPIŠKOVÁ[1], Peter MICHAL[1,2]

[1]Slovak Agriculture University in Nitra, SLOVAKIA

[2]Agricultural Payment Agency, SLOVAKIA

Abstract

Surface runoff is frequently caused by management and frequent changes in land use, which can increase the intensity of water erosion in the region. By calculating water erosion using the USLE model in the environment of geographic information systems (GIS), we can detect or map erosion-prone areas and subsequently evaluate and classify their vulnerability. The aim of this work is to integrate GIS and subsequently to evaluate and propose measures on the example of a land block in the cadastral territory of Ratnovce. The method for determining water erosion was a modified USLE equation. The input data used were the R factor values for the ombrographic stations, the soil vulnerability to water erosion derived from the main soil units, the topographic features derived from the DMR 5.0 digital elevation model and finally the landscape cover from the public office of geodesy, cadaster and cartography. The model resulted in a calculated long-term annual soil loss for the catchment area derived to a given land block with a maximum value of 316 $t.ha^{-1}.yr^{-1}$ and an average value of 1.63 $t.ha^{-1}.yr^{-1}$, with a maximum value of 47.75 $t.ha^{-1}.yr^{-1}$ in the land parcel itself. Therefore, we decided to design transverse measures in the form of depression terraces to regulate the erosivity of the slope.

Keywords: water erosion, land use, USLE, GIS

 https://doi.org/10.15414/2022.9788055225029

Introduction

There are 13.003 million hectares of land in the world, including 4.889 million hectares categorised as agricultural land. According to the FAO (2013), these 4.889 million hectares of agricultural land are divided into three categories: arable land 28 %, permanent crops 3 % and permanent grasslands/pastures and meadows on which 95 % of the world's food production depends. Agriculture is one of the primary drivers of soil and environmental degradation, with cascading effects such as nutrient loss, reduced carbon storage capacity, fragmentation, and decay of biodiversity, and last but not least, erosion (Robinson, Borrelli, 2017,2020). According to O'Neal and Borrelli (2005, 2017), semi-natural cropland ecosystems and actual changes in the hydrological cycle caused by climate change are the main erosion triggers, which and thus potentially cause about half of global water erosion. Water erosion is the most significant cause of physical soil degradation in Slovakia, according to Kobza and Petlušová (2017,2021) water erosion affects 38-40 % of arable land in Slovakia. This problem is largely caused by the historical development of Slovakia as a highly fragmented ownership, remnants of the socialist period in the form of large homogeneous land blocks with inappropriate land management. The combination of these problems and the rugged terrain of Slovakia creates ideal conditions for the formation of water erosion. One of the most appropriate methods to simulate soil loss is universal soil loss equation - USLE established by Wischmeier and Smith (1978). USLE is considered as the best model and is being used worldwide for the estimation of surface erosion generated by water. By incorporating model USLE into of Geographical Information Systems we can map erosion-prone areas, provide spatial dispersion of different factors governing water erosion (Jemai, 2017) and subsequently developing adequate measures, because of its capacity to interpret spatial information at any scale and location (Tahouri et. al., 2022). In practice, after the identification of places at risk of erosion, erosion control measures should be taken to reduce or eliminate adverse surface runoff and especially water erosion. It is necessary to design control measures that are based on the natural character of the landscape with its characteristic green features to increase ecological stability.

Material and methods

The subject of the analysis and subsequent proposal of measures was selected agricultural parcel LPIS 4909/1 with an area of arable land of 14.79 ha. The parcel is in cadastral territory Ratnovce, which is on the left bank of the Váh River in the Dolné Považie region approximately 4 km from the district town of Piešťany (x: - 515 110.15 m to -514 405.30 m y: -1 239 377.45 m to -1 239 924.48 m). As the erosion control measures depend to a large extent on the rainfall-runoff processes in land, it was necessary to derive a sub-catchment to the given parcel. Using hydrological analyses in ArcGis Pro 2.9 software, an orographic watershed of the sub-catchment area of 1.44 km^2 was derived.

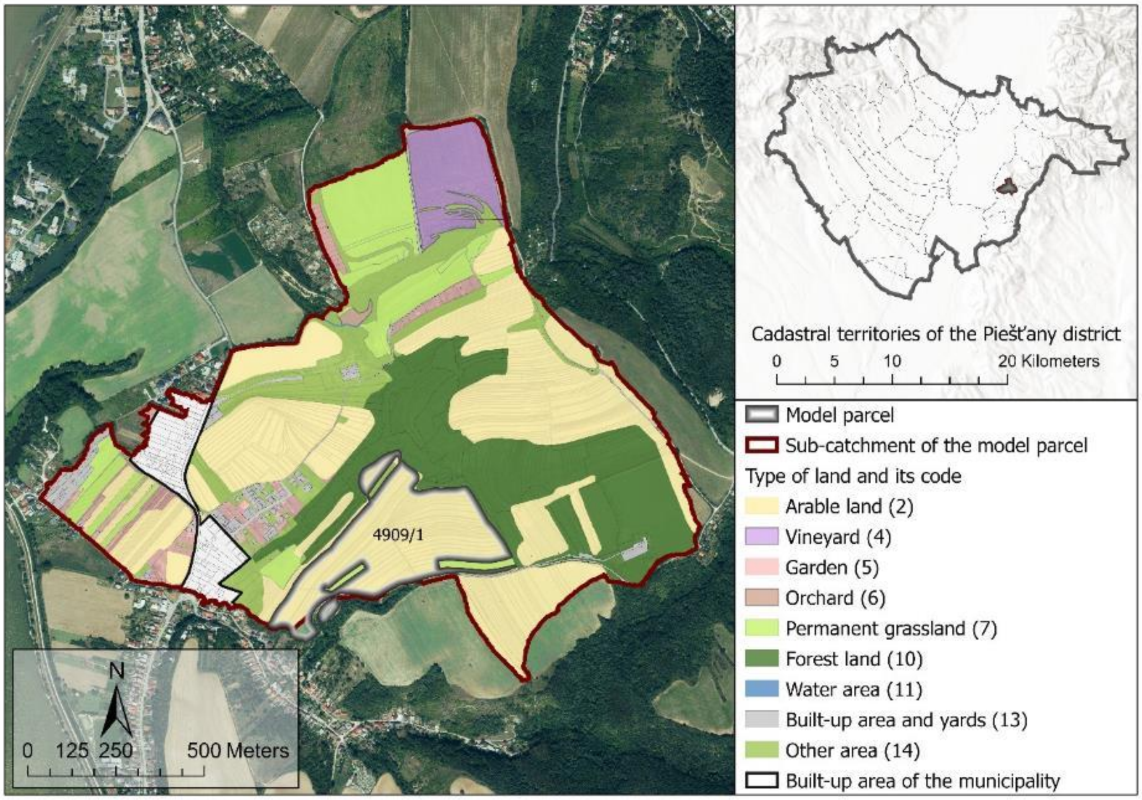


Figure 1 Map of the wider area of interest

From the geomorphological point of view, the sub-catchment begins in the geomorphological sub-unit of the Inovec foothills with a maximum altitude of 290 m (geomorphological unit Považský Inovec), which leads into the sub-unit of the Dolnovažská alluvium with the lowest point at 154 m above sea level (geomorphological unit Podunajská Pahorkatina), where the average slope of the sub-catchment is 8.5° (14.88 %) with a maximum slope length of 2369.25 m. Climatically, the area is classified into two climatic districts: the alluvial area into a warm, very dry, lowland climate and the foothill area into a sufficiently warm, dry, hilly climate. For both areas, the mean annual temperature is 9.5 °C and the mean rainfall is 575 mm (Atlas SR, 2002). On the pedological side, the basin is made up of 109.87 ha of agricultural soil fund, which is made up of deep soils (60 cm or more), without skeletal content (<10 %), where, according to main soil units (HPJ), the highest representations are Cutani-Haplic Luvisols and Calcic Luvisols and Calcaric Fluvisols. Based on the available data from the Cadastre, arable land is the most represented among the land types, accounting for 49 % of the land types. The second largest representation is other areas, which are mainly composed of non-forest woody vegetation, and the third largest representation in the area is permanent grassland with 12 %.

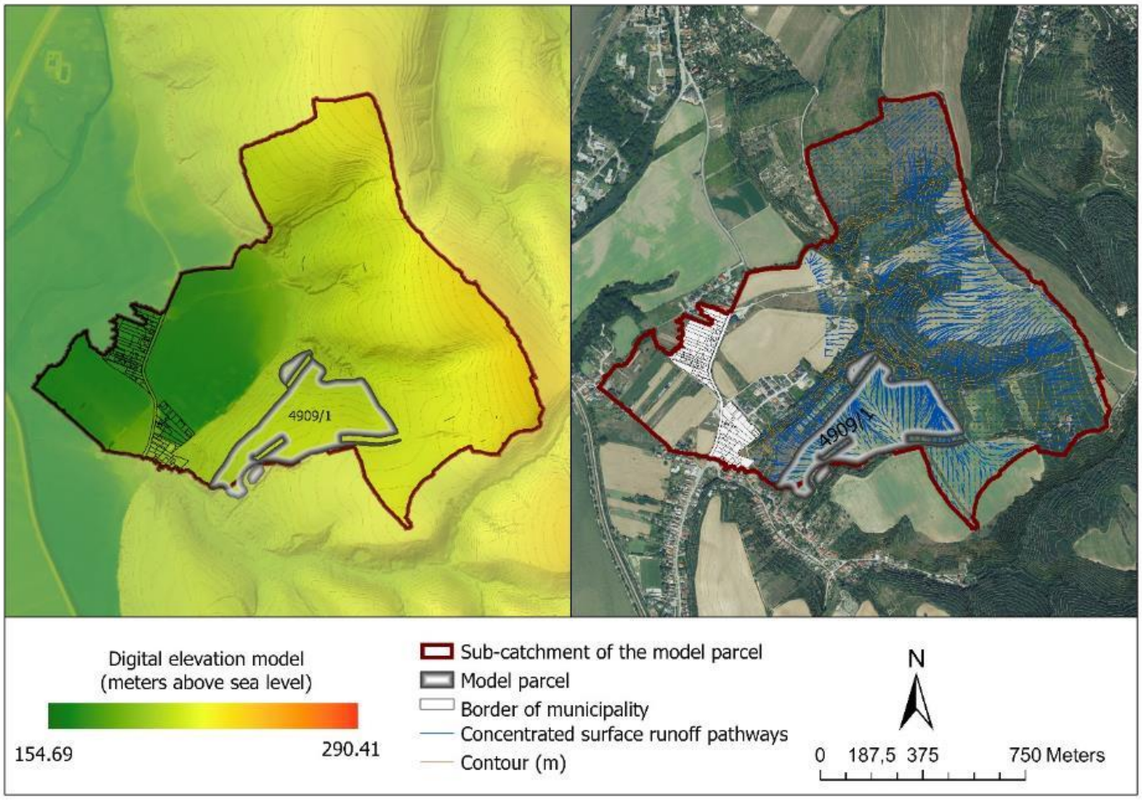


Figure 2 Representation of the digital elevation model and concentrated runoff pathways

<u>Assessment of the average annual soil loss by USLE</u>

The USLE soil loss equation (Wischmeier and Smith,1978) was used to determine the predicted average annual soil loss, which operates on the principle of rainfall impacting the soil surface where it disturbs the soil surface and subsequently carries soil sediments down the slope base.

$\mathrm{A} = R.K.L.S.C.P$ (Equation 1: Universal soil loss equation, Wischmeier, Smith, 1978)

where: A - long term average annual soil loss ($t.ha^{-1}.yr^{-1}$),

R - rain erosion efficiency factor ($MJ.ha^{-1}.cm.yr^{-1}$),

 https://doi.org/10.15414/2022.9788055225029

K - soil erodibility factor ($t.MJ^{-1}$),

LS - slope length-gradient factor (topographic factor) (-),

C - vegetation and management factor (-),

P - support practice factor (-).

The R factor is calculated by multiplying the rain's total kinetic energy by its maximum 30-minute intensity. For our calculations, we used the R factor value from the work Update of the erosive rain factor in Slovakia using data from the period 1961–2009 by Onderka, Pecho (2019). R factor value for nearest meteostation is estimated 25.17.

The K factor is defined as the soil runoff per unit of rainfall factor R from a single unit of land. The K factor was derived from the main soil units (HPJ) from a spatially defined map of the Bonito soil-ecological units (BPEJ) to which indicative values of soil susceptibility to water erosion were assigned by Ilavska et.al. (2005). K factor values are ranging from 0.20-0.72 (-).

Slope length factor L and gradient factor S are combined to form the topographic factor LS. The LS factor is calculated by substituting the area's spatial parameters into the relation:

$$LS = \sqrt{d}.(0.0138 + 0.0097.Is + 0.00138.Is^2)$$

(Equation 2: Equation for calculating the topographic factor LS)

where: LS - topographic factor (-),

d - the length of the interrupted slope (m),

Is - slope gradient (%).

Vegetation and management factor C - The C factor values are subdivided into several tables based on individual crops, precursors, agrotechnical treatment, and time. Based on e-mail correspondence with a local farmer, we were able to obtain information on the crops grown in our case. Crops grown in the model catchment were spring barley (0.15), sown oats (0.10), winter wheat (0.12), grassland (0.003) and for vineyards (0.80). Gardens and orchards have not been included due to their occurrence in the area around the municipalities of the village on flat terrain.

The P-value factors reflects the efficacy of erosion control measures, which are designed to reduce or eliminate the erosive action of water on the modelled land through organizational, agrotechnical, and technical measures. Because no erosion measures have been detected in the area, the factor's value was set to P=1.

Results and discussion

The modified soil loss equation of the USLE model was used to assess the erosion vulnerability of the area, in which all factories were fitted except factor P, since no special measures were recorded in the area. As a result of the model, the water erosion intensity for the sub-catchment of the parcel was calculated. The vineyards in the northern part of the sub-catchment showed the highest soil loss, where the highest soil loss value of 316 $t.ha^{-1}.yr^{-1}$ was obtained. The mean value shows 1.63 $t.ha^{-1}.yr^{-1}$ and standard deviation 4.79 $t.ha^{-1}.yr^{-1}$. As for the model parcel the highest land loss is 47.75 $t.ha^{-1}.yr^{-1}$ and the mean loss is almost 2 tons. The graphical visualization of the resulting USLE model of its threatened sites is shown in Figure 3.

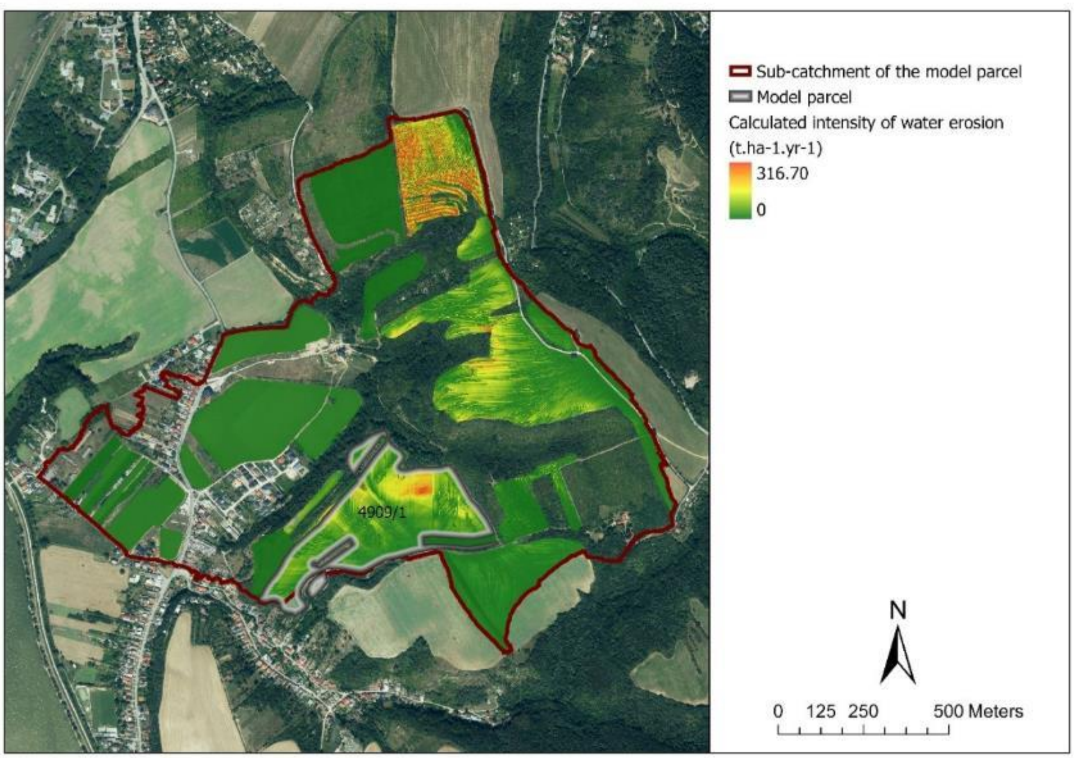


Figure 3 Calculated intensity of water erosion, P=1

Given that water erosion has been identified on parcel 4909/1 and subsequently confirmed by the USLE model, we are proposing 2 shallow passable depression terraces on that parcel. The first depression terrace is proposed between elevations 215-220 with a width of 8m as it is located on a slope of up to 8 %. The second depression terrace is proposed at between elevations 200-205 with a width of 6 m due to the average slope of up to 18 %. Both terraces have been designed to reduce the length of the slope and thus control erosion on the slopes. Another function is to capture surface runoff and cross drain it away from the slope. It should be noted that the design of the depressed terraces was designed to theoretically shorten the length of the slope, for a rigorous design it is necessary to size the measure in question for the design rainfall and surface runoff.

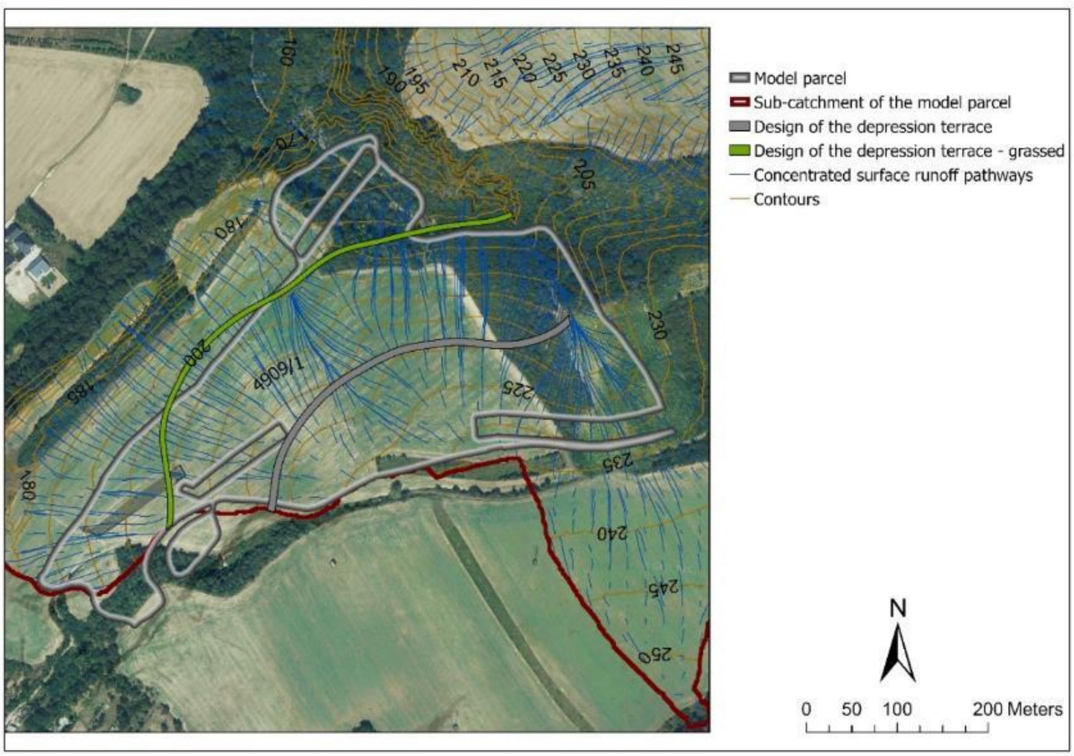


Figure 4 Location of the proposed measures

Table 1 Comparison of soil loss before and after the design of depressed terraces

Soil loss ($t.ha^{-1}.yr^{-1}$)	Area (ha)	Percentage of soil loss (%)	Area (ha)	Percentage of soil loss (%)	Difference (%)
<1.00	4,43	31,71	4,83	36,01	4,30
1.01-5.00	8,14	58,25	7,74	57,69	-0,56
5.01-10.00	1,35	9,64	0,84	6,29	-3,35
10.01-20.00	0,06	0,40	0,00	0,00	-0,40
20.01-50.00	0,00	0,00	0,00	0,00	0,00
50.01-100.00	0,00	0,00	0,00	0,00	0,00
>100.01	0,00	0,00	0,00	0,00	0,00
∑	13,98	100,00	13,41	100,00	0,00

Conclusions

The relevant data were acquired based on the elevation and planimetry of the area to calculate the intensity of water erosion, which was calculated in a GIS context using the universal equation USLE. When calculating the intensity of erosion, we created a map report determining the calculated intensity of water erosion, based on which we localized and determined the erosion drift in the area. In combination with the concentrated runoff paths and the erosion hazard maps, we proceeded to design the depression terraces that shorten the length of the slope and thus regulate the erodibility of the slope. Following the design, soil erosion on the model parcel was reduced to approximately 30 $t.ha^{-1}.yr^{-1}$ from the original 47.75 $t.ha^{-1}.yr^{-1}$.

Acknowledgment

"This publication is the result of the project implementation: „ Scientific support of climate change adaptation in agriculture and mitigation of soil degradation” (ITMS2014+ 313011W580) supported by the Integrated Infrastructure Operational Programme funded by the ERDF."

References

ATLAS KRAJINY SLOVENSKEJ REPUBLIKY, 2002. Bratislava: Ministerstvo životného prostredia Slovenskej republiky; Banská Bystrica: Slovenská agentúra životného prostredia, 2002. 342 s. ISBN 80-88833-27-2.

BORRELLI, P. et. al. 2020. Land use and climate change impacts on global soil erosion by water (2015–2070). PNAS 117(36):21994–22001. https://doi.org/10.1073/pnas.2001403117

FAO. Healthy soils are the basis for healthy food production. 2015. (Food and Agriculture Organization of the United Nations [FAO], 2015), pp. 1–4. http://www.fao.org/documents/card/en/c/645883cd-ba28-4b16-a7b8-34babbb3c505/

O'NEAL, M. R., et al. 2005. Climate change impacts on soil erosion in Midwest United States with changes in crop management. Catena, 61.2-3: 165-184. https://doi.org/10.1016/j.catena.2005.03.003

ILAVSKÁ, B. et al. 2005. Identifikácia ohrozenia kvality pôdy vodnou a veternou eróziou a návrhy opatrení. Bratislava: VÚPOP , 2005. 60 s. ISBN 80-89128-28-22-x.

JEMAI, S. et al. 2021. Soil Erosion Estimation in Arid Area by USLE Model Applying GIS and RS: Case of Oued El Hamma Catchment, South-Eastern Tunisia. J Indian Soc Remote Sens 49, 1293–1305. https://doi.org/10.1007/s12524-021-01320-x

KOBZA J. et al. 2017. Current State and Development of Land Degradation Processes Based on Soil Monitoring in Slovakia. Agriculture (Pol'nohospodárstvo), Vol.63 (Issue 2), pp. 74-85. https://doi.org/10.1515/agri-2017-0007

ONDERKA, M. - PECHO, J. 2019. Update of the erosive rain factor in Slovakia using data from the period 1961–2009, Contributions to Geophysics and Geodesy, 49(3), pp. 355-371. https://doi: 10.2478/congeo-2019-0018.

PETLUŠOVÁ, V. – PETLUŠ, P. – ŠEVČÍK, M. – HREŠKO, J. 2021. The Importance of Environmental Factors for the Development of Water Erosion of Soil in Agricultural Land: The Southern Part of Hronská Pahorkatina Hill Land, Slovakia Agronomy 11 1234: http://dx.doi.org/10.3390/agronomy11061234

ROBINSON, D. A. et al. 2017. Soil natural capital in Europe; a framework for state and change assessment. Scientific reports, 2017, 7.1: 1-14.

TAHOURI, J. - SADIKI, A. - KARRAT, L. et. al. 2022. Using a modified PAP/RAC model and GIS-for mapping water erosion and causal risk factors: Case study of the Asfalou watershed, Morocco. International Soil and Water Conservation Research, Vol. 10 (Issue 2) pp. 254-272. https://doi.org/10.1016/j.iswcr.2021.07.003

WISHMEIER, W. H. – SMITH, D. 1978. Predicting rainfall erosion losses. Hystaville MD: SEA USDA, 1978. 58 p.

Contact address: Ing. Dávid Dežerický, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Institute of Landscape Engineering, Hospodárska 7, 949 01 Nitra, Slovakia, xdezericky@uniag.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 17.05.2022
Received in revised form 31.05.2022
Accepted 01.06.2022

COMPARISON OF SLOVAK AND CZECH STAGES OF LAND CONSOLIDATION PROJECTS

Alexandra PAGÁČ MOKRÁ[1], Jakub PAGÁČ[1], Jozefína POKRÝVKOVÁ[1]

[1]Slovak Agriculture University in Nitra, SLOVAKIA

Abstract

The aim of the paper was to analyse the diversity of methodological procedures of Slovak and Czech land consolidation projects. For better identification and comparison, we have selected cadastral territories that have similar ownership and landscape parameters. Through a detailed analysis of the landscape stages, we found several differences in the stages of the landscaping project. One of the biggest differences is the time taken to process general principles of the functional land rearrangement documentation. Within this stage, the local territorial system of ecological stability is being developed in the Slovak Republic, which is already proposed in the Czech Republic in the zoning plan of the municipality and is taken over into the LC project, where it is subsequently updated. Subsequently, we found out that in Slovakia, the land consolidation project lasted up to 9 years and most of the total cost of the project was spent on geodetic part. On the contrary, in the Czech Republic, the land consolidation project lasted only 6 years and more emphasis in land consolidation is placed on landscape part.

Keywords: land consolidation projects, project stages, Slovakia, Czech Republic

Introduction

Land consolidation (LC) can be defined as planned reorganization, land consolidation and settlement of ownership. Through landscaping, it is possible to improve soil quality and agricultural infrastructure, such as construction of field and forest roads, anti - erosion and water management facilities. Furthermore, it is possible to reduce land consolidation through landscaping while significantly improving land use efficiency (Pašakarnis and Maliene, 2010). One of the main objectives of land consolidation is to ensure food safety and thus contribute to the sustainable use of land resources (Luo and Timothy, 2017). Land consolidation combines fragmented land into a single plot or into larger parts, in a way that reduces fragmentation. Land fragmentation is eliminated in favor of better land productivity, improves rural production and thus living conditions (Du et al., 2018).

According to authors Tezcan et al. (2020) argue that land consolidation is an effective tool in land management that contributes to sustainable rural development. Land consolidation, as we know them in the Slovak Republic (SR), are solved in a similar way mainly in the Czech Republic (CZ), Germany and Austria (Muchová and Konc, 2010). In the Slovak Republic as well as in the Czech Republic, their main task is to create conditions for rational management of landowners and users in accordance with ensuring conditions for improving the environment, protection and fertilization of agricultural land, water management and increasing ecological stability (Žáček, 2013; Izakovičová et al., 2018).

The aim of the paper is to compare the content / process, time, and financial nature of land improvements in Slovakia and the Czech Republic. Based on the results of the comparison, we will try to discuss the need for financial and time reorganization of the current land consolidation projects.

Material and methods

When selecting model cadastral areas between the Slovak Republic and the Czech Republic, the areas where the project of complex land improvements and approximately comparable ownership and landscape parameters were carried out were taken into account. As a model territory in Slovakia was chosen to account. Nýrovce and in the Czech Republic to. ú. Milotice near Kyjov. Complex land consolidation began to be implemented in cadastral area Nýrovce on March 22, 2005, when the decision on the LC regulation was issued. The land consolidation was completed on September 30, 2013, with registration in the cadastre on February 1, 2014. In the village of Milotice near Kyjov, the complex land consolidation began to be implemented on March 5, 2008, when a decision on the land regulation was issued. They were completed on 31 October 2013 with registration in the cadastre on 27 February 2014 (Tab.1). The basic ownership characteristics of the model areas are given in Table 2.

Table 1 Basic information about the LC project in model areas

Name cadastral area	Beginning of the project	Completion of the project	Duration [years]	Area cadastral area	Project perimeter area	Number of plots
Nýrovce	22.03.2005	01.02.2014	9	1 349	1 280	2 594
Milotice near Kyjov	05.03.2008	27.02.2014	6	1 260	1 115	1 398

Table 2 Basic information on ownership before and after project LC in cadastral area Nýrovce and in cadastral area Milotice near Kyjov

	Nýrovce		Milotice near Kyjov	
	before the project LC	after project LC	before the project LC	after project LC
Number of ownership relationships	11 341	889	4 762	2 908
Number of owners	515	517	x	x
Number of plots	2 594	846	1 398	1 050
Average number of co-owners per plot	4,37	1,05	3,41	2,77
Average number of plots per owner	5,04	1,72	x	x
Average plot area [ha]	0,49	1,53	0,89	0,75

The cadastral area of Nýrovce is located in the southern part of Slovakia in the district of Levice, in the Nitra Region. The area of Nitra is 65 km away. The territory of the village of Nýrovce is located in the eastern part of the Danubian Lowland, which is covered by the volcanic mountains Krupinská planina and Štiavnické vrchy. In the solved area, agriculture is the most widespread activity, which is conditioned by suitable natural conditions and excellent climatic conditions with high soil quality. The village has 499 inhabitants (as of 31 December 2019), the population density is 36.99 inhabitants per km^2 (Plán hospodárskeho a sociálneho rozvoja obce Nýrovce, 2008). From a geomorphological point of view, Nýrovce is located at the foot of the Pohronská Uplands in the valley of the Bardoňonský brook. The Nitra region is part of the Alpine-Himalayan system and in the area of interest Nýrovce is geomorphologically divided into the sub-system Pannonian Basin, the province of the West Pannonian Basin, and the sub-province Malá Dunajská kotlina (Hrašna, Klukanová, 2014).

The model area of the village Nýrovce covers an area of 13.49 km2, with an average altitude of 152 m above sea level. m. The dominant representation in the structure of the land fund is arable

 https://doi.org/10.15414/2022.9788055225029

land, which covers 1,151 ha, which represents almost 85 % of the total cadastral area. Degree of maturation in k. ú. Nýrovce is 97 %, which means the share of arable land from agricultural. In Slovakia, it is statistically recorded that the largest decrease in agricultural land (arable land) on non-agricultural land is mainly due to individual housing construction or investment plans. The village of Nýrovce fulfills its residential function mainly by its location to the district town of Levice resp. to the nearest town Želiezovce. The cadastral area of Nýrovce is mostly rural and in recent decades we have not seen any increase in investment or individual housing construction in the village. The reason is the unattractive investment location of the village, accessibility, and also insufficient transport infrastructure. As a result of these factors, arable land has not changed in recent decades. From a climatic point of view, the area belongs to a warm, mildly climatic area, characterized by a dry zone with an average annual temperature of 11 °C and precipitation of an average of 500 mm per year. The average annual air temperature is 9.9 °C (Plán hospodárskeho a sociálneho rozvoja obce Nýrovce, 2008). In the territory of the village, clay soil types predominate, in some places clay arable land without skeleton to weakly skeletal. The main soil types in the area have the largest representation of cultured black earth, eroded and regozeme typical carbonate from loess. The Nýrica watercourse flows through the cadastral area and flows into the Hron River (Maglay, Pristaš, 2014).

The cadastral area of Milotice near Kyjov was chosen as a model area in the Czech Republic. The village is located in the South Moravian Region, Hodonín District, 6 km south of Kyjov. The municipality has 1,885 inhabitants (as of 31 December 2019), the population density is 149.60 inhabitants per km2. In terms of land use in k. ú. Milotice near Kyjov has the largest arable land, which covers 839 ha, which represents almost 66 % of the total cadastral area. Degree of maturation in k. ú. Milotice near Kyjov is 88 %. The structure of the land fund in the village was similar. The village of Milotice belongs to the geomorphological area of the Central Moravian Carpathians and the geomorphological units Kyjovská pahorkatina and Litenčická pahorkatina. The solved area partially extends into the area of the South Moravian Basin, specifically into the Lower Moravian Valley (Atlas krajiny České republiky, 2009). The solved area is located at the foot of the West Carpathian and North Pannonian subprovince. Within the West Carpathian subprovince, these are the Ždánice-Litenčický bioregion and the Chřibský bioregion (Atlas krajiny České republiky, 2009). The area belongs to the warm climate area, which is characterized by very long, warm, and dry summers. Spring and autumn are short, slightly warm to dry (Atlas krajiny České republiky, 2009).

The most widespread in the village is chernozem, brown soil, pararendzina and regoz. Within the Czech Republic, the south-eastern part of the South Moravian Region is one of the most erosively endangered areas. The soil in the whole area of Kyjov, which also includes the solved area of Milotice (Kubík, 2018), is the most endangered by water erosion. Erosion is the result of intensive large-scale farming, which has deprived the country of important stabilizing elements, such as borders, drawbridges or accompanying vegetation of watercourses. The Kyjov hills thus became more susceptible to water and wind erosion, which manifests itself especially on sloping land. The mainstream that flows through the cadastre is the Hruškovice watercourse. There is also a nature reserve Piesočný rybník located about half a kilometer northeast of the village. The geological base of the pond is formed by fine sands and calcareous clays. There are cotton sands on the northern and eastern edges. The total area of the nature reserve is 35.45 ha, of which the water area is about 20 ha (Kubík, 2018).

Stages of land consolidation project in Slovakia

Table 3 Time schedule of the project LC in cadastral area Nýrovce

Stage name	End of stage
Decision to order land consolidation	**22.03.2005**
Minor horizontal geodetic control	31.05.2005
Determining the boundary of the project perimeter	30.05.2005
Thematical mapping of topography	31.08.2007
Thematical mapping of vertical	31.05.2008
BPEJ update	31.05.2008
Register of the original state	31.05.2008
Local territorial system of ecological stability	31.05.2010
General principles of the functional land rearrangement documentation	31.01.2011
Principles of location of new land	30.09.2011
Plan of common facilities and measures	31.03.2012
Distribution plan in the form of a placement and setting-out of a plan	31.10.2012
Realization of the LC project	30.09.2013
Update of the register of the original state and the distribution plan in the form of a placement and setting-out of a plan	31.07.2014
Distribution plan in the form of renewal of the cadastral map by new mapping	31.07.2014
Map work	31.07.2014
Registration in the real estate cadastre	**01.02.2014**

The stages of the land consolidation project in the cadastral area of Nýrovce are elaborated in the time schedule for the land readjustment project (Tab. 3) (zmluvy.gov.sk). LC projects are governed in the Slovak Republic by Act no. 330/1991 Coll. on land consolidation, land ownership arrangements, land offices, land fund and land associations, as amended. The elaboration of design and landscape activities is carried out according to the methodological standards of landscaping design (Muchová et al., 2009).

Stages of complex land consolidation in the Czech Republic

Table 4 shows the stages of the complex land consolidation project of the cadastral area of Milotice (eagri.cz). The valid legal regulation of land regulations is based on Act no. 284/1991 Coll., On land readjustments and land offices, further Decree of the Ministry of Agriculture no. 13/2014 Coll., On the procedure for making land readjustments and the requirements for the design of land consolidation.

Table 4 Time schedule of the project LC in cadastral area Milotice u Kyjova

Stage name	End of stage
Decision to order land consolidation	**05.03.2008**
BPEJ data update	31.10.2009
Revision horizontal geodetic control point	31.10.2009
Detailed measurement of topography	31.01.2010
Detailed measurement of vertical	
Determining the boundaries in the area of complex land consolidation, geometric plan for determining the area of complex land consolidation	31.05.2010
Identification of deficiencies in the real estate cadastre	31.05.2010
General principles of the functional land rearrangement documentation	31.01.2011
Purpose measurement of topography for land consolidation project outside permanent crops	31.01.2011
Purpose measurement of vertical for a land consolidation project in permanent crops	
Elaboration of a proposal for a new land arrangement	30.11.2011
Consideration of a proposal for a new land arrangement	31.05.2012
Land demarcation	31.10.2013
Map work	31.10.2013
Registration in the real estate cadastre	**27.02.2014**

Results and discussion

The stages of the land consolidation project in the Slovak Republic and the Czech Republic were compared on the basis of a thorough study of the objectives, definitions, inputs and outputs of the individual stages. Table 5 shows the activities related to geodetic and cadastral content, which are carried out in the project of land improvements in the Slovak Republic and the Czech Republic.

Table 5 Stages of the land consolidation project and work progress SR and CZ (geodetic part)

SR/CZ	Name stage	Stage duration [months]	Stage price [€/MJ]	Notes
SR	Minor horizontal geodetic control point	2	15 (point)	The stages are similar.
CZ	Revision horizontal geodetic control point	3	175 (point)	
SR	Determining the boundary of the project perimeter	4	140 (ha)	The stages are similar.
CZ	Determining the boundary of the project perimeter	5	168 (bm)	
SR	Thematical mapping of topography	23	160 (ha)	The stages are similar.
CZ	Detailed measurement of topography	3	311 (ha)	
SR	Thematical mapping of vertical	9	30 (ha)	It is performed simultaneously with the altimetry, it is not as detailed in the Czech Republic as in the Slovak Republic, the advantage is free access to ZABAGED data in the Czech Republic.
CZ	Detailed measurement of vertical	10	105 (ha)	
SR	BPEJ update	9	20 (ha)	In the Slovak Republic, the update is performed only for the needs of the LC and only based on visual characteristics; in the Czech Republic, the BPEJ update is performed for the entire cadastral area new soil survey.
CZ	BPEJ data update	3	17 (ha)	
SR	Register of the original state	9	25 (ha)	The statement in the SR is made for each owner separately. In the Czech Republic, there may be more than one owner on one list claim.
CZ	List of claims	15	70 (pcs)	

In both countries, geodetic activities (Table 5) are more or less the same in terms of content. In the Slovak Republic, great emphasis is placed on the accuracy of measuring the purposeful mapping of topography and elevation. As shown in Table 5, measuring topography in the Slovak Republic will take 7.5 times more time than in the Czech Republic, while measuring about half as much territory as in the Slovak Republic. This stage is similar in Slovakia and CZ in terms of content within the activities performed, but they are different in length. When measuring elevation, in the Czech Republic, data from the ZABAGED database are downloaded and they focus on the areas in which the construction of common facilities and measures is expected in more detail.

When carrying out land consolidation, geodetic activities include securing, evaluating, and incorporating data, revising the point field and supplementing the detailed positional point field, detailed topography measurement, finding out the boundaries of the land consolidation area and land boundaries necessary to develop a geometric plan to determine land boundaries land consolidation (Dumbrovský, Mezera, 2000). The register of the original state with the valuation of land is a list and display of all land or their parts in the area of the land consolidation project, with areas and types of land commissioned and in the purpose mapping topography focused and updated. (Vanek, Hudecová et al. 2008). In Slovakia, the purpose of compiling the register of the original state is to obtain an overview of land and ownership relations in the district in the district, as well as to acquaint individual participants about the state with which they enter the land consolidation project. In the Czech Republic, the equivalent state register is the design of new land. When designing new landowners, the designer is based on the list of owners' entitlements, their requirements for new location and must comply with the criteria set by law. This is a quality criterion (price), where it must not be exceeded by 4% of the original quality. However, if the owner agrees to the overrun, this value may be overrun, and the owner will reimburse or reimburse the split.

In the landscape activity (Tab. 6), in the stage of the distribution plan, a proposal for the location of new land and the owner's requirements for the location of new land was discussed with each owner. The general principle of the functional arrangement of the territory belongs to the important phases of the land consolidation project, which represents a long-term initial state of optimal use of the solved area for all activities by which the area creates conditions for their implementation (Pagáč et al., 2019). To increase the ecological stability and biodiversity of the country, the land consolidation project also includes the elaboration of a local territorial system of ecological stability. In Slovakia, the local territorial system of ecological stability is being developed for the purposes of the land consolidation project within the stage of the general principles of the functional layout of the territory as a separate documentation. This stage represents the largest

 https://doi.org/10.15414/2022.9788055225029

share of time in the landscaping activities of the land consolidation project. In the Czech Republic, the local territorial system of ecological stability is already proposed in the municipal zoning plan and is taken over into the land consolidation project. The local ecological stability system is then updated for the land consolidation project (Table 6).

Table 6 Stages of the land consolidation project and work progress SR and CZ (landscape part)

SR/CZ	Name stage	Stage duration [months]	Stage prices [€/MJ]	Notes
SR	Local territorial system of ecological stability	24	12 (ha)	It is processed as a separate stage as a basis for General principles of the functional land rearrangement documentation, in the Czech Republic a separate Local territorial system of ecological stability documentation is not prepared.
CZ	- - -	-	-	
SR	General principles of the functional land rearrangement documentation	8	50 (ha)	The stages are similar.
CZ	Draft plan for common facilities	3	61 (ha)	
SR	Distribution plan in the form of a placement and setting-out of a plan	7	80 (ha)	In the Czech Republic, the process of creating a draft (the criterion of adequacy in area, price and distance) is being addressed. For each plot in the perimeter of the LC project, a value (price) is determined, simpler ownership fragmentation.
CZ	Draft for a new arrangement of the land	18	93 (ha)	
SR	Principles of location of new land	8	9 (ha)	The stage is not carried out independently in the Czech Republic, it is part of the stage of the Draft for a new arrangement of the land.
CZ	- - -	-	-	
SR	Plan of common facilities and measures	6	46 (ha)	In the Slovak Republic, the reworking of the General principles of the functional land rearrangement documentation plan into the detail of the accuracy of the cadastre of real estate map, in the Czech Republic, the draft plan of common facilities and measures is already being made in such accuracy.
CZ	- - -	-	-	

Prior to the project of land consolidation in the cadastral area of Nýrovce, there was no ownership management, because not a single block of agricultural land belonged exclusively to one owner, who would also be its user. In the Nýrovce land consolidation project, agricultural land use blocks for smaller self-employed farmers were created. The land owned by them was placed in these blocks, respectively. their landlords. The result of land consolidation was a change in the owner's relationship to his new ownership - a specific land with defined boundaries. Prior to the land consolidation project, there was a former landfill on the original land in the cadastral area of Nýrovce, where it was jointly owned by more than 200 owners. After land readjustments, the merger of ownership made the land an opportunity for a new owner to make a good investment and turned the land into a riding school (Urban, 2015).

In the Czech Republic, a plan for joint facilities needs to be drawn up before the lands of the owners concerned are proposed. It forms the so-called multifunctional skeleton of land consolidation, which deals with all the problems of the landscape in the area. The aesthetic and landscape assessment of the design is not forgotten in the design. To improve the overall ecological spatial stability of the country, new ecostabilization elements of the territorial system of ecological stability in the cadastral area of Milotice near Kyjov, revitalization of the Hruškovice stream and establishment of a local biocorridor were proposed. Such a connection connects to the ecological network in the surrounding cadastres. Interaction elements have been defined and designed to strengthen the ecological stability as well as other environmental functions of the landscape. A total of 27 interaction elements were defined and designed to be created. Of this number, 18 elements are eco-stabilizing, and 9 elements are of cultural and social importance for strengthening recreational functions and making the landscape accessible. As part of the plan of joint facilities and measures, in. ú. Milotice u Kyjova proposed road network consisting of 27 field roads, of which 2 are included in the category of main field road, 11 in secondary field roads and 14 in additional field roads. There were also 2 main field roads in the area with proposed elements of single-lane purpose-built roads with a width of 4.0 m - category P 4.0 / 30. The road follows the local road and continues through a watercourse. The length of the journey is 1,459 m. Single-lane 3.5 / 20 (4 roads) and 3.0 / 20 (6 roads) were included in the network of secondary field roads, and at the same time these roads were designed to modify the route. The plan of joint facilities included the implementation of 6 bridges, 10 culverts and 15 exits. In addition, a total of 15 farm trips were included in the joint establishment plan, of which 6 represent a trip from the agricultural area to route II. or III. classes.

The total price of the project in the Slovak cadastral territory is approximately 125 euros per ha lower than in the Czech cadastral territory. This difference in the amount in the Czech Republic per hectare is the result of higher costs for landscaping activities. In the Slovak cadastral territory, approximately 10 % more funds were spent on geodetic activities in the land consolidation project compared to the Czech cadastral territory.

Conclusions

In this paper, we compared the content, time, and financial nature of land improvements in the Slovak cadastral area of Nýrovce and in the Czech cadastral area of Milotice near Kyjov. Prior to the implementation of the landscaping project, there were 11,341 ownership relationships in Nýrovce, which decreased by up to 92 % to 889 ownership relationships after the landscaping project. The number of plots before the start of the land readjustment project was 2,594, which decreased by up to 67 % to 846 plots after the land use project. The average plot area increased from 0.49 ha to 1.53 ha and the average number of co-owners per plot decreased from 4.37 to 1.05. In the Czech Republic, the cadastral area of Milotice near Kyjov had up to 4,762 ownership relations before the land improvement project, and after the land improvement project, this number dropped to 2,908 ownership relations. The number of plots before the start of the landscaping project was 1,398, which decreased by up to 25 % to 1,050 plots after the landscaping project was completed. The average plot area decreased from 0.89 ha to 0.75 ha and the average number of plots per owner decreased from 4.14 to 2.71.

Acknowledgment

VEGA 1/0244/21 „Appropriate criteria-based selection of localities for land consolidation respecting environmental aspects”

VEGA 1/0676/22 „Blue-green infrastructure as a water policy tool in the process of adaptation to climate change “

References

ATLAS KRAJINY ČESKÉ REPUBLIKY, 2009. - 1. vyd. - Měřítka různá. - Praha, Průhonice: Výzkumný ústav Silva Taroucy pro krajinu a okrasné zahradnictví, 2009. - 1 atlas (331 s.): ca 1115 barev. map; 62 cm. ISBN 978-80-85116-59-5: Kč 20000,00

CENTRÁLNY REGISTER ZMLÚV SR [online]. [cit. 2020-09-20]. Available on internet: https://www.crz.gov.sk/

DU, X. et al. 2018. Assessing the effectiveness of land consolidation for improving agricultural productivity in China. In Land Use Policy, 70, 2018, pp. 360-367.

DUMBROVSKÝ, M. – MEZERA, J. 2000. Metodický návod pro pozemkové úpravy a související informace. 1.vyd. Praha: Výzkumný ústav meliorací a ochrany půdy Praha, 189s., 2000, ISSN: 1211-3972.

EAGRI POZEMKOVÉ ÚPRAVY CZ [online]. [cit. 2022-04-20]. Available on internet: https://eagri.cz/public/app/eagriapp/PU/Prehled/

HENDRICKS, A. – LISEC, A. 2014. Land consolidation for large-scale infrastructure projects in Germany. Geodetski vestnik. Volume 58. Pages 46 – 68.

HRAŠNA, M. – KLUKANOVÁ, A. 2014. Inžinierskogeologická rajonizácia [online]. Bratislava: Štátny geologický ústav Dionýza Štúra, 2014. Available on internet: http://apl.geology.sk/atlaskrajiny.

IZAKOVIČOVÁ, Z. et al. 2018. Integrated Approach to Sustainable Land Use Management. In Environments, 2018, vol. 5, no 3. Available on internet: https://doi.10.3390/environments5030037

KUBÍK, B. 2018. Územní Plán Milotice 2018. [online]. 2018. [cit. 2022-04-29]. Available on internet:

http://www.mestokyjov.cz/assets/File.ashx?id_org=7843&id_dokumenty=34221

LUO, W. – TIMOTHY, D. J. 2017. An assessment of farmers' satisfaction with land consolidation performance in China. In Land Use Policy, 61,2017, pp. 501-510.

MAGLAY, J. – PRISTAŠ, J. 2014. Kvartérny pokryv [online]. Bratislava: Štátny geologický ústav Dionýza Štúra, 2014. Available on internet: http://apl.geology.sk/atlaskrajiny.

MUCHOVÁ, Z. – KONC, B. 2010. Pozemkové úpravy – postupy, prístupy a vysvetlenia. Nitra: Slovenská poľnohospodárska univerzita. 228 s. ISBN 978-80-552-0426-0.

MUCHOVÁ, Z. – PETROVIČ, F. 2014. Impact of land consolidation on the visual characteristics (scenery) of a landscape. Journal of Central European Agriculture. 2014, 15 (1). p. 76 – 85.

 https://doi.org/10.15414/2022.9788055225029

MUCHOVÁ, Z. – VANEK, J. 2009. Metodické štandardy projektovania pozemkových úprav. Nitra: SPU, 2009. 397 s. ISBN 978-8-552-0267-9.

PAGÁČ, J. et al. 2019. The description of benefits and procedures of land consolidation with emphasis on landscaping activities on the example of the cadastral territory of melek, Slovakia. 19th International Multidisciplinary Scientific Geoconference, SGEM 2019; Albena; Bulgaria; Volume 19, Issue 5.2, 2019, Pages 709-716.

PAŠAKARNIS, G. – MALIENE, V. 2010. Towards sustainable rural development in Central and Eastern Europe: Applying land consolidation. In Land Use Policy, 2010, 545-549 s.

PLÁN HOSPODÁRSKEHO A SOCIÁLNEHO ROZVOJA OBCE NÝROVCE 2008. [online]. 2020. [cit. 2020-09-20]. Available on internet: http://www. nyrovce.sk/evt_file.php?file=740

TEZCAN, A. et al. 2020. A multi-criteria model for land valuation in the land consolidation. In Land Use Policy, 2020, Volume 95.

URBAN, J. 2015. Komora Pozemkových Úprav SR [online]. Bratislava 2012. Pozemkové úpravy nástroj na riešenie rozdrobenosti pozemkového. [cit. 2022-05-02]. Available on internet: http://www.kpu.sk/clanky-nazory

VANEK, J. et al. 2008. Metodický návod na vykonávanie geodetických činností pre projekt pozemkových úprav. Bratislava: Úrad geodézie, kartografie a katastra Slovenskej republiky a Ministerstvo pôdohospodárstva SR. 44 s., 2008, MN 74.20.73.46.30.

ZOZNAM ZMLÚV SR [online]. [cit. 2022-04-15]. Available on internet: https://www.zmluvy.gov.sk/

ŽÁČEK, J. 2013. Pozemkové úpravy pomáhají obcím i krajině: ovlivňují ekonomickou stabilitu venkova a zvýšenou životní úroveň jeho obyvatel. In: Enviweb. Available on internet: http://www.enviweb.cz

Contact address:

Ing. Alexandra Pagáč Mokrá, Slovak University of Agriculture in Nitra, Horticulture and Landscape Engineering Faculty, Institute of Landscape Engineering, Hospodárska 7, 949 76 Nitra, Slovakia, xmokraa@uniag.sk.

Ing. Jakub Pagáč, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia, +421 37 641 4947, jakub.pagac@uniag.sk.

 https://doi.org/10.15414/2022.9788055225029

Ing. Jozefína Pokrývková, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia, +41 37 641 4901, jozefina.pokryvkova@uniag.sk.

ARTICLE HISTORY:
Received 17.05.2022
Received in revised form 31.05.2022
Accepted 01.06.2022

PROPOSAL OF ECOLOGICAL MEASURES AFTER LAND CONSOLIDATION IN THE CADASTRAL TERRITORY OF SLOPNÁ, SLOVAKIA

Jakub PAGÁČ[1], Alexandra PAGÁČ MOKRÁ[1], Jozefína POKRÝVKOVÁ[1], Vladimír KIŠŠ[1]

[1]Slovak Agriculture University in Nitra, SLOVAKIA

Abstract

The aim of the paper is to develop a proposal for general principles of functional landscaping in the area of the land consolidation project with emphasis on spatial and functional optimization of land distribution in the country, analysis of communication and erosion measures in the model area. Based on data from a real land consolidation project provided to us at the District Office, Land and Forestry Department, Považská Bystrica, we processed and analysed the current land use, digital relief model, traffic conditions and the risk of water erosion. We verified the results by reconnaissance of the area and by preparing detailed photo documentation of problematic localities. Based on the obtained results, it can be stated that the area of interest is, in terms of erosion risk, slightly endangered. 4 endangered areas have been identified where we propose specific solutions.

Keywords: land consolidation, erosion control measures, functional land rearrangement

Introduction

Land consolidation (LC) is defined as a process that removes soil fragmentation by combining parcels of equivalent value into a single entity. One of the basic goals of land consolidation is to make economic and spatial conditions for agriculture more efficient by reducing fragmented land owned by one owner, adapting the shape of the land for better mechanized land cultivation, and reducing the distance between farm and land (Kupidura et al., 2014). One of the main goals of land consolidation is to ensure food safety and thus contribute to the sustainable use of land resources (Luo, Timothy, 2017). Authors Ge et al., (2020) The purpose of land consolidation as a process for agricultural land and the creation of sustainable rural development. According to the author, the success of land consolidation projects depends on the correct determination of the land index for all agricultural land. In land consolidation, the administrative body from the proposal to develop and implement land consolidation in a certain territory, must perform and ensure a number of technical, administrative, control and decision-making actions (Látečka and Muchová, 2005). Proceedings on the commencement of land consolidation, the so-called the preparatory proceedings are carried out before the actual start of the land consolidation project, after evaluating the results of the preparatory proceedings, the administrative body decides on the permit or regulation of the land consolidation.

According to Act no. 330/1991 Coll. on land consolidation is divided into three stages, namely the elaboration of the project (initial project documents and proposal for a new arrangement of land in the project district), project implementation and implementation of the proposed common facilities and measures. Land consolidation include all land in the district of land consolidation. Some plots of land may be excluded from land consolidation if this does not defeat the purpose of the land consolidation. These are mainly land reserved for state defence, motorways, water management works, protection zones of water resources, roads, railways, building plots, cemeteries, mining areas, protected areas and their protection zones, archaeological sites, and important parts of the territorial system of ecological stability. The area of the land consolidation project is the sum of all lands designated for land consolidation. It is bounded by a boundary which separates contiguous areas of land included in land readjustment from contiguous areas with land that is excluded from land consolidation and from land not included in land consolidation (Muchová and Antal, 2013). The authors of Urban et al. (2019) argue that land consolidation has a positive impact on several areas of our lives in parallel. In the given area, land consolidation projects contain resolved ownership relations to the proposed measures and at the same time respect technical constraints and natural conditions.

The aim of the paper is to develop a proposal for general principles of the functional layout of the area in the area of land consolidation project with emphasis on spatial and functional optimization of land distribution in the country, analysis of communication and erosion measures in the model area of Slopná.

 https://doi.org/10.15414/2022.9788055225029

Material and methods

We chose the cadastral area of Slopná for the analysis due to the fact that a land consolidation project was carried out in this area. We therefore had the opportunity to work with real data, which was also directly used in the land consolidation project. This data was provided to us by the Považská Bystrica District Office - Land and Forestry Department. Proceedings on land consolidation in the cadastral area of Slopná were ordered on 20 June 2005. The land consolidation project was completed in 2011. The main reason for carrying out the land consolidation project in the cadastral area of Slopná was primarily the condition of land and ownership rights to them.

The cadastral area of Slopná belongs, according to the territorial-administrative division, to the Trenčín Region, the Považská Bystrica District, and the Central Považie Region. The western border of the cadastre is also the district border of Považská Bystrica and Púchov, the northern border is formed by the river Pružinka - left tributary Váh and in the east the village borders the village Dolný Lieskov, which was a merger in 1967 – 1990. The development of Slopná was considerably limited in these years. The area lies in the Manín Hills in the valley of the Slopňanka stream - the tributary Pružinka, in the south it reaches the mountains of the Strážovské vrchy. The territory of the cadastre is mostly slightly sloping, flat in the north and in the south the terrain turns into steep slopes. A tourist path leads through the village to the Ostrá Malenica hill (909 m above sea level), which is located on the southern border of the cadastre and is the highest point of the area. The total area of the cadastre is 764.16 ha. Agricultural land (54 %) and forests (32 %) have a dominant position in the landscape structure, with permanent grassland (36 %) and arable land (17 %) predominating on agricultural land.

In terms of climatic conditions, almost the entire area in the sense of Konček (1980) belongs to the moderately warm climatic area to the district of moderately warm, humid with cold-to-cold winter (valley / basin) with average temperatures of -3 °C in January and 16 °C in July. The southern mountainous part belongs to a moderately warm district, humid highlands with average temperatures of -5 °C in January and around 13 °C in July. The average annual rainfall is 650 mm. Precipitation, together with air temperature, is the basic climatic characteristic of the area. Precipitation highs occur in June. They are minimal in the winter months when precipitation in the form of snow prevails (maximum snow cover). A decrease in precipitation activity can be observed in September, which is related to the warm, almost cloudless weather. West and northwest winds predominate in the area (Boltižiar, 2012). From the hydrological conditions, the Slopňanka and Pružinka watercourses flowing through the territory belong, in terms of the type of runoff regime according to Šim and Zaťek (1980), to the highland-lowland area with a rain-snow type runoff regime with high water content in the spring months (March and April). March and the minimum in September. From a hydrogeological point of view, our territory belongs to the Váh river basin. Flows in the area can be characterized as flows with an unadjusted regime of runoff conditions (Malík and Švasta, 2002).

Current land use

For the analysis of the current land use, we used topographic data provided by the Považská Bystrica District Office - Land and Forestry Department, which were in the *vgi exchange format. The tip of the *vgi file is primarily intended for work in geodetic programs, so we had to convert the topographic data. We used the Kokeš geodetic program to *shp format to convert the VKM856479.VGI file so that we could work in ArcGIS 10.2.2.

Erosion risk

To determine the potential and calculated (real) intensity of water erosion, we had to be the first to create a digital relief model. When creating the DMR, we used the topo to raster interpolation method and we chose a resolution of 2x2m. We proceeded by creating a slope in percent; we identified barriers in the lines (roads, urban areas, water areas, forest); we converted the barriers to a raster using the polyline to raster function; we made the flow direction from the created DMR, which we multiplied by the barriers in the raster; we created a flow length from the direction of flow interrupted by the barriers; we created the relief effect factor (LS - factor) using the equation LS = slope length 0.5 * (0.0138 + 0.0097 * slope) + (0.00138 + slope2); we calculated the potential erosion and the calculated erosion; we determined the degree of soil erosion risk, according to the soil erosion risk index.

A modified USLE equation by Wischmeir, Smith (1978) was used to analyse soil erosion risk. The slope length and slope factor has been replaced by the LS factor, which is based on slope slope and length (e.g., Mitasova et al., 1998, Šimonides, 2000, Antal, 2013). The rain erosion efficiency factor (R - factor) is defined as the product of the kinetic energy of rain E and its maximum 30 - minute intensity. For the R factor we used the value measured at the Žilina station R = 14.42 taken from the work Identification of soil quality threat by water and wind erosion and proposals for measures from the authors Ilavská - Jambor - Lazúr (2005).

$$G = R * K * C * P * LS \qquad \text{(Equation 1)}$$

 https://doi.org/10.15414/2022.9788055225029

G – average annual land loss [t.ha^{-1}.year^{-1}]
R – rainfall-runoff erosivity factor [MJ.ha^{-1}.cm.H^{-1}]
K – soil erodibility factor [t. ha^{-1}. year^{-1}]
C – cover management factor
P – support practice factor
LS – topographic factor

Soil erodibility factor (K – factor) is defined as the erosion intensity on a unit plot, per unit of the rainfall-runoff erosivity factor R. The following K factor values were used for individual soils (according to Ilavská - Jambor - Lazúr, 2005): 0.2 for pseudogley cambizems; 0.26 typical for fluvial weights; 0.3 typical for cambium, moderate 0.31 typical for cambium, medium to severe and typical for frybizeme; 0.34 for fluvial gleys, medium heavy 0.39 for cuttings typical on steeper slopes, for typical cuttings and cambium soils medium difficult to heavy 0.4 for cambium typical on steeper slopes medium to heavy and cambium shallow, medium to heavy .

Cover management factor (C – factor) is defined as the ratio between the erosion intensity on covered vegetation and the erosion intensity on cultivated eel under the same action of other factors (Wischmeier - Smith 1978). C-factor values for individual elements of the secondary landscape structure were taken from the author Alena (1986): 0.005 for grasslands; 0.45 for orchards; 0.61 - 0.11 for arable land; 0.82 for field roads.

Forests, state roads, urban boundaries, water areas and strips of non-forest woody vegetation, which interrupt resp. retain surface runoff. They were modeled as surface runoff barriers in the calculation of the LS factor.

The influence factor of slope length (L - factor) and slope slope (S - factor) was replaced in the revised USLE equation by the LS factor, which expresses the effect of topography on the amounts of transported soil mass. The importance of the shape of the area is mainly from the point of view of surface runoff formation because there is an indirect proportionality: with increasing surface runoff rate, the time for water infiltration into the soil profile decreases. Relief contributes to the formation and course of water erosion by slope length and slope.

According to equation (1) above, we calculated the potential and real erosion runoff of agricultural land.

 https://doi.org/10.15414/2022.9788055225029

Results and discussion

Based on the purpose mapping of the topography in the district of the land consolidation project, we specified 7 types of land, which are listed with area and percentage. Permanent grasslands account for the largest share with a percentage of 42 % and forest land with 34 %. The solved area is situated in the foothills, which results in the predominance of forests and meadows. From the identified types of land (7), we identified 22 elements of land use.

The cadastral territory of the village of Slopná is part of an agricultural landscape with a predominance of large-scale use of arable land and intensive use of permanent grasslands. The largest area in the area of interest consists of permanent grasslands, which are located mainly in the southwestern, south-eastern and central part of the perimeter of the land consolidation project. We can divide permanent grasslands according to land use into intensively used meadows with a percentage of 37.5 %, extensively used meadows (3.6 %), terrace pastures with non-forest woody vegetation (1 %), abandoned meadows, pastures, and temporarily unused meadows (0.08 %).

In the model area, the last stage in the project of land consolidation was not carried out - the implementation of the proposed facilities and measures. As the area of interest is characterized by high logging and sheep breeding, which burden the current network of field and forest roads. The interest of our measurement was mainly field roads, which were created since 2010 when the land consolidation was completed, or field roads, which significantly disturb the stability of the landscape and water erosion occurs on them.

According to the USLE equation from Wischmeir, Smith, we calculated and plotted in Figure 1 the potential intensity of water erosion and the calculated intensity of water erosion (Figure 2).

We divided our area of interest into 5 categories of soil removal according to the degree of soil erosion risk (Figure 3).

 https://doi.org/10.15414/2022.9788055225029

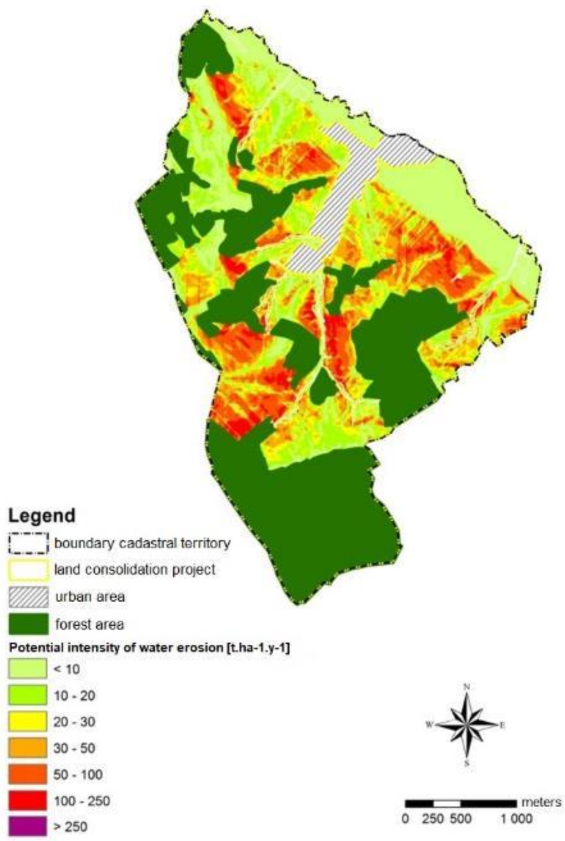


Figure 1 Potential water intensity erosion provided that C = P = 1

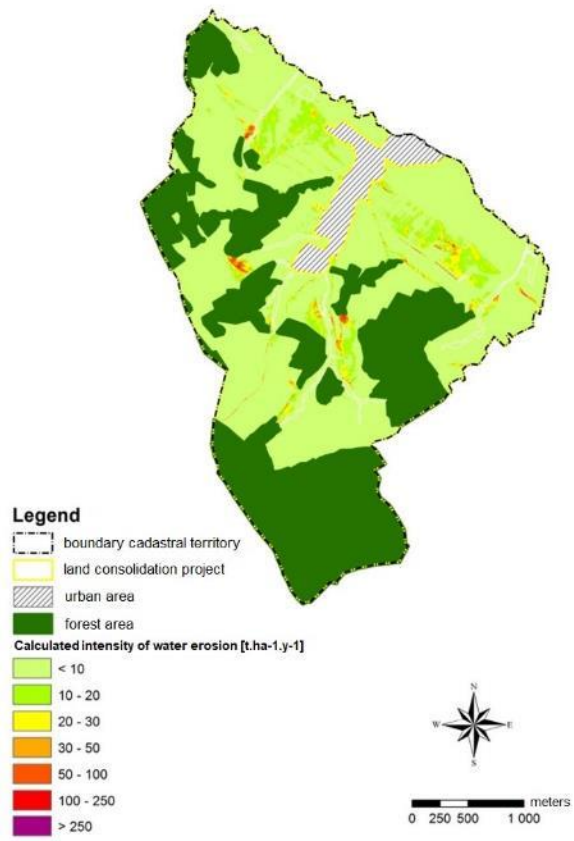


Figure 2 Calculated water intensity erosion provided that C < 1, P = 1

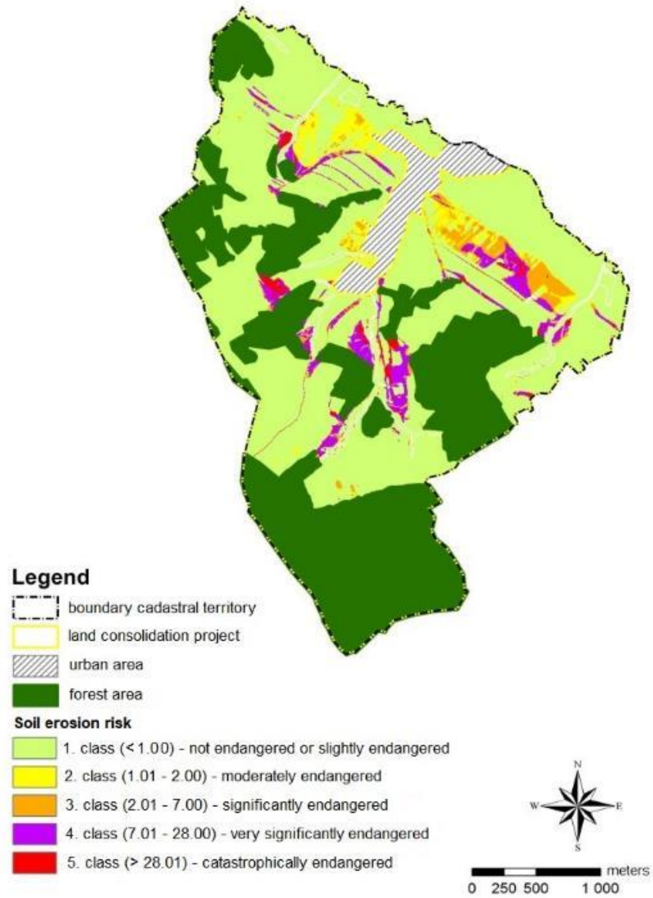


Figure 3 Degree of soil erosion risk

<u>Category 1</u>

It includes areas with minimal erosion effect, resp. they are free of erosion. The value of potential soil removal reaches max. 4 $t.ha^{-1}.year^{-1}$. This category corresponds to the flat area and gentle slopes at the transition of the highlands to a plain with a slope of up to 7°. In the highlands themselves, there are some parts of the flat inter-valley and distribution ridges and the bottoms of the low-lying valleys. This category includes the area around the village and along the local stream.

<u>Category 2</u>

It characterizes the gentle slopes of the highlands in its peripheral parts, flat inter-valley ridges and partly also the ends of the valleys with a potential soil abatement of 4 - 10 $t.ha^{-1}.year^{-1}$. Slopes reach 7 - 15°. This category covers about half of the cadastre of the village Slopná.

Category 3

It is a serious limitation for tillage, tillage is only suitable if strict anti-erosion measures are observed. Steeper sections of slopes of valleys with slopes of 15 - 25° correspond to this category. The potential yield reaches the value from 10 to 30 $t.ha^{-1}.year^{-1}$, which testifies to the high susceptibility of soils to water erosion, which manifests itself mainly in the form of tear erosion. Category in cadastral area Slopná village occurs on steeper slopes.

Category 4

It includes areas very prone to erosion, i. steep slopes with a slope above 25° - 35°, where the potential soil flow reaches 30 $t.ha^{-1}.year^{-1}$. Land in this category is severely limited for agricultural purposes. In the model area, this category is represented in the southern and western part of the cadastral area in the rugged lower mountains. It occupies a small area.

Category 5

These areas are extremely susceptible to water erosion, steep slopes with a slope above 35°, where the potential soil flow reaches above 30 $t.ha^{-1}.year^{-1}$ and more. The territory belonging to this category is unsuitable for agricultural purposes. In the territory in question, this category is represented in the southern part of the cadastral area in the rugged lower mountains north of the Ostrá Malenica elevation (909 m above sea level). It occupies a small area.

In our model area, we have identified four localities that are most endangered by water erosion. The area with marked localities is shown in Figure 4.

 https://doi.org/10.15414/2022.9788055225029

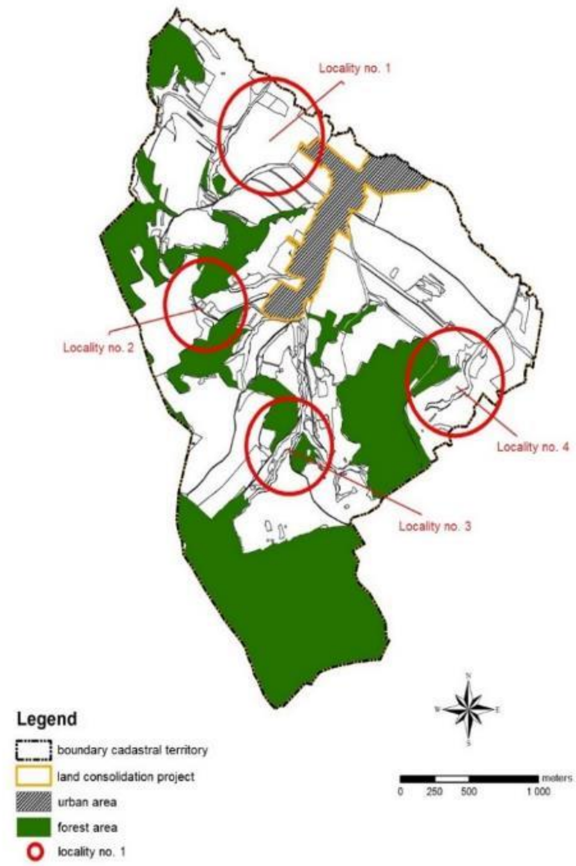


Figure 4 Locality most endangered by water erosion

Locality no. 1: is located in the northern part of the territory on arable land. The occurrence of water erosion is aided by the slope and non-compliance with agrotechnical anti-erosion measures such as contour tillage. In the spring months, when the snow heats and heavy rains, the soil is washed away, which is without vegetation cover. At the given locality, I propose compliance with soil agrotechnics and mulching. We also recommend the selection of suitable crops grown on the area.

Locality no. 2: in the central part of our model area there is a crossing road on the slope, which is used to move farm animals (mainly sheep) from the cooperative to the pasha. The road is unpaved and consists only of crushed soil, on which water flows during the rains and creates scratches in the crossing road (Figure 5). On the contrary, deposits of mud form under the slope, which is floated with surface runoff from the tight body (Figure 6). To reduce water erosion, we propose to limit the number of crossings of grazing animals between the cooperative and the pasha. Built-up paved road in a selected location with transverse drainage.

Locality no. 3 a 4: in our territory there are field and forest roads, which are situated on steep slopes. Since these roads are unpaved and have insufficient or no surface runoff, a concentrated runoff is created on them. The flowing water thus concentrated forms deep tens of centimeters in the road body, as demonstrated in figure 7 using a PET bottle. We propose a suitable route route on the slope in the given localities (zigzag route route). Also capturing surface runoff from adjacent land into road ditches and draining outflowing water from the road cover by aquifers.

Figure 5 Formation of water erosion on the road

Figure 6 Mud deposition below the slope on the driveway

Figure 7 Influence of water erosion on unpaved field road

 https://doi.org/10.15414/2022.9788055225029

Furthermore, we propose to implement organizational anti-erosion measures on arable land in the whole cadastral area in the form of management, on the highest quality soils endangered by erosion processes that reduce the risk of erosion of the highest humus part crops with an emphasis on the cultivation of permanent and temporary grasslands and clover, to use organic fertilizers to increase the proportion of nutrients in the soil, to introduce anti-erosion measures (eg contour tillage, exclusion of growing broad crops on erosion-prone soils).

Preserve forest stands as important eco-stabilization elements in the area, implement more gentle management methods and ban large-scale deforestation, especially in parts with an increased risk of landslides and high potential water erosion. In the northern part of the cadastre with an increased risk of water erosion and large-scale use of arable land, it is necessary to preserve existing line stands and drawbridges that fulfill the ecostabilizing function in the area, supplement and stabilize the surrounding roads by planting fruit tree strips or planting non-forest woody vegetation.

Implement technical road erosion measures, which is one of the important regulators of surface runoff. It is necessary to ensure the drainage of roads by road ditches. Access roads dividing soil units will reduce the possibility of water erosion in other localities as well. In the cadastral area of Slopná, in the place of the greatest impact of water erosion (northwestern part of the area), it is necessary to design an access field road with a green belt, which interrupts the length of the slope and prevents water erosion. Simultaneously with the green belt, it also performs a landscaping function.

The longest focused field road is 421 m long and is mainly used to drive sheep pasture. In figure 8 and 9 it is evident that compaction and considerable water erosion occur on this newly created field road.

Figure 8 and **Figure 9** Driveway

There are also field roads in the area to weigh wood and access arable land or tourism and recreation. In figure 10 is a field road that is used to weigh wood from the adjacent forest to the main field road. Some field roads are located in a sloping area, but are on soils that are prone to water erosion, as can be seen in figure 11.

Figure 10 Field road for timber weighing

Figure 11 Formation of water erosion

The public transport network serves all residents and enters the inner city of Slopná. There is no public transport network in the area of the land consolidation project. The state road III-06151 runs through the village of Slopná, which is connected to the main transport network by road III / 6150 (Visolaje - Domaniža), which passes over the northern part of the cadastral area. Slopná and feeds further to the state road I / 61 (Trenčín - Žilina), through which there is a transport connection with the surrounding villages and the district town of Považská Bystrica. Local roads in the village are also used for agricultural activities. Special-purpose roads (field and forest roads) within the perimeter of the land consolidation serve to make land accessible and are among the common facilities and measures. Special-purpose roads are made up of unpaved roads, which serve mainly as access roads to agricultural and forest land. As they are unreinforced, they are degraded by water erosion. Much of the field roads lead through meadows, leading to their devastation and degradation. After starting the road, new routes are selected, where the degradation process is repeated. The old field roads, which were situated in the entrances, are not used and over time most of them have overgrown and thus remained impassable.

There are 13 field roads in our territory. Based on the parameters of the road body, we have included the existing field roads in the category of secondary field roads Pv 4.0 / 30 and Pv 3.5 / 30 and in the category of additional (auxiliary) field roads Pp 3.0 / 30. In the area of the landscaping project, there are also side crossing roads (Pr) 6-8 m wide road. Through a detailed reconnaissance of the terrain, we found that field roads meet the given category only in certain parts of their sections. A graphical representation of the current and proposed network of field roads is shown in figure 12.

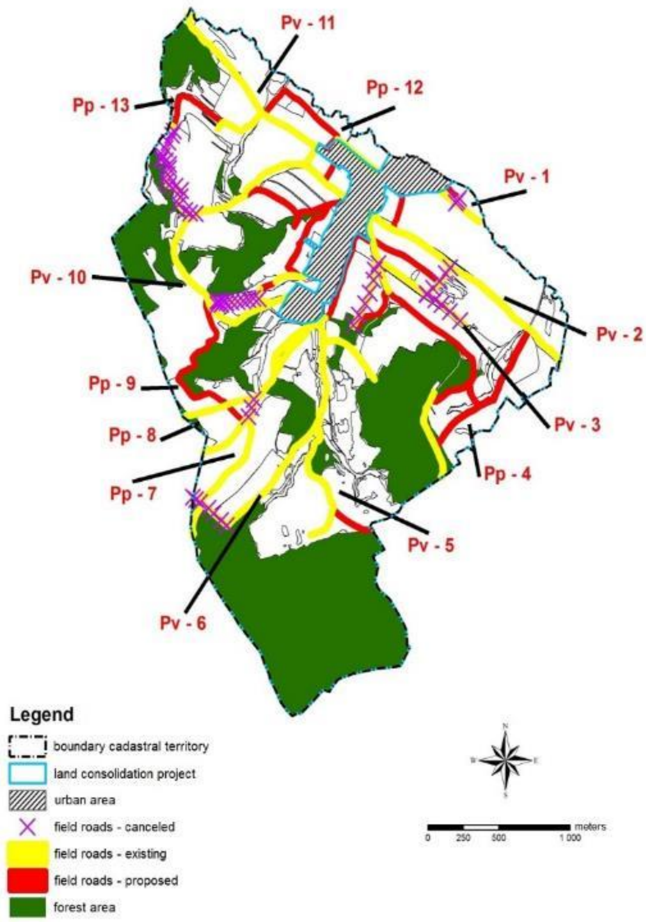


Figure 12 Current state and propose of the field road network

Pv – 1 (3,5/30): The current state of the road is unsatisfactory, as in bad weather the road becomes difficult to pass and depressions are formed from agricultural machinery. In the design part, it was intended to reconstruct the field road and keep the category of the secondary field road Pv 3.5 / 30. The reconstruction concerns the strengthening of the lane with a bitumen cover and the construction of curbs.

Pv – 2 (3,5/30): Auxiliary field roads and auxiliary field roads should be fed to the field road, therefore it was proposed to reclassify the field road to the main field road (single lane) P 4.0 / 30 with switches. In rainy weather, the road is difficult to cross and deep potholes are formed on it, which are currently temporarily covered with construction waste. The body of the road is cut into the slope and tracks are formed after passing agricultural machines. The field road was designed to meet the category of the main field road P 4.0 / 30 with curbs and a moat built on the slope side to drain surface runoff from the surrounding land. Pavement reinforcement should be done by modifying the subsoil, the protective layer, the base layer and the top cover, which will form an asphalt carpet.

Pv – 3 (3,5/30): The side field road serves as an access road to arable land, but it also leads to steeper slopes for access to orchards. We propose to strengthen the road in sections with low soil bearing capacity by bituminous coating on the surface of the prepared road. As the field road leads to the slope, it is necessary to drain the road longitudinally through ditches, but also transversely by waterways.

Pp – 4 (3,0/30): The auxiliary field road is unpaved, grassed and passable only seasonally. Its length is 473 m and connects the land units of the owners. The current state of the road is very good, also because the road is rarely used.

Pv – 5 (3,5/30): The current state of communication is in a very bad state. The field road does not meet the conditions of year-round descent due to the embankment of the local stream Slopňanka and 200 m long water flows along the entire width of the road. In the next part, the road is cut deep into the unpaved terrain and deep cuts are made in the soil from the wheels of heavy machinery. The field road must be reconstructed so that it meets the Pv category (3.5 / 30), is passable all year round and does not cause water erosion. We propose a combination of paved and unpaved sections, construction of a new riverbed in the part of the embankment on a field road, longitudinal drainage through ditches and planting of accompanying vegetation.

Pv – 6 (3,5/30): The road is unpaved and grassed, waterlogged in places and water cuts in the notches from the wheels of heavy forest machines, which makes the track a small watercourse. Due to the importance of the road in rural development and tourism, we propose to reclassify the road to the main field road P 4.0 / 30 with curbs and to build a road ditch in the slope part to drain surface runoff from the surrounding land. We also propose planting greenery to integrate the road into the country. At the intersections of the road and the stream, we propose the modification of

 https://doi.org/10.15414/2022.9788055225029

the stream bed. To cross the stream, it is necessary to build a bridge with a pipe passage. The modification of the creek bed is a proposed trapezoidal paved ditch with a bottom width of 0.5 m.

Pp – 7 (3,0/30), Pp – 8 (3,0/30) a Pp – 9 (3,0/30): The field roads connect the land units of the owners and are connected to the secondary field road Pv - 6 and Pv - 11. They are located in the southern sloping part of the territory and are unpaved, grassed and passable only seasonally. Their total length is 2,845 m. The current state of auxiliary field roads is very good. The use of these roads is only seasonal and therefore I do not propose any measures.

Pv – 10 (3,5/30): In the part of the entrance to the forest and during the entire length of the passage through the forest, the road is exposed and erosive grooves, even several 10 cm deep, are formed on it. The path continues through meadows and pastures and auxiliary field paths feed on it. The side field road is used mainly by the owners of the orchards, so there is no need for the road to be passable all year round. We propose to strengthen the road body in the part where the road passes through the forest and to build a drainage ditch in the slope part and also to build wooden gutters in the road cover. In the other part, the side road is in good condition and does not need reconstruction.

Pv – 11 (3,5/30): The beginning of the road is located in the village and is connected to the asphalt local road. The end of the journey is on the border of the cadastral area of Slopná and Visolaje. The condition of the road is unsatisfactory due to waterlogging of the road and insufficient drainage. The road is muddy in the notch even in nice weather and impassable in bad weather. The field road has the potential to connect the villages of Visolaje, Slopná and Trstie and attract tourists by bicycle or skate. Therefore, I propose to change the road category from secondary to main field road P 4.0 / 30. Build drainage ditches, restore and plant accompanying greenery. Pavement reinforcement is performed by modifying the subsoil, protective layer, base layer and top cover, which will be formed by an asphalt carpet.

Pp – 12 (3,0/30) a Pp – 13 (3,0/30): The field roads Pp - 12 and Pp - 13 connect the land units of the owners and are connected to the secondary field road Pv - 11. They are unpaved, grassed and passable only seasonally. Their total length is 1,821 m. The Pp - 12 road is led through the middle of the small block part of the land use by the owners. The current condition of the roads is in good condition, so we do not propose any measures.

 https://doi.org/10.15414/2022.9788055225029

Conclusions

In order to thoroughly manage the issue in the evaluation of analyses, we had to get acquainted with the natural characteristics of the model area. In the article, we described the information obtained, which we studied by studying scientific and archival documents in the analysis of the area. The reason for processing the area was to point out the absence of proposed field roads and anti-erosion equipment and measures. In the proposal of the functional land rearrangement of the area, we proposed a network of field paved and unpaved roads in the area of the land consolidation project so that access to all plots was ensured. The total length of the proposed roads, including the existing state and field roads in the area of the land consolidation project is 25 km. We divided the field roads into three categories: main, secondary, and auxiliary. In the vicinity of the built-up area, the main field roads have been proposed, which are proposed with sufficient area to fulfill several cumulated functions (transport, landscaping, land drainage, social interest). The priority was to connect the roads to the road network in the urban area, while partially solving the problematic traffic situation with the passage of agricultural and forestry machinery through the urban area of the municipality. At the same time, these roads should solve the problem of draining the nearest area, especially during the snowmelt period. The main field roads connect the site with neighboring cadastral areas. Visolaje and Třstie and form the basic transport skeleton of cadastral area Slopná. We proposed side field roads, if the terrain conditions allowed, on the sites of the original roads. The original side field roads have been neglected and need reconstruction or new construction. We proposed side field roads with a reinforced base. Access field roads lead through soil units and we have proposed them as grassy, which will have a positive effect on reducing water erosion.

Acknowledgment

"This publication is the result of the project implementation: „ Scientific support of climate change adaptation in agriculture and mitigation of soil degradation” (ITMS2014+ 313011W580) supported by the Integrated Infrastructure Operational Programme funded by the ERDF."

References

ALENA F. 1986. Stanovenie straty pôdy eróznym splachom pre navrhovanie protieróznych opatrení, Bratislava, 1986.

ANTAL, J et al. 2013. Ochrana a zúrodňovania pôdy. Nitra: SPU, 2013, 206 s. ISBN 978-80-552-0966-1.

BOLTIŽIAR, M. et al. 2006. Miestny územný systém ekologickej stability k. ú. Slopná pre účel projektu pozemkových úprav. Bratislava: Ústav krajinnej ekológie SAV, 2006. 60 s.

GE, X. et al. 2020. Probing Influence Factors of Implementation Patterns for Sustainable Land Consolidation: Insights from Seventeen Years of Practice in Jiangsu Province, China. In Sustainability 2020, 12, 3576.

ILAVSKÁ, B. et al. 2005. Identifikácia ohrozenia kvality pôdy vodnoua veternou eróziou a návrhy opatrení. Bratislava: VÚPOP, 2005. 60 s.

KONČEK, M. 1980. Klimatické oblasti. In Mazúr, E., ed. Atlas Slovenskej socialistickej republiky. Bratislava (SAV a SÚGK), p. 64.

KUPIDURA, A. et al. 2014. Public perceptions of rural landscapes in land consolidation procedures in Poland. In: Land Use Plolicy, roč. 39, 2014, s. 247-251, ISSN 0264-8377.

LÁTEČKA, M. – MUCHOVÁ, Z. 2005. Pozemkové úpravy a cesty. Nitra: SPU, 2005. 193 s. ISBN 80-8069-561-X.

LUO, W. – TIMOTHY, D. J. 2017. An assessment of farmers' satisfaction with land consolidation performance in China. In Land Use Policy, 61,2017, pp. 501-510.

MALÍK, P. – ŠVASTA, J. 2002. Hlavné hydrogeologické regióny. In: Atlas krajiny Slovenskej republiky. Banská Bystrica: Slovenská agentúra životného prostredia, 104 s.

MITASOVA, H. – MITAS, L. 1998. Process Modeling and Simulations, NCGIA Core Curriculum in GIScience, posted November 1998.

MUCHOVÁ, Z. – ANTAL, J. 2013. Pozemkové úpravy. Nitra: SPU, 2013. 325 s. ISBN 978-80-552-1130-5.

ŠIMONIDES, I. 2000. Intenzita vodnej erózie pôdy a metódy jej stanovenia. Habilitačná práca, Nitra: SPU, 2000.

ŠIMO, E. – ZAŤKO, M. 1980. Typy režimu odtoku. Mapa 1:500 000. In Mazúr, E., ed. Atlas Slovenskej socialistickej republiky. Bratislava (SAV a SÚGK).

URBAN, J. et al. 2019. Slovensko, Krajina neznámych vlastníkov. Usporiadanie pozemkového vlastníctva pomocou pozemkových uprav. Komora pozemkových uprav SR [online] 125s. Bratislava: 2015 [cit. 2022-04-25]. Dostupné na internete: http://www.kpu.sk/aktuality/slovensko-krajina-neznamych-vlastnikov.

WISCHMEIER, W. H. – SMITH, D. D. 1978. Predicting Rainfall Erosion Losses - a Guide to Conservation Planning. U. S. Department of Agriculture, Agr. Handbk., 537, Hyatsville, 58 pp.

Zákon č.330/1991 Zb. o pozemkových úpravách, usporiadaní pozemkového vlastníctva, pozemkových úradoch, pozemkovom fonde a pozemkových spoločenstvách v znení neskorších predpisov.

Contact address:

Ing. Jakub Pagáč, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia, +421 37 641 4947, jakub.pagac@uniag.sk.

Ing. Alexandra Pagáč Mokrá, Slovak University of Agriculture in Nitra, Horticulture and Landscape Engineering Faculty, Department of Landscape Planning and Land Consolidation, Hospodárska 7, 949 76 Nitra, Slovakia, xmokraa@uniag.sk.

Ing. Jozefína Pokrývková, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia, +41 37 641 4901, jozefina.pokryvkova@uniag.sk.

Ing. Vladimír Kišš, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 949 76, Nitra, Slovakia, +421 37 641 5247, vladimir.kiss@uniag.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 13.05.2022
Received in revised form 18.06.2022
Accepted 19.06.2022

LAND CONSOLIDATIONS – A TOOL FOR "EFFECTIVE" AGRICULTURE

Peter MICHAL[1,2], Zlatica MUCHOVÁ[2] , Petra PIPÍŠKOVÁ[2] , Dávid DEŽERICKÝ[2]

[1]Agricultural Paying Agency, SLOVAKIA

[2]Slovak University of Agriculture in Nitra, SLOVAKIA

Abstract

Although land consolidations (next as "LC") are currently more and more popular, not all parties involved in this process (owners, users, designers or law makers) are sufficiently aware of the reasons for which land consolidations are carried out, their benefits but also side effects brought by the new cadastral territory consolidations. In this article we will try to point out the shortcomings of land consolidations in the area of effective land agriculture. In the model cadastral territory of the township Trenčianska Turná and the majority agricultural subject, which is a recipient of land subsidies, we demonstrate in graphical and in table forms so-called dead areas, on which currently land subsidies are taken because they are cultivated, but there is no possibility to get a legal title on these areas as one of the conditions for obtaining subsidies.

Keywords: Land consolidation, agrodotation, system of mutual facilities and measures, SZO

Introduction

In the conditions of the Slovak republic, land consolidations are carried out following to Act No. 330/1991 Coll. on land consolidations, settlement of land ownership rights, district land offices, the Land Fund and land associations as amended. The priority of land consolidations is the rationalization of the space arrangement of the land ownership with regard to the protection of the environment and the creation of the land system of ecological stability, functionality of the agricultural landscape, with operational-economic-management aspects of modern agriculture (Muchová, Konc, 2010).

Together with solving of owner relationships, land consolidations allow to identify problems in the landscape and to propose a system of mutual facilities and measures. It concerns mainly forest and country roads together with relative objects (water ducts, shallows, shunting loops). In addition to solving of several problems at once, when the proposed road acts as an anti-erosion and anti-flood element up to the bio-corridor and windbreak, it primarily solves the accessibility to the new parcels. The biggest problem is the fact, that many of proposals left abandoned and the real implementation of the land consolidations along with proposed infrastructure remain on the paper. If the township (at the same time the owner of the given parcels for the creation of mutual facilities and measures) has a correctly elaborated such plan, it can apply for the subsidy from APA to complete the facilities proposed in the project (Chamber of land consolidation, 2019).

Due to the impact of collectivisation and the formation of agricultural cooperatives, property rights walked back to joint agricultural production in order to optimise the agricultural crops. Over the course of the ‘60s sixties, small farmers have become large agricultural cooperatives and the state of the land corresponds to this. The situation during which land owners lost their interest in farming on their land (they were not able to carry out real farming) was compounded by the state of fragmentation of land ownership. Whereupon by creating of the register of the new status as a result of the new ownership arrangement, it is needed to take into consideration not the land owners, but mainly the real agricultural use of the land.

Agriculture has been in decline for a longer time in the conditions of the Slovak republic. People are losing interest in farming and, with a few exceptions (small farmers, private tillers) the majority have agricultural cooperatives and establishments with acreage over 300 hectares. Mainly in the cadastral areas where land consolidations have not yet been made, large establishments are almost exclusively represented. On the other hand, it is needed to point out to the fact, that even after the land consolidations were carried out the number of land owners does not increase (in meaning to “farming on their own”). They are not motivated even by the financial support from the side of the European Union. In the process of the Land Consolidations Projects the land owners had the opportunity to express their interest regarding future farming on their own parcels so that the Land Consolidations Projects’ designer could take into consideration their farming requirements and allocate the parcel to them in the new arrangement in such a way as to allow the owner to farm but not to disrupt the farming of the agricultural cooperatives at the same time.

 https://doi.org/10.15414/2022.9788055225029

This means leaving the owners who have expressed a will to farm with an integrated LPIS (Land Parcel Identification System) and the rest of Parts of the Land Block to offer to the agricultural cooperative.

The current EÚ agricultural policy that is being enforced in the Slovak republic, does not reflect our history and historical experience and small farmers are getting into the foreground (just like in the western countries). But these small farmers do not represent the majority in production of agricultural commodities. And although various financial penalties are being introduced and prepared for farming on large acreages, we think that only the transformation of agricultural cooperatives onto smaller establishments will happen. The subsistence of farming will remain the same. Unfortunately, this is also partly to the Land Consolidations Projects, where the new land ownership arrangement includes parcels of agricultural land in the C CN register owned by the township, but which the township cannot dispose of. This means in practice, that the subject farming on such parcels receives the land subsidies illegally.

EU subsidy policy is covered by the Agricultural Paying Agency (next as "APA") in our context. APA was established by the Act No. 473/2003 Coll. and it is a state administrative body with the task of providing support and subsidies in the field of agriculture and rural development. Under direct subsidies (the basic area payment – SAPS) are basic conditions for granting of subsidies these:

- The right to use:
  - ➢ Details of the parcels ownership certificates, owned by the applicant (title deeds)
  - ➢ Rental contracts
  - ➢ Sub rental contracts – submission also of the rental contracts from which the sublease relationship is derived
  - ➢ A valid decision of the district authority on the establishment of a sub rental relationship to the existing replacement parcel following §12b (1) of Act No. 504/2003 Coll. on the rent of agricultural parcels, agricultural establishment and forest parcels as amended
  - ➢ Other documents to prove the legal relationship, for example replacement use agreement, agreement on exchange of the agricultural land
  - ➢ A valid decision of the district authority on the allocation of the substitutionary use together with the demarcation plan following § 12 of Act No. 504/2003 Coll.

- Farming on land (the book of used parcels – records of farming and crop rotation, statements of work, invoices, photo documentation...)

Material and methods

The agricultural establishment in the region Trenčín, farming since 1993, in the year of subsidy 2021 farmed on acreage of 1129, 12 hectares (50 LPIS parcels) of which in the cadastral territory Trenčianska Turná farmed on acreage of 696,28 hectares (32 LPIS parcels). Land Consolidation Project in the given cadastre was registered in 2013 and the new arrangement of the cadastre area with a minor change has persisted since 2013 to the present day (Figure 1).

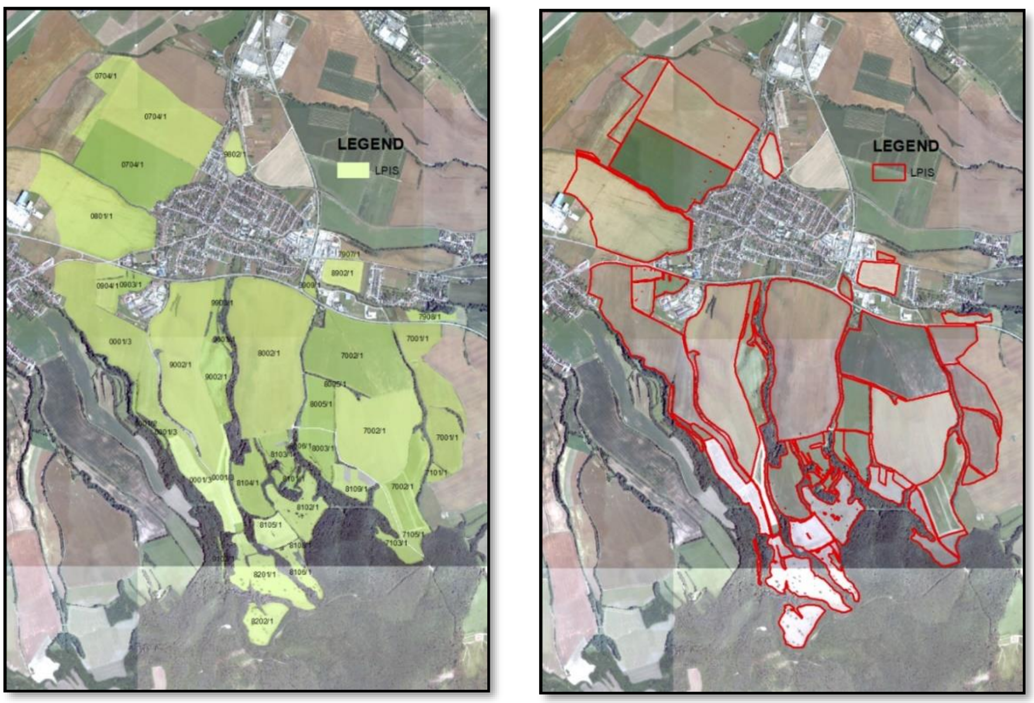


Figure 1 Map of current land use (Michal, 2022)

Following the Government Ordinance No. 342/2014 Coll. on rules for subsidy granting in agriculture in connection with the schemes of separated direct payments, § 2 (2) letter b) states that the subsidy will be provided to that applicant, which is the land owner up to 31st May of the current calendar year. That means that the applicant must have a legal title on that land. The Paying Agency is entitled to call upon the beneficiary in accordance with Act No. 280/2017 Coll.

§ 28 on providing support and subsidies in agriculture and rural development and on amending Act No. 292/2014 Coll. on the contribution from the European Structural and Investment Funds, to prove compliance with the stipulated conditions and the right of use of the agricultural land, where the right of use is understood to mean the right to use the agricultural area as an owner, renter or on the basis of another legal title.

In this paper we analyse all the parcels that have been allocated by the land consolidation project for common facilities and measures. We analyse who is managing the plots in question and how, and discuss the issue of illegal subsidies being received by the operators of such plots.

Results and discussion

After the land improvement project, the land designated for common facilities and measures is transferred to the ownership of the village with a clear designation. They cannot be alienated and cannot be used for purposes other than those defined in the common facilities and measures proposal in the land-use plan. On the ownership certificate No. 4127 in the owner section (remark) prohibits the owner to deal with immovable assets following the § 11 (20) of Act No. 330/1991 Coll. Following this paragraph, parcels intended for common facilities and measures cannot be dispossessed or encumbered. They can be used only for purposed regulated by an individual regulation. But there no special instructions in this individual regulation, that these parcels can be used for agricultural purposes. This restriction shall be indicated in the land register on the basis of the decision approving the implementation of the Land Consolidation Project. The district authority may this restriction cancel by the decision, if it is needed for the land development and in accordance with the town-planning documentation. The condition is to protect the access to parcels and to keep the functions of the water utilization facilities. Inter alia, that means that with the implementation of the Land Consolidation Project, all the approach roads to the newly created parcels of the owners have fallen into the township's ownership.

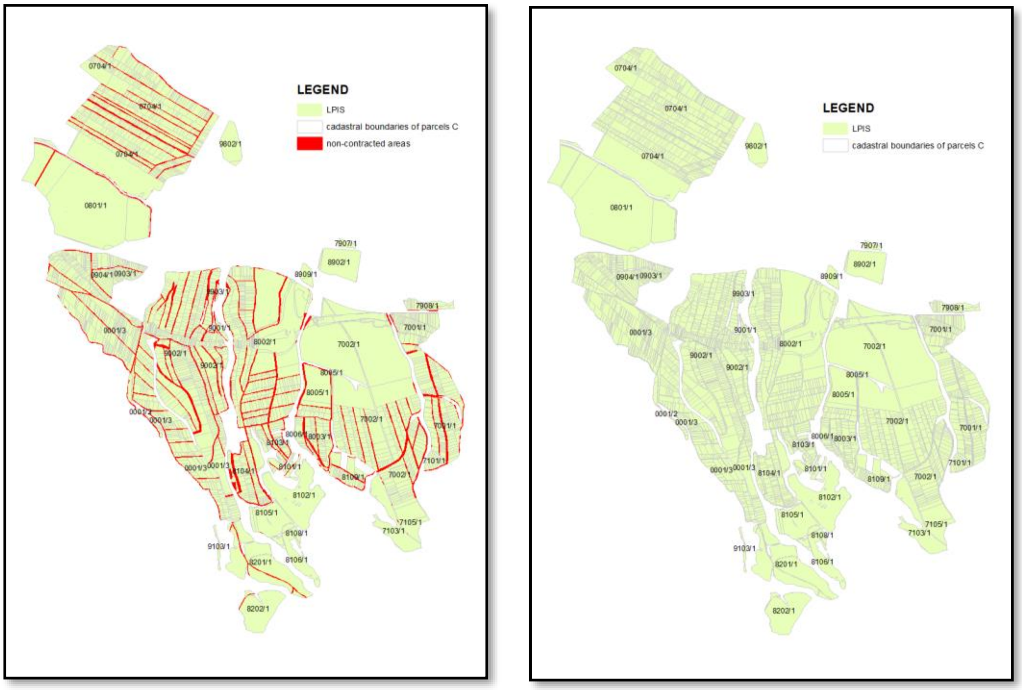


Figure 2 Map of non-contracted areas after Land Consolidation Project (Michal, 2022)

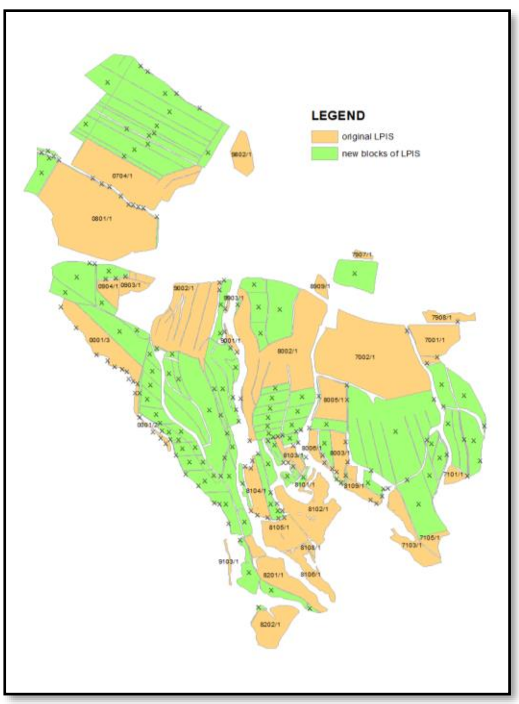


Figure 3 Map of the original and new (X) LPIS (Michal, 2022)

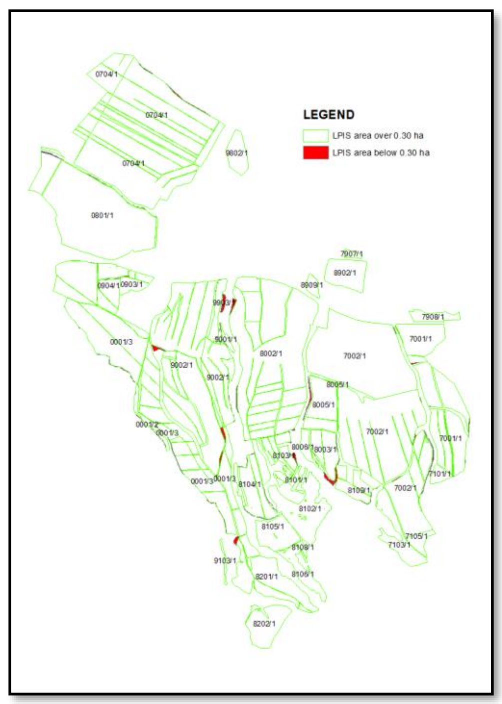


Figure 4 Map of areas under 0,3 ha without subsidies (Michal, 2022)

 https://doi.org/10.15414/2022.9788055225029

In table 1 we present a comparison of parameters indicating the state of farming of the agricultural cooperative before and after the physical implementation of common facilities and measures (country roads) in the cadastral area in question.

Table 1 Comparison of farming parameters

	Before LC	**After LC**
Used acreage	696,28 ha	666,46 ha
Number of used areas	49	279
Number of used areas with acreage under 0,30 ha	0	159
The total subsidy	129 508,08 €	123 961,56 €

Source: Michal, 2022

The results show that the area in use has been reduced by almost 30 ha on paper/administratively due to the design of common facilities and measures after the land consolidation project. The 30 ha designated for common facilities and measures, so far without any implementation on the ground, allow for the continued disposal of these lands. The entity using the blocks of land in question is placed in a situation where it continues to use them for agricultural purposes despite their clearly defined purpose.

Not only have the parcels become unused in reals terms, but the type of parcel registered on the certificate of ownership has also changed. So, where it before was and actually is the arable land in the field, in the cadastral records under the relevant parcel number are parcels registered as other area. This has also reduced the acreage of the land fund.

The implementation of the Land Consolidation Project in the cadastral area has consequently cancelled all the previously concluded rental contracts and no new contracts on these areas in the township' ownership can be concluded. It follows from the above that, according to the law, the agriculture cooperative cannot farm these parcels without the valid rental contract and these parcels have to be excluded from the subsidiary scheme.

Unfortunately, or rather fortunately, APA till this time does not examine the right of use on agricultural land, due to some reasons:

- The control mechanism is absent (interaction: owner-renter-control body)
- The legal title to the land does not to be submitted at the time of application

 https://doi.org/10.15414/2022.9788055225029

- No one registers the excess numbers of rental and sub rental contracts
- Fragmentation of land ownership

Conclusion

Land consolidations undoubtedly present benefit for both country and its inhabitants, whether we look at it through the lens of property rights or the improved functionality of the area as a result of the construction of common facilities and measures. The fact remains, however, that not actually carrying out of the Land Consolidation Project in the field as designed brings a number of constraints. We have pointed out on one of them in this article. Such cases unfortunately occur in all cadastral areas in which land consolidations have been carried out. The result is complication in farming on land and inability to prevent them by law. Therefore, it would be advisable to adjust the legislative framework in that way in the future, that parcels in township' ownership which are intended for building of the new road network, can be used for agricultural purposes till the moment of its physical implementation.

Acknowledgment

This study was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sports of the Slovak Republic and the Slovak Academy of Sciences (VEGA) (No. 1/0244/21) and Cultural and Educational Grant Agency of the Ministry of Education, Science, Research and Sports of the Slovak Republic (KEGA) (No. 029SPU-4/2022).

References

Act No. 280/2017 Coll. on providing support and subsidies in agriculture and rural development and on amending Act No. 292/2014 Coll. on the contribution from the European Structural and Investment Funds.

Act No. 330/1991 Coll. on land consolidations, settlement of land ownership rights, district land offices, the Land Fund and land associations as amended.

Act No. 473/2003 Coll. on the Agricultural Paying Agency, on the support of business in agriculture and on the amendment of certain laws.

Act No. 504/2003 Coll. on the lease of agricultural enterprise, and forest land and on the amendment of a certain laws.

CHAMBER OF LAND CONSOLIDANTION. 2019. Slovakia, the country of unknown owners. CLC. Bratislava. 127p. Internal document. Available on internet: http:// www.kpu.sk/sites/default/files/slovensko_-_krajina_neznamych_vlastnikov_3__sk5.pdf

MUCHOVÁ, Z. – KONC, Ľ. 2010. Land consolidation - procedures, approaches and explanations. SUA. Nitra. 210 p. ISBN 978-80-552-0426-0.

Ordinance of the Government of the Slovak Republic No. 342/2014 Coll. on conditions for granting subsidies in agriculture through direct payments.

Contact address: prof. Ing. Zlatica Muchová, PhD., Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Institute of Landscape Engineering, Hospodárska 7, 949 76 Nitra, Slovakia, zlatica.muchova@uniag.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 01.06.2022
Received in revised form 24.06.2022
Accepted 25.06.2022

CLIMATE CHANGE IMPACT IN AGRICULTURAL LANDS

Jakub Pagáč[1], Jozefína Pokrývková[1]

[1]AgroBioTech Research Centre, Slovak University of Agriculture in Nitra, SLOVAKIA

Abstract

A resilient country capable of retaining water and mitigating the negative effects of climate change, creating water resources of the required quality for sustainable consumption. Climate change is likely to make a significant contribution to food insecurity in the future by raising food prices and reducing food production. Food can be more expensive as efforts to mitigate climate change increase energy prices. Water needed for food production may become scarcer due to increased water use for crops and drought. In order to avoid exposure to extreme weather conditions, a belt machining method has been proposed. Various GIS tools, a detailed field survey, the cooperative's machinery and calculations were used to design the correct lane size to determine the correct scale distribution. This work points out the extreme weather events and its effects on the rural landscape in the form of muddy access roads, threats to housing, threats to soil quality by extreme events, threats to crops and other serious consequences.

Keywords: agricultural lands, climate change

Introduction

A resilient country able to retain water and mitigate the negative effects of climate change, create water resources of the required quality for sustainable consumption. Forest management, agricultural land and urbanization significantly affect the water regime of the country (Wheeler et al., 2013). The change and degradation of the natural water regime, the reduction of the area for watercourses and wetlands, the decrease of groundwater levels and the reduced natural retention capacity increase the risk of endangering the site by floods and droughts.

The aim is to have a landscape in the river basins that is able to retain water and mitigate the negative effects of climate change and create water resources of the required quality and quantity for sustainable consumption. The basic condition for agricultural production is to create suitable living conditions together with heat, light, nutrients and water. Water scarcity or surplus in the critical period significantly affects growth and the ability to produce sufficient crops (Bailey at al., 2015). In the summer, we face more torrential rainfall and long periods without rainfall, which leads to a greater climatological debate as to why rainfall suddenly comes not in the form of persistent or regular light rain, but during an hour of extremely heavy downpour.

If we have a long-term drought, then a torrential rain will not solve it, because it will not have time to soak in and saturate the soil more than a few centimeters below the surface. These are the reasons why droughts and floods alternate in our territory.

Climate change is likely to contribute substantially to food insecurity in the future, by increasing food prices, and reducing food production. Food may become more expensive as climate change mitigation efforts increase energy prices (Porter et al., 2014). Water required for food production may become scarcer due to increased crop water use and drought. Competition for land may increase as certain areas become climatically unsuitable for production. In addition, extreme weather events, associated with climate change may cause sudden reductions in agricultural productivity, leading to rapid price increases (Tubiello et al., 2007).

Drought is often referred to as a "creeping phenomenon" and its impact varies from region to region. Drought is difficult to define and therefore poorly understood.

What can be considered drought in areas of tropical rainforests (eg in Bali for six days without rain) cannot be considered as drought in desert areas (eg in Libya, where rainfall is less than 180 mm). In the most general sense of the word, such a situation occurs when there is a lack of precipitation over a longer period of time (in Slovakia in the range of weeks to months) and leads to a lack of water for a certain activity, group of people or the environment. Its effects are the result of the interplay of natural phenomena (less precipitation than expected) and the demands of suppliers for water supply. Human activity can thus exacerbate the effects of drought (Bailey at al., 2015). In Slovakia, they cause such problems mainly in agriculture, forestry and water management.

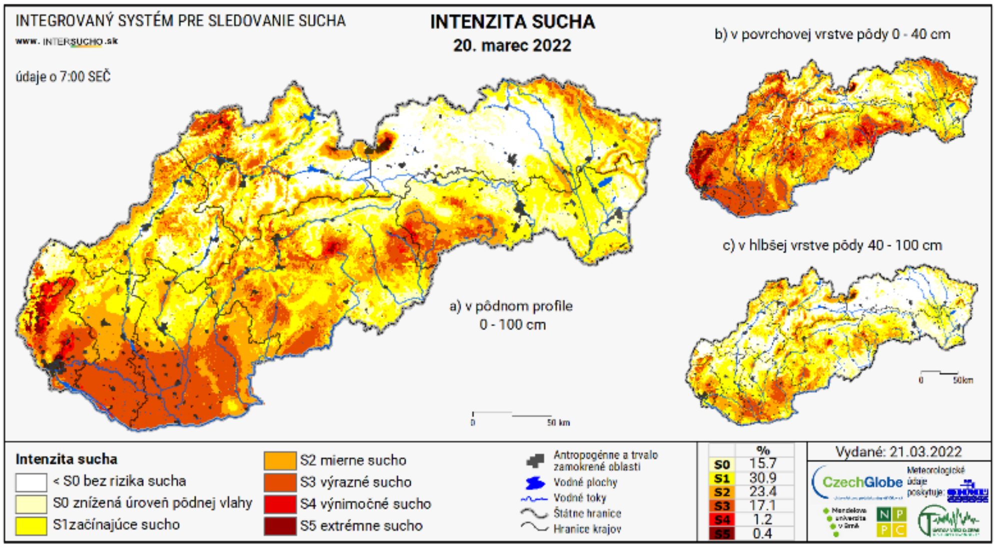


Figure 1 Current drought in Slovakia (www.intersucho.cz, 2022)

The rate of drought intensity in the whole soil profile (comparison of the current state with the usual conditions in the same period during the years 1961 - 2010) is at the level of exceptional to extreme drought locally in Záhorie, Kysucie, Podpoľany and Gemeri. Significant drought prevails in the Danubian Lowland. Significant to extreme drought (intensity level S3 to S5) is in total 18.7 % of the territory. The situation is more serious in the surface layer. There is an extreme drought in a large part of Záhorie, Kysucie and locally in the southern half of central Slovakia. Overall, extreme drought affects up to 2 % of the territory. In the deeper layer, there is a significant drought only rarely in western and central Slovakia (Fig. 1) (www.intersucho.cz, 2022).

A flood is a natural process during which water temporarily floods normally uninhabited areas. A flood occurs when water floods normally uninhabited areas as a result of:

- increase of water flow in the watercourse,
- the occurrence of obstacles in the watercourse bed or on the objects crossing the watercourse, which restrict the smooth flow of water, cause it to swell and spill out of the riverbed,
- prolonged or heavy rainfall or melting snow,
- surface runoff from precipitation or melting snow flowing into the territory from adjacent areas,

- rising of the groundwater level above the ground surface due to the long-lasting above-average water level in the watercourse (Weger et al., 2018).

Material and methods

The village of Pastuchov is located about 10 km from the town of Hlohovec, in the southwestern part of the Nitra loess hills at an altitude of about 200 m. The longitudinal axis of its cadastral territory is formed by the valley of the Blatina stream, which flows in a south-easterly direction, and in the north it also extends into the valley of the Galanovka stream. There are oak-hornbeam forests in the peripheral parts of the area, especially in the north-western and north-eastern parts. The cadastral area of the village is included in a warm, slightly humid climate with a mild winter. The average annual air temperature ranges from 9 to 10 ° C. On average 50 to 60 days a year, the temperature is above 25 ° C. Precipitation averages 650 - 700 mm.year^{-1}. The direction of the prevailing winds is northwest (www.pastuchov.sk, 2022). The background material is long-term findings of the locality problem in the cadastral area of the village of Pastuchov (Fig. 2). Problems of the investigated locality and consequences after extreme manifestations of rain (Fig.3). To prevent exposure due to extreme weather conditions, a belt machining method has been proposed. Various GIS tools, a detailed field survey, the cooperative's machinery and calculations were used to design the correct size of the individual lanes, which determined the correct distribution of the measure.

Figure 2 Area of interest cadastral area Pastuchov (Pokrývková, 2015)

Basic calculation

The width of the belts depends on the slope and length of the slope, the permeability of the soil, its susceptibility to erosion and the width of the implement. Crop belt cultivation consists of alternating crops with a small anti-erosion effect (mostly wide-row crops) with crop strips providing high anti-erosion protection (permanent grasslands) (Weger et al., 2018). The width of the infiltration belt is determined by calculation, the minimum width is 30 m (Dumbrovský et al., 2005).

The width of the infiltration belt D is generally determined from:

$D = (\varphi.i.L) / (w - i)$

Where: D - width of infiltration belt (m),

φ - volume runoff coefficient,

i - design precipitation intensity ($m.s^{-1}$),

L - width of the protected strip (L = max L) (m),

w - infiltration intensity of the grass strip ($m.s^{-1}$) (Dumbrovský et el., 2005).

Figure 3 Problems of the investigated locality (Pokrývková, 2015)

Results and discussion

The basic precondition for a correct draft of a measure in a country is to have enough information about it. There are several ways to get them. It may be a direct collection of data by physical presence in the surveyed country or other written and graphic material. The map showing the earth's surface and the phenomena located on it also has an important position among the data sources used in landscape planning. Through his own field research, the designer can obtain new information that can more accurately capture landscape-ecological relationships than other statistical data and available map materials. Terrain mapping in terms of new geodetic surveying of the area is usually approached in cases where otherwise available data do not meet the requirements of the project. Their accuracy or timeliness is not sufficient. The new focus of the whole area is possible, but it is time-consuming and costly. Therefore, older map materials are used more often and the actual surveying takes place only at pre-selected localities, so that the missing data are supplemented. The aim of the study was to find solutions to prevent soil abstraction on adjacent roads and houses. To do this, it is necessary to know the characteristics of the area, its runoff conditions, other geotechnical and geophysical characteristics. In addition to field research and geodetic survey, DMR also provides valuable data, which can be used in subsequent hydrological analyses.

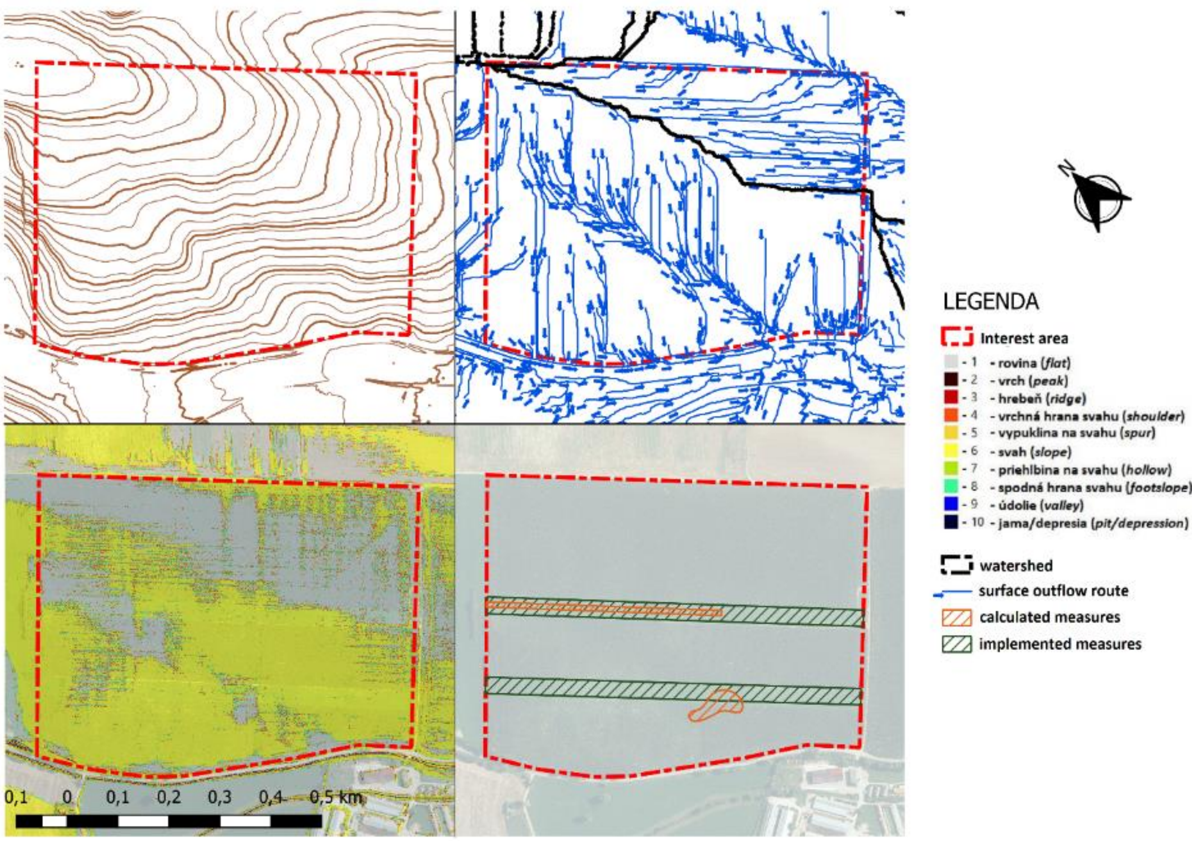


Figure 4 Territory analysis using GIS

 https://doi.org/10.15414/2022.9788055225029

Elaborated study of runoff conditions of the studied area (Fig. 4). To determine these characteristics, we used GIS that operate at the cell level of the raster. The resulting values are thus refined, as the need for averaging is eliminated and the weight of the error caused by the human factor is reduced. With the necessary knowledge of the principles of GIS operation and the correct setting of input values, the calculation of runoff ratios in GIS systems can completely replace manual calculations in the future.

Organizational measures consist in the overall concept of landscape organization in the use of the protective effect of vegetation cover. The above-ground parts of plants reduce the kinetic energy of raindrops and create obstacles to surface runoff, and the roots strengthen the soil and improve its properties (Konečná et al., 2014). The basis of organizational measures is the location of land on the longer side in the direction of contours, selection of appropriate size and shape of land and delimitation of plots suitable for land changes (delimitation), protective grassing or afforestation (Janeček et al., 2012) and grassing along watercourses. Large plowed soil blocks can be diversified by growing different types of crops. It is recommended to use belt rotation of crops, classification of grassed infiltration belts, use of biobelts, etc. In our case, we have also adapted to the requirements of the farm, which uses the belts (Fig. 5) to grow meadow clover and during the growing season on parts with other crops, mow the clover and uses it for feeding purposes.

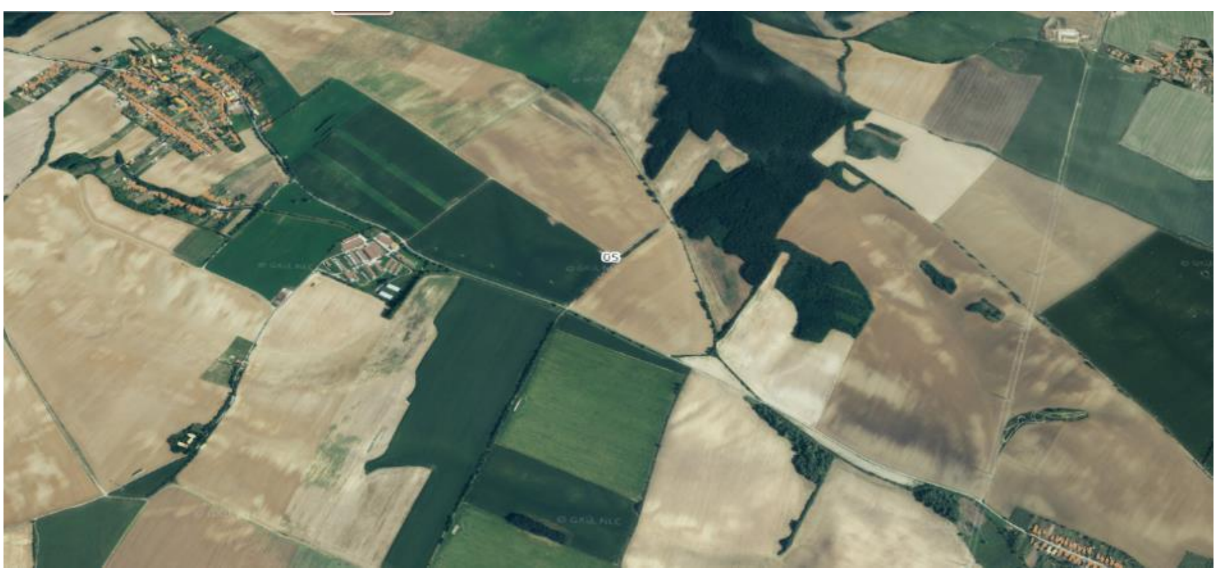


Figure 5 Aerial image ZB GIS

Conclusions

This work points out the extreme manifestations of weather and its effects on the rural landscape in the form of muddy access roads, threats to homes, threats to soil quality by extreme events, threats to crop yields and other serious consequences. Increasing rainfall is expected in the region, which is spreading to floodplains and, as a result, existing arable land is declining. On the other hand, there are opportunities to increase the value of arable land through adaptive farming practices. It should be noted that more explicit impact assessments and the active involvement of agricultural adaptation measures, such as rainfall harvesting and water accumulation, can mitigate the negative effects of climate change on soil suitability, thus maintaining current levels of available arable land. These problems indicate the need for a more detailed examination of each problem area.

Acknowledgment

“These publications are the result of support under the Operational Program Research and Innovation for the project: Research on the impact of biotic and abiotic factors on soil-water-atmosphere-plant cover components, 313011T620, co-financed by the European Regional Development Fund." 13-GASPU-2021 „Blue-green infrastructure as a basis for climate adaptation of land management in agricultural and urbanized land “

References

BAILEY, R. et al. 2015. Extreme weather and resilience of the global food system 2015. Final Project Report from the UK-US Taskforce on Extreme Weather and Global Food System Resilience, The Global Food Security programme, UK.

DUMBROVSKÝ, M. et al. 2005. Komplexní pozemkové úpravy v k.ú. Šardice etapa I: Návrh plánu společných zařízení technická zpráva. Brno.

JANEČEK, M. et al. 2012. Microstructure and dislocation density evolutions in MgAlZn alloy processed by severe plastic deformation. J Mater Sci 47, 7860–7869. https://doi.org/10.1007/s10853-012-6538-4.

https://www.intersucho.cz/sk/?mapcountry=sk&from=2022-03-01&to=2022-03-29&current=2022-03-27.

https://www.pastuchov.sk/o-obci-0.html, 02.05.2022

KONEČNÁ, J. et al. 2014. Erosion Processes and Sediment Transport during Extreme Rainfall-Runoff Events in an Experimental Catchment. Polish Journal of Environmental Studies, 23(4), 1195-1200.

PORTER, J.R. et al. 2014. Food security and food production systems. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability.Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

TUBIELLO, F. N. et al. 2007. Crop and pasture response to climate change. Proceedings of the National Academy of Sciences, 104(50), 19686-19690.

WEGER, J. et al. 2018. Katalog přírodě blízkých opatření pro zadržení vody v krajině: Činnosti k podpoře výkonu státní správy v problematice sucho [online]. Praha, 105 [cit. 2020-09-01]. Dostupné z: http://www.suchovkrajine.cz/sites/default/files/vystup/p1_katalog_opatreni_0.pdf.

WHEELER, T. – VON BRAUN, J. 2013. Climate change impacts on global food security. Science, 341(6145), 508-513.

Contact address: Ing. Jozefína Pokrývková, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre (ABT RC), Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, +421 37 641 4901, jozefina.pokryvkova@gmail.com

ARTICLE HISTORY:
Received 01.06.2022
Received in revised form 24.06.2022
Accepted 25.06.2022

BLUE-GREEN INFRASTRUCTURE AND ITS IMPACT ON THE ENVIRONMENT

Jozefína Pokrývková[1], Jakub Pagáč[2]

[1]AgroBioTech Research Centre, Slovak University of Agriculture in Nitra, SLOVAKIA

Abstract

Water scarcity is greatly underestimated on a global scale. Therefore, it is important to focus on sustainable water management and to support the development of the country's infrastructure towards blue-green infrastructure. Developing countries, which have more than 40 % of the world's population, suffer from a lack of water resources and an inadequate drinking water supply system for the rural population. For the correct application of blue-green infrastructure, it is necessary to provide greenery, especially trees, with suitable habitat conditions, which are very unfavourable in cities due to the amount of technical infrastructure in the country. The basis is sufficient overpowerable space, structural substrate or cells and sufficient moisture. The development of cities and municipalities has a negative impact on our natural resources and leads to the disruption of urban ecosystems. This study focuses on the positives of BGI in terms of their contribution to improving the environment. This paper describes the different opinions of experts on different techniques of BGI application, their impact on the environment.

Keywords: blue - green infrastructure, environment,

Introduction

Water scarcity is greatly underestimated worldwide. It is therefore important to focus on sustainable water management and to support the development of infrastructure in cities moving towards blue-green infrastructure. Developing countries, which have more than 40 % of the world's population, suffer from a lack of water resources and an inadequate drinking water supply system for the rural population (Jarabica, et al., 2018).

The development of cities and municipalities has a negative impact on our natural resources and leads to the disruption of urban ecosystems (Mentens et al., 2006; Elbeltagi et al., 2021). Green Infrastructure (GI) refers to the nature-based systems that mimic the natural hydrology and regulate surface energy processes through evaporation, shadowing, and adjusting emissivity, and positively affecting air movement and heat exchange (Liu et al. 2019). Blue Infrastructure (BI) refers to the natural or man-made forms of water implemented in the city that slows runoff by providing temporary storage, emitting longwave radiation to cool surfaces, and effectively absorbing shortwave radiation and releasing it through evaporation (Wu et al. 2019). Blue-green infrastructure (BGI) has been viewed as a sustainable and long-term solution for mitigating the effects of urbanization on the ecosystem. BGI consists of a network of interconnected wetlands, basins, and natural spaces, forming an essential means for coping with extreme weather conditions floods (Jeong et al., 2016). BGI includes rain gardens, bio-swales, green roofs, bio-retention cells, permeable pavements, parks, constructed wetlands, etc. (Mguni et al., 2016).

Urban Ecological Infrastructure (UEI) is another relatively new term that has been recently introduced to describe blue, green, and grey infrastructures as a combined system aimed to integrate ecosystem services (Liao et al. 2017). UEI involves networks of natural lands and working landscapes that conserve ecosystems' functions.

Recent research has shown the effectiveness of BGI to reduce floods and urban heat (Sörensen, Emilsson 2019).

Material and methods

The subject of the article is a list of BGI solutions that act as representatives of a wide group of landscape objects of the diversity of structures and rainwater retention systems implemented in the country that can be used in the formation of public spaces. The selection of cases was made on the basis of a literature review. They include a selection of BGI applied three on the surface, one applied underground and two applied above the surface.

 https://doi.org/10.15414/2022.9788055225029

Distribution of facilities and objects according to their function of rainwater management:

1. Measures to improve the microclimate or to prevent precipitation

- lawns
- trees
- semi-permeable surfaces
- vegetation roofs
- vegetation facades
- shallow infiltration swales and its variants

2. Infiltration equipment without regulated drain

- surface infiltration (without retention)
- infiltration swales and its variants
- infiltration retention tank
- infiltration retention furrow and its various forms
- infiltration swale with retention furrow and its variants
- infiltration shaft

3. Infiltration devices with regulated outflow

- infiltration swale with retention furrow and regulated drain (and its variants)
- infiltration retention tank with regulated drain
- infiltration retention furrow with regulated outflow

4. Retention objects with regulated outflow

- dry retention rainwater tank and its variants (eg water square, water playground, park)
- retention rainwater tank with storage
- underground retention rainwater reservoir
- artificial wetland

5. Accumulation and rainwater use (Pokrývková et al., 2020, Krejčí et al., 2002).

The second phase of the study involved comparing BGI solutions to identify similarities and differences between them. The assessment was carried out in relation to the following two parameters characterizing the BGI: spatial and environmental. Based on the data from the above literature, these aspects have been further developed to identify the key factors as well as the

 https://doi.org/10.15414/2022.9788055225029

main criteria used to define the constraints and options associated with the implementation of water retention solutions in planning and design.

The presented studies are quantitative and use the scoring method, while each factor is assigned a specific number of points resulting from the characteristics of the relevant criteria according to the author methodology (Jakiel,2015; Myga – Piatek, 2007).

This is an adapted method for evaluating valorisation. The rating scale is as follows:

- The 0–2 scale expresses the intensity of the factor influence, where 0 means no, 1 - partial and 2 - significant factor influence;
- The scale 0–3 results from a detailed valorisation conditioned by the presence of a large number of characters characterizing the factor, where 0 means none, 1 - low degree, 2 - medium degree and 3 - significant degree of occurrence or influence factor.

Results and discussion

In practice, we tend to encounter exemplary solutions for certain forms of water retention. However, if we want to respect their role - eliminating changes in the natural water cycle in the country caused by cessation or land use - we should create a set of follow-up measures for all types of water in the land. We should also include wastewater in the current approach and try to create places to live or work where all types of water are treated together, not separately. By combining the solution of rainwater and wastewater, the sustainability of the solution of the area will be achieved, as well as the effort for an ecological approach. An interesting example is a residential house in a model development on the outskirts of Hamburg, where a non-traditional local wastewater solution has also come up with a comprehensive solution. The glass façade of the building consists of a wide double glazing into which wastewater enters and colonies of special algae convert the pollution into its oily content. It can be used similarly to biodiesel for fast energy production. The surrounding area and roof are used to collect rainwater and runoff from the area is minimized in quantity and production of pollution.

Scharnhauser Park is an area of ecologically modeled housing, especially suitable for families. Housing for 9,000 people and 2,500 jobs is created here.

The ecological approach is also applied to drainage. Although the subsoil is not permeable throughout the area, all surface water from roads, public spaces, roofs, and all other private lands does not enter the sewers, but infiltration is encouraged over an unusually large area and only the rest of the water is drained into streams. The water is drained by open ditches and grassy depressions. In these depressions, the water is retained, partially evaporated, and cleaned by infiltration through the humus layer and through the gravel body, which is inserted under the humus layer and whose depth reaches up to 1.5 m. These ditches and depressions are located in the vast green areas of the city, in Baumhain (tree grove), in the Landschaftstreppe (so-called natural stairs) - this is a park area running from north to south throughout the city, and ends in the park Holzwiesen (Bennett, 2005).

Figure 1 Stepped terraces Stuttgart (Pokrývková, 2015)

The photograph of the stepped terrace (Figure 1) was taken with an excursion in Stuttgart and avisit by ZinCo GmbH. Many other cases that are implemented and have a positive impact on the environment.

BGI solutions were evaluated in terms of environmental impact in the country, where they could obtain a maximum of 15 points in the evaluated 9 spectra. The results of the environmental impact are presented in Table 1 and Figure 2.

 https://doi.org/10.15414/2022.9788055225029

The distribution of points according to the intensity of the impact is as follows:

- 10-15 points - positively evaluated solutions;
- 9-7 points - medium positive solutions;
- 1-6 points - solutions with a low value of positivity.

Table 1 Selected BGI in terms of environmental impact

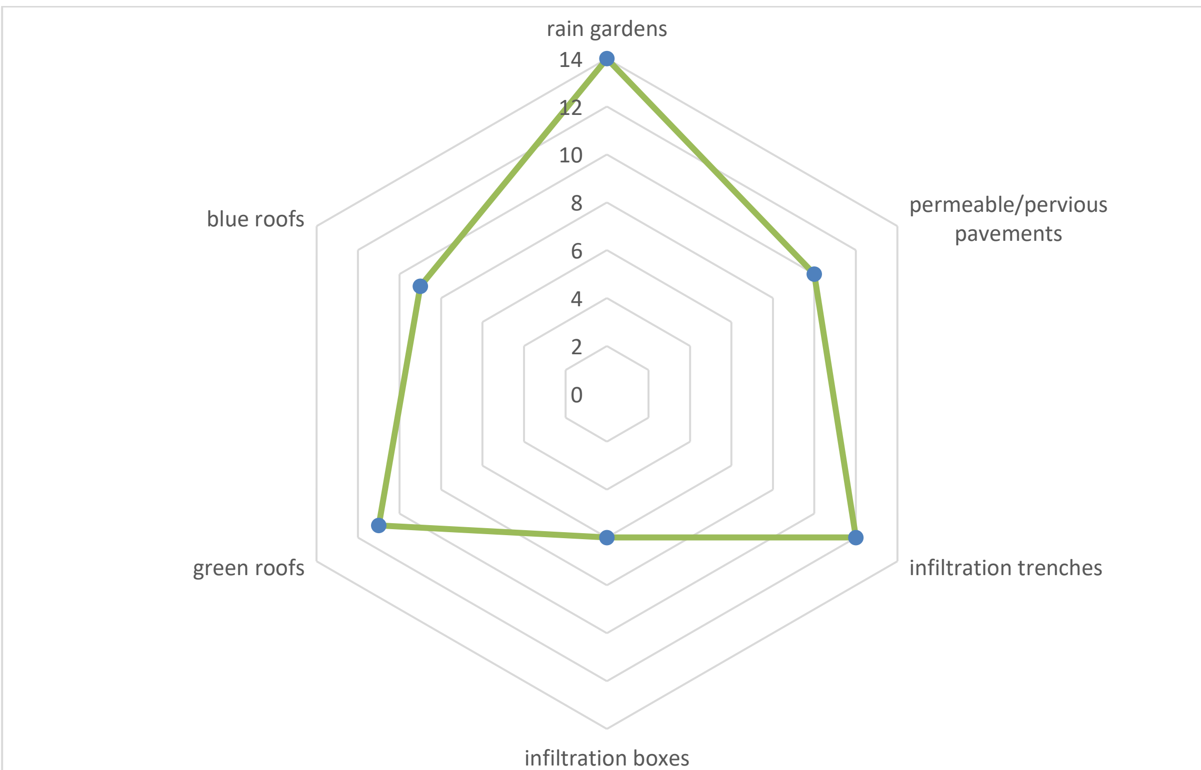
Evaluation parameter	**BGI**					
	rain gardens	permeable/pervious pavements	infiltration trenches	infiltration boxes	green roofs	blue roofs
Air Temperature (0–1 pts)	1	1	1	0	1	1
Elimination of Air Pollution (0–1 pts)	1	1	1	0	1	1
Removal of Pollutants from Rainwater (0–1 pts)	1	1	1	0	1	1
Shaping Biologically Vital Areas (0–2 pts)	1	0	1	0	1	1
Diversity of Plant Species (0–3 pts)	3	1	3	0	3	0
Reduction of Surface Water Runoff (1–2 pts)	2	2	2	1	1	2
Rainwater Retention (0–2 pts)	2	1	1	2	2	2
Stormwater Infiltration into the Ground (0–2 pts)	2	2	1	2	0	0
Use of Low Emission Materials, Recycling (0–1 pts)	1	1	1	1	1	1
SUM	**14**	**10**	**12**	**6**	**11**	**9**

None of the BGI measures evaluated received a full score of 15 or a minimum of 1.

The most valuable measure of the BGI in the context of the environment is the rain garden, green roofs, all of which have achieved a very positive impact assessment. In the number of points from 10 to 14, where fourteen reaches the rain garden for is variability and diversity, which is almost

 https://doi.org/10.15414/2022.9788055225029

the maximum. Most of them are surface solutions. They received the average number of points in relation to the evaluated factors: blue roofs, infiltration boxes. Some, such as green roofs, have not gained any points in terms of rainwater infiltration into the ground due to their tight construction. Rain gardens gain a large number of points in terms of combating climate change or improving environmental conditions, which are the result of a high proportion of vegetation that supports biodiversity. In terms of environmental impact among the lowest valuable group of these 6 measures BGI infiltration boxes. They got the number of points (6). Due to their limited use and placement underground, they do not have a major impact on improving air quality and reducing temperature. Only in a small number of cases do they allow rainwater treatment.



Therefore, it is a suitable solution in the implementation to take into account the combination of BGI measures used in the area and thus create an ideal impact on the environment.

Conclusions

The review article highlights the need to implement BGI at national level, which will help to better understand the potential obstacles and challenges of the issue. The study describes various findings related to BGI tools, model studies, environmental and economic aspects. Future studies should focus on identifying barriers to promoting BGI implementation. However, identifying barriers is a challenging task, as it depends on different environmental, legislative, socio-economic, and other contexts. Examples of realizations from other cabins are valuable in terms of implementation procedures, their positive impact on the city. From the given examples, we can avoid mistakes and implement BGI on a successful scale. Therefore, more emphasis should be placed on conducting research on the practical application of BGI. BGI strategies and techniques need further study and refinement in phases from start-up through distribution to application focused on various issues and related solutions. Potential problems and shortcomings in BGI can be solved after a thorough understanding of the issue and the individual steps of BGI implementation. Each municipality, city should have the means to assess the resilience of water management in order to identify current and future shortcomings. The BGI proposal, which would meet the forthcoming challenges due to climate change, would serve as an opportunity to present it to the public. Studies on the practical implementation of the BGI should be emphasized and the scientific base should be strengthened. Although the benefits of flood risk mitigation and BGI water quality improvement have been substantially studied, improving urban biodiversity, and reducing heat require further understanding in addition to cultural benefits. A better understanding of BGI services would therefore lead to an improvement in the design of BGI systems, making them more efficient and thus convincing evidence would help to promote them. Although the BGI is not new to urban water management, the assessment of the BGI as an environmental management tool instead of possible future climate change risks needs to be further explored.

Acknowledgment

These publications are the result of support under the Operational Program Research and Innovation for the project: Research on the impact of biotic and abiotic factors on soil-water-atmosphere-plant cover components, 313011T620, co-financed by the European Regional Development Fund", 13-GASPU-2021 „Blue-green infrastructure as a basis for climate adaptation of land management in agricultural and urbanized land “.

References

BENNETT, D. 2005. Scharnhauser Park, Ostfildern. In: The Art of Precast Concrete. Birkhäuser Basel. https://doi.org/10.1007/3-7643-7668-6_14. 2005.

ELBELTAGI, A. et al. 2021. Applications of Gaussian process regression for predicting blue water footprint: case study in Ad Daqahliyah, Egypt Agric. Water Manag., 255, p. 107052.

JAKIEL, M. 2015. Ocena atrakcyjnosc wizualnej krajobrazu dolinek krakowskich–Mozliwo´sci zastosowania w planowaniu przestrzennym. Współc. Probl. Kierun. Badaw. Geogr. 3, 91–107.

JARABICA, V. – KURUC, M. 2018. Jarabica, Vladimír; Kuruc, Marián – Územný plán mesta Nitra, aktualizácia 2018, San-Huma `90 s.r.o., Nitra. 2018. https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjy5_Gjs9vuAhVEyxoKHUxXAHgQFjABegQIAhAC&url=https%3A%2F%2Fwww.nitra.sk%2FFiles%2FShowFile%2F70102&usg=AOvVaw0ffbhPSQmar6nfDDivBaOO, (accessed on 27 Jul 2020).

JEONG, H. et al. 2016.Life Cycle Assessment of Low Impact Development Technologies Combined with Conventional Centralized Water Systems for the City of Atlanta.

KREJČÍ, V. et al. 2002. Odvodnění urbanizovaných území - koncepční přístup. Brno : NOEL 2000. ISBN 80-86020-39-8.

LIAO, K.-H. et al. 2017. Blue-green infrastructure: new frontier for sustainable urban stormwater management P.Y. Tan, C.Y. Jim (Eds.), Greening 67 Cities: Forms and Functions, Advances in 21st Century Human Settlements, Springer Nature Singapore, pp. 203-226.

LIU, J. – NIYOGI, D. 2019. Meta-analysis of urbanization impact on rainfall modification Sci. Rep., 9, p. 7301, 10.1038/s41598-019-42494-2.

MENTENS, J. et al. 2006. Green roofs as a tool for solving the rainwater runoff problem in the urbanized 21st century? Landsc. Urban Plann., 77 (3), pp. 217-226, 10.1016/j.landurbplan.2005.02.010.

MGUNI, P. et al. 2016. Sustainable urban drainage systems: examining the potential for green infrastructure-based stormwater management for Sub-Saharan cities Nat. Hazards, 82, pp. 241-257.

MYGA-PIATEK, U. 2007. Kryteria i metody oceny krajobrazu kulturowego w procesie planowania przestrzennego na tle obowi ˛azuj ˛acych procedur prawnych. In Waloryzacja ´srodowiska

Przyrodniczego w Planowaniu Przestrzennym; Kistowski, M., Korwel-Lejkowska, B., Eds.; Fundacja Rozwoju Uniwersytetu Gda´L: Gda´nsk-Warszawa, Poland, Volume 19, pp. 101–110. ISBN 978-83-7531-005-4.

POKRÝVKOVÁ, J. et al. 2020. Water retention in urban areas in the Danube Region: Study on facts, activities, measures and their financial assessment. In Slovak University of Agriculture in Nitra 2020, ISBN: 9788055222998. DOI: 10.15414/2021.9788055222998.

SÖRENSEN, J. – EMILSSON, T. 2019. Evaluating flood risk reduction by urban blue-green infrastructure using insurance data. J. Water Res. Plan. Manage. 145:04018099. doi: 10.1061/(ASCE)WR.1943-5452.0001037.

WU, C. – MURRAY. A.T. 2003. Estimating impervious surface distribution by spectral mixture analysis Remote Sens. Environ., 84, pp. 493-505.

Contact address: Ing. Jozefína Pokrývková, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre (ABT RC), Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, +421 37 641 4901, jozefina.pokryvkova@gmail.com

ARTICLE HISTORY:
Received 17.05.2022
Received in revised form 31.05.2022
Accepted 01.06.2022

AGROCLIMATIC EVALUATION OF THE NITRA RIVER BASIN IN 2021

Vladimír Kišš[1], Ján Čimo[2], Andrej Tárník[2]

[1]Research Centre Agrobiotech, Slovak Agriculture University in Nitra, SLOVAKIA

[2]Faculty of Horticulture and Landscape Engineering, Slovak Agriculture University in Nitra, SLOVAKIA

Abstract

The weather is beginning to change, higher atmospheric temperatures bring more extreme weather, which means one thing - the instability of the yields of the plants on which we depend. The aim of this study is to (i) evaluate monthly precipitation and air temperature according to the climatic normal 1990 – 2020, (ii) determine wet and dry periods according to Standard Precipitation Index (SPI) and (iii) evaluate soil moisture in Nitra River Basin from October 2020 to March 2022. There are rapid changes in temperature, when we get directly from the below-average month to the above-average temperature. According to the precipitation assessment, large fluctuations can be seen. From extreme drought there is a quick shift to extremely wet weather. Rainfall fluctuations then also affect the course of soil moisture, and in certain periods the humidity drops below critical values. The SPI assessment also confirms our previous statements. Our measurements show new era in weather trends and climate change impact could be observed well. We can see colder and wetter springtime, summers with extreme weather changes and hotter and dryer winter periods. Our measurements are short for definitive conclusions, but they show trends in important climatic parameters.

Keywords: temperature, precipitation, soil moisture, climate change

Introduction

Climate change is one of the most severe issues the world is facing today, and it has placed humanity in a challenging position (Dehrashid et al., 2022). Climate change is expected to affect almost every environmental and societal aspect (Vogel et al., 2018) and will have a vigorous impact on soils and ecosystems (Gelybó et al., 2018). Among the most critical impacts of climate change are their effects on the system of hydrology and water management (Zeleňáková, Fendeková, 2018; Koutroulis et al., 2018; Betts et al., 2018). Several episodes of extreme precipitation or extreme lack of precipitation (and high temperature) leading to dramatic and high-impact floods and droughts have occurred in Europe in recent years (Kundzewicz et al., 2006). The attention paid to drought periods occurrence is going to be more and more pronounced in both – scientific research community and governmental economy sector (Fendeková et al. 2018).

Drought is defined as a marked deficiency of precipitation relative to normal, occurs as periods of below-average precipitation or complete failure of precipitation inputs, and can be limited to a single season or prolonged over multiple years (Carroll et al., 2021; Palmer, 1965). The existence and the deepening of drought is influenced by atmospheric parameters impacting on evapotranspiration like air humidity, sunshine, wind speed but also on area slope and soil water characteristics (hydrolimits) (Labudová et al. 2015).

Drought stress is one of the major causes for crop loss, reducing an average yield with 50% and over. Soil water deficits that occur during the reproductive growth are considered to have the most adverse effect on crop yield (Habibi, 2011).

The aim of this study is to (i) evaluate monthly precipitation and air temperature according to the climatic normal 1990 – 2020, (ii) determine wet and dry periods according to Standard Precipitation Index (SPI) and (iii) evaluate soil moisture in Nitra River Basin from October 2020 to March 2022.

Material and methods

Study area

The Nitra River Basin (Figure 1) is located in the western part of Slovakia. An area is 4501 km^2. The territory is in the orographic subsystem of the Carpathian Mountains and the Pannonian Basin (Igaz et al., 2021; Borgula, 2004; Mazúr, Lukniš, 1980). In the basin is 61% of the area agricultural land

and 30% of the area forest land (Tárník, Igaz, 2015). In terms of climatic conditions, there are 3 climatic areas – warm climatic area (65% of the basin), moderate climatic area (north of the basin) and cold climatic area (small area at the highest altitudes). The mean annual temperature in the studied basin is according to climatic normal 1991-2020 within 10 °C (Prievidza) to 11.2 °C (Hurbanovo). Average annual precipitation is from 559 mm (Nitra) to 679 mm (Prievidza) (Igaz et al., 2021; SHMÚ, 2022).

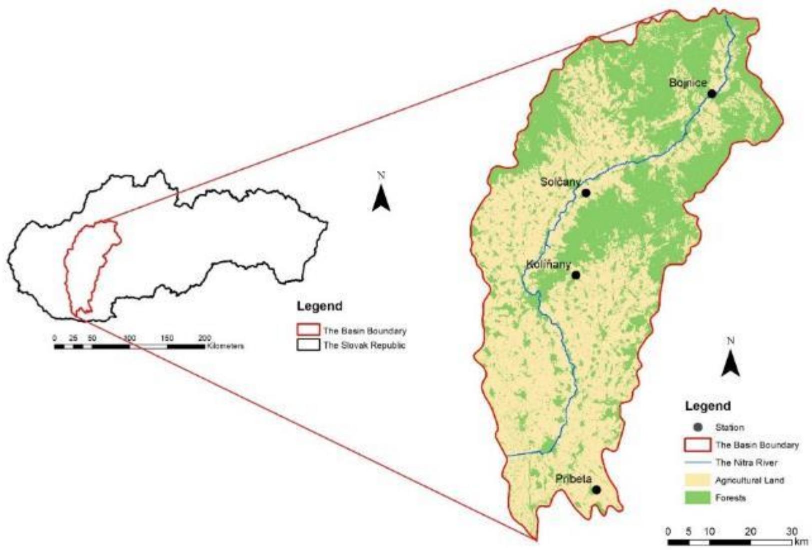


Figure 1 The Nitra River Basin

Table 1 Locality of meteorological stations and selected soil parameters

STATION	Locality		Altitude [m a.s.l.]	Soil type¹	K [cm/day]²	Particle size distribution			
	long.	lat.				I. category < 0.01 mm [%]	II. category 0.05- 0.01 mm [%]	III. category 0.1- 0.05 mm [%]	IV. category 0.1- 2.0 mm [%]
Bojnice	48.7816	18.5977	265	Loam	3,37	34,25	36,08	8,84	20,83
Solčany	48.5439	18.2133	175	Loam	133,01	41,06	42,09	5,56	11,29
Kolíňany	48.3643	18.2032	187	Loam	0,88	36,53	49,96	5,51	8,00
Pribeta	47.9033	18.3299	134	Sandy Loam	3,38	25,61	29,51	8,86	36,02

¹ According to Novak classification; ² Hydraulic conductivity

Table 1 lists selected stations with their altitude, soil type at the locality, hydraulic conductivity, and particle size distribution of the soil.

Data collection and analysis

Data from the Nitra River Basin were provided from the Slovak Hydrometeorological Institute (SHMI) and from the hydrological stations of the Institute of Landscape Engineering Slovak University of Agriculture in Nitra (ILE SUA). For our study we used data at localities Bojnice, Solčany, Kolíňany and Pribeta (Figure 1).

For the agroclimatic evaluation were used mean monthly temperatures, total monthly precipitation, and soil moisture. For analyses were applied the most commonly used methodologies - comparison of temperature and precipitation characteristics according to the climate normal, calculation of the Standardized Precipitation Index (SPI), and evaluation of the soil moisture according to the point of lower availability and the wilting point.

From the provided data were evaluated mean monthly air temperature deviations from the climatic normal 1990 – 2020 and monthly total precipitation in % of normal 1990 – 2020 SHMÚ, 2022; Čimo et al., 2012).

To quantify precipitation deficits/surpluses on a variety of time scales, usually between 1-month and 24-month sums, the SPI was developed by McKee et al. (1993) (Costa, 2011). It is based on a comparison of observed total precipitation amounts for an accumulation period of interest with the long-term historic rainfall record for that period. The historic record is fitted to a probability distribution (the “gamma” distribution), which is then transformed into a normal distribution. Therefore, the average SPI value for the study area and the specific reference period is zero, leading to a straightforward identification of wet (positive values) and dry (negative values) periods (EDO, 2020; Tikgas et al., 2018).

Table 2 Drought classification according to SPI values (WMO, 2012)

≥ 2,00	extremely wet
1,50 to 1,99	very wet
1,00 to 1,49	moderately wet
-0,99 to 0,99	near normal
-1,00 to -1,49	moderately dry
-1,50 to -1,99	very dry
≥ -2,00	extremely dry

The 1-month SPI, which was used, reflects short-term conditions, its application can be related closely to meteorological types of drought along with short-term soil moisture and crop stress, especially during the growing season (WMO, 2012). For SPI calculation was used software SPI Generator by the National Drought Mitigation Centre, University of Nebraska (NDMC, 2018).

The hydrological stations of ILE SUA measure soil moisture at 10 depths (0.10, 0.20, 0.30, 0.40, 0.50, 0.75, 1.00, 1.50, 2.00 and 2.5 m) with sensors 10HS by Decagon Devices and transfer data on-line (Tárník, Igaz, 2015). These sensors are based on Frequency Domain Reflectometry method with accuracy in mineral soils ± 0.03 m3/m3 if standard calibration equation is used (Meter group, 2017; Tárník, Igaz, 2020).

To assess the available water storage in the soil for vegetation cover, the characteristic point of the moisture retention curve is selected based on a convention (Kutílek, Nielsen, 2015). The point of lower availability is corresponding to a value of pF=3.3 and is characterized by soil moisture at which the physiological processes of the plant cover are limited by the deficiency (Gomboš et al., 2021). The wilting point corresponding to pF = 4.18. It is such soil moisture when the plant cover is permanently insufficiently supplied with water from the soil and withers (Šútor et al., 2005) Data on soil retention properties were taken from Skalová et al. (2015) and Igaz et al. (2011) who analysed several soil properties in the Nitra River Basin.

For our study we used data of soil moisture at a depth of 0.10 m. Data were processed, checks and corrections were made. If sensor failed, incorrect data were removed. Soil moisture was measured in hourly intervals. The daily average was calculated and compared to the point of lower availability and the wilting point at studied localities.

Results and discussion

From the evaluation of average monthly air temperatures according to deviations from the climate normal 1991 - 2020 (Table 3) it is seen that December 2020 was warm (Pribeta) and very warm (Bojnice, Solčany and Kolíňany). The temperature was 3.0 to 3.7 °C higher than normal. In 2021, April and May were very cold to extremely cold (April - Solčany). The temperature was lower by -2.6 to -3.0 °C in April and by -2.2 to -2.4 °C in May compared to normal. A very cold May was followed by a very hot June (Solčany, Pribeta) to an extremely hot one (Bojnice, Kolíňany) with temperatures 2.8 to 3.5 above normal. Similarly, July was very warm (warm - Kolíňany) followed by cold August with temperatures -1.0 to -1.6 °C lower than normal. The remaining months were normal. Until January and February 2022. At that time, temperatures were above normal by 1.6 to 2.2 °C (January) and by 3.0 to 3.1 °C (February).

Table 3 Evaluation of mean monthly temperature from the climatic normal 1991 – 2020

	BOJNICE	SOLČANY	KOLÍŇANY	PRIBETA
X.2020	normal	normal	normal	normal
XI.2020	normal	normal	normal	normal
XII.2020	very hot	very hot	very hot	hot
I.2021	normal	normal	hot	hot
II.2021	normal	normal	normal	normal
III.2021	normal	normal	normal	normal
IV.2021	very cold	extremely cold	very cold	very cold
V.2021	very cold	very cold	very cold	very cold
VI.2021	extremely hot	very hot	extremely hot	very hot
VII.2021	very hot	very hot	hot	very hot
VIII.2021	cold	cold	cold	cold
IX.2021	normal	normal	normal	normal
X.2021	normal	normal	normal	normal
XI.2021	normal	normal	normal	normal
XII.2021	normal	normal	normal	normal
I.2022	hot	hot	hot	hot
II.2022	hot	very hot	hot	very hot
III.2022	normal	normal	normal	normal

Table 4 Evaluation of monthly total deviation precipitation in % of normal 1990 - 2020

	BOJNICE	SOLČANY	KOLÍŇANY	PRIBETA
X.2020	extremely wet	extremely wet	extremely wet	extremely wet
XI.2020	very dry	very dry	very dry	very dry
XII.2020	normal	normal	normal	dry
I.2021	normal	normal	wet	normal
II.2021	normal	normal	normal	wet
III.2021	very dry	dry	extremely dry	extremely dry
IV.2021	normal	dry	normal	wet
V.2021	very wet	extremely wet	very wet	very wet
VI.2021	extremely dry	extremely dry	very dry	extremely dry
VII.2021	wet	wet	normal	dry
VIII.2021	very wet	very wet	extremely wet	dry
IX.2021	normal	normal	normal	normal
X.2021	extremely dry	very dry	very dry	very dry
XI.2021	dry	normal	normal	dry
XII.2021	normal	normal	normal	normal
I.2022	normal	very dry	very dry	extremely dry
II.2022	very wet	wet	normal	normal
III.2022	very dry	very dry	very dry	dry

It is seen from the data above that extreme temperature situations occur quite often. There are rapid changes in temperature, when we get directly from the below-average month to the above-average temperature (compared to the normal). The trend of warming in the winter is also clear. This fact must also be taken into account in terms of the form of winter precipitation when we will not be able to rely on the slow melting of snow in the spring and thus the spring supply of water to the soil.

According to precipitation (Table 4), October 2020 was extremely wet, and November 2020 was very dry. March 2021 was dry (Solčany) to extremely dry (Kolíňany, Pribeta). The biggest fluctuation was in May and June. May was very wet to extremely wet (Solčany) and June was very dry (Kolíňany) to extremely dry. August was very wet, and October was very dry. In 2022, like in 2021, it was a dry to very dry March. For the Pribeta station, the period from June 2021 to March 2022 is dry to extremely dry. Except for September, December, and February when precipitation is normal.

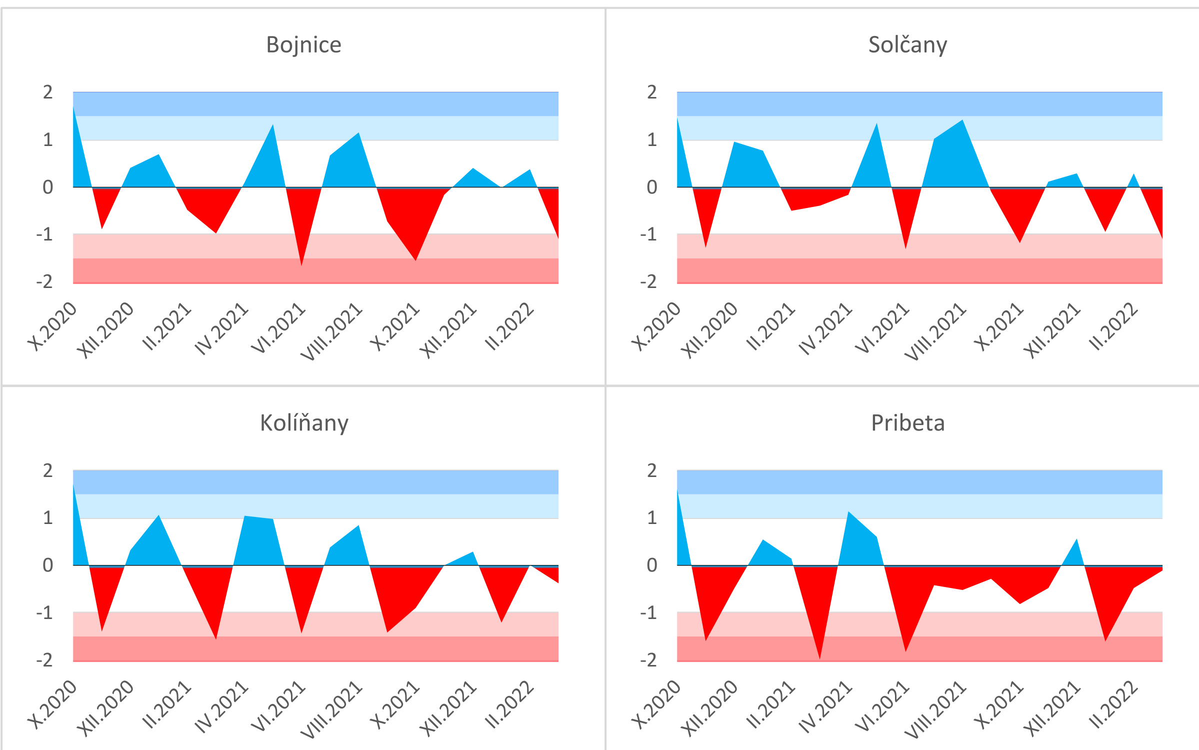


Figure 2 Standard precipitation index (1 month)

Figure 3 Course of soil moisture and hydrolimites - point of lower availability and wilting point

According to the precipitation assessment, large fluctuations can be seen. From extreme drought there is a quick shift to extremely wet weather. Rainfall fluctuations then also affect the course of soil moisture, and in certain periods the humidity drops below critical values.

According to the SPI index (Figure 2), October 2020 passes from moderately wet (Solčany) to very wet. November 2020 is moderately dry (Solčany, Kolíňany) and severely dry (Pribeta). Also, June 2021 and October 2021 (except Kolinany and Pribeta) is at all stations from moderately to severely dry. On the contrary, May and August are moderately wet at Bojnice and Solčany stations. Drought reappears at the beginning of 2022. Also, at the Pribeta station there is a visible deficit of precipitation from June 2021 to March 2022 (except December 2021), even though SPI values are in the limit (near normal). The SPI assessment also confirms our previous statements based on the assessment of temperature and precipitation.

Soil moisture in the Bojnice locality (Figure 3) has been below the hydrolimit - point of reduced availability - since March 2021, when the mobility of water in the soil and its accessibility for plants was reduced. Soil moisture values increased slightly in May, August, and winter (December - February), but did not exceed the level of point of reduced availability. On the contrary, Solčany was above the hydrolimit point of reduced availability during the observed period (except in April 2021). There is a more pronounced drought in the localities of Kolíňany (May 2021) and Pribeta (August 2021), when the values of soil moisture exceeded the limit of the wilting point, at which the plants are insufficiently supplied with water.

It is seen from the course of soil moisture that even wetter periods did not significantly increase the water content in the soil. This is mainly due to the extremeness of precipitation. On the other hand, longer-lasting less intense precipitation is needed to replenish the water in the soil, because the extreme precipitation does not have time to infiltrate the soil.

Climate change is a major threat that could lead to a decline in agricultural production in many regions of the world (Hamidov et al., 2018). Riedel and Weber (2020) said that Central Europe's current transition from a temperate and relatively moist climate towards a more variable and Mediterranean-like climate may shift groundwater recharge patterns and increase the ratio of focused-to-diffusive groundwater recharge as precipitation patterns change and the frequency and intensity of climatic extremes (e.g., heavy rainfall, heatwaves, droughts, floods, and wildfires) increase. Grillakis´s (2019) results show that drought conditions are expected to exacerbate in Europe with substantial differences among regions. Eastern Europe and Mediterranean regions are found to be the most affected. Vido, Nalevanková (2020) founded that increasing air temperature increased the difference in drought trends between lowlands and mountains during the studied period in Slovakia. Vido et al. (2019) researched the trend analyses showed that drought occurs in the Horné Požitavie region (Slovakia) regularly (recurrent climate feature), while the trend analysis indicated the trend toward more arid climatic conditions.

Also, The Supreme Audit Office of the Slovak Republic states that the Slovak Republic is not prepared to deal with drought so as to eliminate future threats to the environment and society, because the issue of drought is not addressed comprehensively and systemically (NKÚ SR, 2021).

Conclusions

This paper is focused on worldwide actual topic - assessment of climate change impact. Trends in air temperature, precipitation and soil moisture were analysed based on data from October 2020 to March 2022. Also, SPI was analysed. Our results shows that character of weather is changing very rapidly. Weather was switching from hot and dry periods to cold and wet ones. Our measurements show new era in weather trends and climate change impact could be observed well. We can see colder and wetter springtime, summers with extreme weather changes and hotter and dryer winter periods (Markovič et al., 2020). Of course, our measurements are short for definitive conclusions, but they show trends in important climatic parameters.

Acknowledgment

This publication was supported by the Operational Program Integrated Infrastructure within the project: Demand-driven research for the sustainable and inovative food, Drive4SIFood 313011V336, cofinanced by the European Regional Development Fund; by the Grant Agency of SUA in Nitra no. 19-GASPU-2021; by the Cultural and Educational Grant Agency no. KEGA 031SPU-4/2021 and by the Cultural and Educational Grant Agency no. KEGA 026SPU-4/2020.

References

BETTS, R.A. et al. 2018. Changes in climate extremes, fresh water availability and vulnerability to food insecurity projected at 1.5°C and 2°C global warming with a higher-resolution global climate model. In Phil. Trans. R. Soc. A. http://doi.org/10.1098/rsta.2016.0452.

BORGULA, A. (2004). Rieka Nitra v Okolí Mesta Nitra [The Nitra River Near the Nitra City] [cit. 2022-04-05]. Available online: http://riekanitra.szm.com/ (accessed on 5 April 2022) (In Slovak).

CARROLL, Ch. J. W. et al. 2021. Is a drought a drought in grasslands? Productivity responses to different types of drought. In Oecologia vol. 197, pp. 1017–1026. https://doi.org/10.1007/s00442-020-04793-8.

ČIMO, J. et al. 2012. Praktická biometeorológia [Practical Biometeorology]. SPU: Nitra. 201 p. ISBN 978-80-552-0771-1 (In Slovak).

Copernicus European Drought Observatory (EDO). 2020. Standardized Precipitation Index (SPI) [online] [cit. 2022-04-11]. Available online: https://edo.jrc.ec.europa.eu/documents/factsheets/factsheet_spi.pdf.

COSTA, A. C. 2011. Local patterns and trends of the Standard Precipitation Index in southern Portugal (1940–1999). In Adv. Geosci., 30, 11–16, https://doi.org/10.5194/adgeo-30-11-2011.

DEHRASHID, A. A. et al. 2022. Perspectives of Climate Change. In Bandh, S.A. (eds) Climate Change. Springer, Cham. https://doi.org/10.1007/978-3-030-86290-9_21.

FENDEKOVÁ, M. et al. 2018. Analysing 21st century meteorological and hydrological drought events in Slovakia. In Journal of Hydrology and Hydromechanics, vol.66, no.4, pp.393-403. https://doi.org/10.2478/johh-2018-0026.

GELYBÓ, G. et al. 2018. Potential impacts of climate change on soil properties. In Agrokémia és Talajtan, vol. 67, issue 1, pp. 121-141. ISSN 1588-2713.

GOMBOŠ, M. et al. 2021. Influence of Soil Type on Statistical Characteristics and Graphical Results Interpretation of the Water Storage Distribution Monitoring Along the Vertical of the Soil Profile. In Acta Hydrologica Slovaca, vol. 22, no. 1, pp. 97 – 105. https://doi.org/10.31577/ahs-2021-0022.01.0011.

GRILLAKIS, M. D. 2019. Increase in severe and extreme soil moisture droughts for Europe under climate change. In Science of The Total Environment, vol. 660, pp. 1245-1255. ISSN 0048-9697. https://doi.org/10.1016/j.scitotenv.2019.01.001.

HABIBI, G. 2011. Influence of Drought on Yield and Yield Components in White Bean. In International Journal of Agricultural and Biosystems Engineering, vol . 5, no. 7. [cit. 2022-04-11]. Available online: https://publications.waset.org/12610/pdf.

HAMIDOV, A. et al. 2018. Impacts of climate change adaptation options on soil functions: A review of European case-studies. In Land Degradation & Development. vol. 29, iss. 8, pp 2378-2389. https://doi.org/10.1002/ldr.3006.

IGAZ, D. et al. 2011. Analýza hydrofyzikálnych charakteristík pôd v povodí rieky Nitra [The Analysis of Soils Hydrophysical Characteristics in the Nitra River Basin]. Influence of Anthropogenic Activities on Water Regime of Lowland Territory Physics of Soil Water, 17-19. ISBN 978-80-89139-23-1 (In Slovak).

IGAZ, D. et al. 2021. The Evaluation of the Accuracy of Interpolation Methods in Crafting Maps of Physical and Hydro-Physical Soil Properties. In Water 2021, 13, 212. https://doi.org/10.3390/w13020212.

KOUTROULIS, A.G. et al. 2018. Freshwater vulnerability under high end climate change. A pan-European assessment. In Science of The Total Environment, vol. 613-614, pp. 271-286. ISSN 0048-9697. https://doi.org/10.1016/j.scitotenv.2017.09.074.

KUNDZEWICZ, Z. W. et al. 2006. Precipitation extremes in the changing climate of Europe. In Climate Research, vol. 31, pp. 51-58. ISSN 1616-1572.

KUTÍLEK, M. – NIELSEN, D. R. 1994. How Water Flows in Soil. In Soil. Dordrecht: Springer. https://doi.org/10.1007/978-94-017-9789-4_9.

MARKOVIČ, L. et al. 2020. Zmeny v skupenskom zastúpení atmosférických zrážok v zime na území Slovenska [Changes in phase of precipitation during winter in Slovakia]. In Meteorologické zprávy, vol. 73. ISSN 0026-1173.

MAZÚR, E. - LUKNIŠ, M. 1980. Geomorfologické Jednotky. Atlas SSR [Geomorfological Units. Atlas of Slovakia]; SAV, SÚGK: Bratislava, Slovakia (In Slovak).

MCKEE, T. B. et al. 1993. The relationship of drought frequency and duration to time scales. In 8th Conference on Applied Climatology, Am. Meteorol. Soc. Boston, pp. 179–184.

Meter group. (2017). [cit. 2022-04-11] Available online: https://www.metergroup.com/environment/products/ech20-10hs-soil-moisture-sensor/.

Najvyšší kontrolný úrad (NKÚ) SR. 2021. Správa o výsledku kontroly: Pripravenosť Slovenskej republiky na riešenie sucha [Inspection result report: Readiness of the Slovak Republic to deal with drought]. [cit. 2022-04-12]. Available online: https://www.nku.gov.sk/aktuality/-/asset_publisher/9A3u/content/slovensko-treba-pripravit-na-riesenie-sucha-chyba-system-a-strategia.

National Drought Mitigation Centre (NDMC). 2018. SPI Program [online] [cit. 2022-04-11]. Available online: https://drought.unl.edu/monitoring/SPI/SPIProgram.aspx.

PALMER, W. C. 1965. Meteorological Drought. Washington, D.C.: U.S. Weather Bureau.

RIEDEL, T. – WEBER, T.K.D. 2020. Review: The influence of global change on Europe's water cycle and groundwater recharge. In Hydrogeol J 28, 1939–1959. https://doi.org/10.1007/s10040-020-02165-3.

SHMÚ. 2022. Prechod klimatologických hodnotení a produktov Klimatologickej služby na nové štandardné normálové obdobie 1991 – 2020 [Transition of climatological evaluations and products of the Climatological Service to the new standard normal period 1991 - 2020] [cit. 2022-04-05]. Available online: https://www.shmu.sk/sk/?page=2049&id=1197 (In Slovak).

SKALOVÁ, J. et al. 2015. Regionalizácia pedotransferových funkcií vlhkostných retenčných kriviek pôd Slovenska [Regionalization of Pedotransfer Functions of Soil Moisture Retention Curves]. STU: Bratislava, Slovakia. ISBN 9788022744553 (In Slovak).

ŠÚTOR, J. et al. 2005. Kvantifikácia pôdneho sucha a jej interpretácia [The Quantification of Soil Drought and Its Performance]. In Acta Hydrologica Slovaca, 6(2), 299-306 (In Slovak).

TÁRNÍK, A. – IGAZ, D. 2015. Quantification of soil water storage available to plants in the Nitra River basin. In Acta Scientiarum Polonorum Formatio Circumiectus. 14(2), 209-216. http://dx.doi.org/10.15576/ASP.FC/2015.14.2.209.

TIGAS, D. et al. 2018. Drought characterisation based on an agriculture-oriented standardised precipitation index. In Theoretical and Applied Climatology 135:1435–1447. DOI /10.1007/s00704-018-2451-3.

VIDO, J. – Nalevanková, P. 2020. Drought in the Upper Hron Region (Slovakia) between the Years 1984–2014. In Water 12, no. 10: 2887. https://doi.org/10.3390/w12102887.

VIDO, J. et al. 2019. Drought Analyses of the Horné Požitavie Region (Slovakia) in the Period 1966–2013. In Advantes in Meteorology, vol. 2019, p. 10. https://doi.org/10.1155/2019/3576285.

VOGEL, M. M. et al. 2018. Varying soil moisture–atmosphere feedbacks explain divergent temperature extremes and precipitation projections in central Europe. In Earth Syst. Dynam.,vol 9, pp. 1107–1125. https://doi.org/10.5194/esd-9-1107-2018.

WILHITE, D A. 2000. Chapter 1 Drought as a Natural Hazard: Concepts and Definitions. Drought Mitigation Center Faculty Publications. 69. http://digitalcommons.unl.edu/droughtfacpub/69.

WORLD METEOROLOGICAL ORGANIZATION. 2012. Standardized Precipitation Index User Guide (M. Svoboda, M. Hayes and D. Wood). (WMO-No. 1090), Geneva. ISBN 978-92-63-11090-9.

ZELEŇÁKOVÁ, M. – FENDEKOVÁ, M. 2018. Climate Change Impacts on Water Resources. In Negm, A. M. – Zeleňáková, M. 2018. Water Resources in Slovakia: Part II – Climate Change, Drought and Floods. Springer International Publishing AG 2018, pp. 3-19. DOI 10.1007/698_2018_268.

Contact address: Ing. Vladimír Kišš, PhD., Research Centre Agrobiotech, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, +421 37 641 5247, vladimir.kiss@uniag.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 17.05.2022
Received in revised form 01.06.2022
Accepted 01.06.2022

SUNSHINE DURATION, ITS VARIABILITY AND VISUALISATION IN SLOVAKIA IN 1971-2020

Vladimír Kišš[1], Jakub Pagáč[1], Ján Čimo[2], Andrej TÁRNÍK[2]

[1]Research Centre Agrobiotech, Slovak Agriculture University in Nitra, SLOVAKIA

[2]Faculty of Horticulture and Landscape Engineering, Slovak Agriculture University in Nitra, SLOVAKIA

Abstract

Climate change and its impact on various areas of human activity are currently among the most serious global living problems of mankind. In the field of agricultural sciences, there is extensive discussion, reflection, and often conflicting views on this issue among scientists, especially on the recommended interventions to respond to these changes. The paper analyses the impact of climate change on the change in the sunshine duration for the period from 1971 to 2020 in Slovakia. The analyses so far clearly show an increase in the amount of sunshine on average from 11 % to 28 %, depending on the location, which is also confirmed by the Mann-Kendall trend analysis. Statistically increasing trends ($p < 0.05$) are in every station in April, June (except Rimavská Sobota), July (except Milhostov) and August. A statistically significant increase in the duration of sunshine, as well as cloudiness, is also related to precipitation. The change in the distribution of precipitation during the year, the occurrence of dry periods in the spring months and the lack of soil water.

Keywords: climate change, sunshine duration, GIS analysis, Mann-Kendall test

 https://doi.org/10.15414/2022.9788055225029

Introduction

The main tasks of agrometeorology include the analysis of the interrelationships between climatic factors and agricultural production, or the study of agroclimatic differences in various areas and time periods (Špánik, Repa, 1978). In this paper we present the agroclimatic characteristics of the meteorological element - sunshine in Slovakia for the time series 1971 – 2020. The sunshine duration, defined as the amount of time that the sunshine intensity exceeds a threshold of brightness when the disk of the sun is above the horizon, is the most common type of solar radiation measurements (Zheng et al., 2008).

The term "sunshine" is associated with the brightness of the solar disc exceeding the background of diffuse sky light, or as is better observed by the human eye, with the appearance of shadows behind illuminated objects. According to World Meteorological Organization (WMO) (2010), sunshine duration during a given period is defined as the sum of the time for which the direct solar irradiance exceeds 120 W m^{-2} (WMO, 2018). We do not express the duration of sunlight by the intensity of direct sunlight and do not affect diffuse radiation even at higher intensities, such as the sensitivity of the device. It is most often given in hours per day, month, year, or is converted to some relative values (usually a percentage of the possible duration of sunshine) (Havlíček et al., 1986).

The duration of sunshine in European conditions is influenced by meteorological factors (clouds, fog, metropolitan atmosphere) that it usually does not reach even half of its possible duration. The astronomically possible duration of sunshine in Slovakia is almost 4,500 hours per year, the average annual amount in Hurbanovo, for example, is approximately 2,000 hours per year (Špánik et al., 2002).

In this work, we focused on the evaluation of the length of sunshine duration by Mann-Kendall statistical analysis for the months of the year in the period 1971 – 2020 and on the map outputs of the average annual length of sunshine duration for decades.

Material and methods

<u>Study area</u>

Slovakia is located in Central Europe (Figure 1). The area of Slovakia is 49,035 km^2. The surface of Slovakia is characterized by great diversity and representation of several geographical types. From

 https://doi.org/10.15414/2022.9788055225029

the lowlands in the south, the country passes through a range of hills and highlands to the mountains, represented in the north. However, most of the country is slightly undulating. About two-thirds of the territory is the Carpathian Mountains. One third of the country's territory belongs to the Pannonian Basin, within which there are 3 areas in Slovakia: Záhorská lowland in the west, Podunajská lowland in the southwest and Východoslovenská lowland in the southeast (Čimo et al., 2012).

Figure 1 Slovakia in Europe (Wikipedia, 2022)

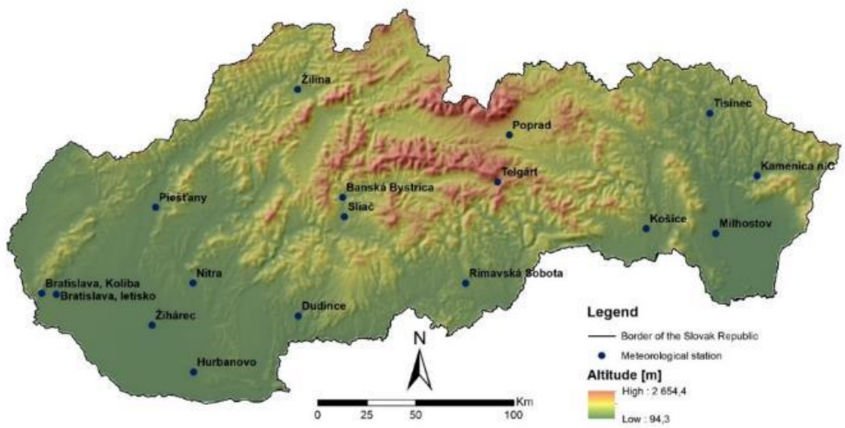


Figure 2 Locality of meteorological stations

Data collection and analysis

Data of the sunshine duration were provided from the Slovak Hydrometeorological Institute (SHMI) at selected localities (Figure 2).

The rank-based Mann–Kendall (MK) test is the most widely used nonparametric method for trend detection. Being a nonparametric test, it can be applied to data no matter what the probability distribution is (Önöz, Bayazit, 2011). The basic principle of MK tests for trend is to examine the sign of all pair wise differences of observed values (Libiseller, Grimvall, 2002; Gocic, Trajkovic, 2013; Hamed, 2018; Al Buhairi, 2010; Alhaji et al., 2018).

The Mann-Kendall test statistic S (Mann, 1945, Kendall, 1975) is calculated as:

$$S = \sum_{i=2}^{n} \sum_{j=1}^{i-1} sign\left(x_i - x_j\right) \tag{1}$$

where *n* is the length of the data set, *xi* and *xj* are two generic sequential data values, and the function $sign\left(x_i - x_j\right)$ assumes the following values:

$$sign\left(x_i - x_j\right) \begin{cases} 1, if \left(x_i - x_j\right) > 0, \\ 0, if \left(x_i - x_j\right) = 0, \\ -1, if \left(x_i - x_j\right) < 0. \end{cases} \tag{2}$$

The *S* statistic represents the number of positive differences minus the number of negative differences found in analysed time series. Under the null of that there is no trend in the data no correlation between considered variable and time, each ordering of the data set is equally likely. Under this hypothesis the statistic *S* is approximately normally distributed with the mean *E(S)* and the variance *Var (S)* as follows:

$$E(S) = 0 \tag{3}$$

$$Var\ (S) = \frac{1}{18}\left[n(n-1)(2n = 5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right] \tag{4}$$

where *n* is the length of the times-series, t_p is the number of ties for the p_{th} value and *q* is the number of tied values i.e., equals values. The second term represents an adjustment for tied or censored data. The standardized test statistic *Z* is given by:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var\ (S)}} & if\ S > 0, \\ 0 & if\ S = 0, \\ \dfrac{S-1}{\sqrt{Var\ (S)}} & if\ S < 0. \end{cases} \tag{5}$$

The presence of a statistically significant trend is evaluated using the *Z* value. This statistic is used to test the null hypothesis such that no trend exists. A positive *Z* indicates an increasing trend in the time-series, while a negative *Z* indicates a decreasing trend. To test for either increasing or decreasing monotonic trend at p significance level, the null hypothesis is rejected if the absolute value of *Z* is greater than $Z_{(1-p/2)}$; where $Z_{(1-p/2)}$ is obtained from the standard normal cumulative distribution tables. In this work, the significance levels of 0.01, 0.05 and 0.1 were applied, and the significant level p-value was obtained for each analysed time-series. It is also possible to obtain a non-parametric estimate for the magnitude of the Sen's slope of trend:

$$b = Median\left[\frac{(\mathrm{X_j} - \mathrm{X}_i)}{(j-i)}\right], \qquad for\ all\ i < j \tag{6}$$

Where *b* is the slope between data points X_j and X_i; measured at times *j* and *i*; respectively.

Sen Slope estimator test (Sen, 1968) are applied to the whole time series to detect the direction and magnitude of a trend.

Excel XLSTAT was used for Mann-Kendall statistical test to detect if there are any statistically significant trends existing in the data.

ArcGIS analysis

For the analysis was used ArcGIS software (ESRI) to create and process map outputs. From the interpolation methods available in ArcGIS, the Topo to Raster method was used, which is based on ANUDEM version 4.6.3. The method combines the properties of IDW, Spline and Kriging interpolation techniques. It is optimized for the computational efficiency of local interpolation methods such as IDW, but without losing the surface continuity of global interpolation methods such as Spline and Kriging. Depending on the type of interpolation, it is a discrete spline method.

The input files in the interpolation process were meteorological stations (as a point vector) containing attributes - meteorological data, as well as the vector border of the Slovak Republic due to the limitation of the interpolation process only within the state (Čimo, 2019). The raster resolution was chosen at the level of 100 m, due to the density of the input data and the extent of interpolation.

Results and discussion

The values of the Z statistics of the MK test are given in Tab. 1 and Tab. 2. The tables show statistically increasing trends ($p < 0.05$) in every station in April, June (except Rimavská Sobota), July (except Milhostov) and August. Sen´s slope shows an increase in these months. In April from

0,80 h.year^{-1} to 1,98 h.year^{-1}, in June from 0,50 h.year^{-1} to 2,14 h.year^{-1} and in July from 0,67 h.year^{-1} to 1,88 h.year^{-1}. The greatest increase is at locality Kamenica nad Cirochou in April (1,98 h.year^{-1}) and in June (2,14 h.year^{-1}).

In recent months, there have been statistically significant trends at some stations. At the station Bratislava - airport, a significant increase occurred except in October to December during all months. On the contrary, at stations in eastern Slovakia (Košice, Tisinec and Milhostov) there is a decrease in the duration of sunshine during the months of January - February and December. At the Milhostov station, there was even a statistically significant decrease in December.

The statistically significant increase in the duration of sunshine, and thus in the cloudiness, is also related to precipitation. Several authors describe the change in the distribution of precipitation during the year (Repel et al., 2021; Zeleňáková et al., 2017), the occurrence of dry periods in the spring months (Brezianská, Vitková, 2015) and the lack of soil water (Šútor et al., 2011).

Table 1 Results of Mann-Kendall test (Z) with Sen's slope estimator (b) for monthly sunshine duration time series 1971 - 2020 (January – June)

Locality	January		February		March		April		May		June	
	Z value	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*
BA - Koliba	1,71	*0,34*	1,42	*0,43*	**2,12***	*0,90*	**4,15***	*1,41*	1,76	*0,76*	**3,55***	*1,32*
BA - letisko	**2,68***	*0,52*	**2,24***	*0,73*	**3,13***	*1,27*	**5,05***	*1,81*	**2,49***	*1,01*	**4,10***	*1,66*
Žihárec	0,99	*0,17*	0,94	*0,21*	1,57	*0,60*	**3,45***	*1,20*	1,07	*0,61*	**3,55***	*1,54*
Piešťany	0,18	*0,02*	0,43	*0,15*	1,04	*0,43*	**2,58***	*1,00*	0,23	*0,14*	**2,09***	*0,80*
Dolný Hričov	1,43	*0,20*	-0,25	*-0,07*	1,15	*0,43*	**3,56***	*1,43*	1,84	*0,86*	**3,06***	*1,58*
Nitra	0,55	*0,11*	0,70	*0,26*	1,12	*0,54*	**3,21***	*1,14*	1,00	*0,51*	**2,39***	*1,05*
Hurbanovo	1,36	*0,30*	0,69	*0,31*	1,72	*0,74*	**3,28***	*1,10*	1,00	*0,61*	**2,51***	*1,03*
Dudince	1,00	*0,15*	0,17	*0,05*	1,39	*0,59*	**3,95***	*1,34*	1,71	*0,93*	**2,26***	*0,91*
Banská Bystrica	1,00	*0,29*	0,42	*0,11*	1,39	*0,61*	**3,04***	*1,05*	**1,99***	*0,91*	**2,44***	*1,01*
Sliač	0,99	*0,25*	0,52	*0,19*	1,73	*0,69*	**3,66***	*1,22*	**2,17***	*1,18*	**2,04***	*0,82*
Poprad	**2,07***	*0,52*	0,47	*0,21*	**2,02***	*0,78*	**4,33***	*1,66*	**3,28***	*1,53*	**3,36***	*1,52*
Telgárt	0,67	*0,21*	-0,42	*-0,10*	1,12	*0,42*	**3,26***	*1,26*	1,86	*0,99*	**2,22***	*0,87*
Rimavská Sobota	0,80	*0,20*	0,12	*0,03*	1,44	*0,56*	**3,00***	*0,80*	1,09	*0,54*	1,15	*0,50*
Košice	-0,40	*-0,07*	0,12	*0,03*	1,61	*0,61*	**3,83***	*1,36*	1,50	*0,74*	**2,81***	*1,26*
Tisinec	-1,19	*-0,25*	-0,35	*-0,08*	0,59	*0,27*	**3,98***	*1,53*	1,52	*0,87*	**2,98***	*1,26*
Milhostov	-1,52	*-0,32*	-0,79	*-0,21*	0,08	*0,06*	**3,15***	*1,02*	1,05	*0,56*	**2,39***	*1,03*
Kamenica n. Cirochou	1,00	*0,19*	0,30	*0,13*	1,70	*0,71*	**5,65***	*1,98*	**2,02***	*1,21*	**4,30***	*2,14*

* $p < 0.05$

 https://doi.org/10.15414/2022.9788055225029

Table 2 Results of Mann-Kendall test (Z) with Sen's slope estimator (b) for monthly sunshine duration time series 1971 - 2020 (June – December)

Locality	July		August		September		October		November		December	
	Z value	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*	*Z value*	*Sen´s slope (b)*
BA - Koliba	**3,65***	*1,67*	**2,59***	*1,22*	**2,04***	*0,98*	0,40	*0,15*	0,97	*0,25*	1,27	*0,21*
BA - letisko	**4,12***	*1,88*	**2,98***	*1,40*	**2,41***	*1,10*	0,57	*0,20*	1,54	*0,38*	0,90	*0,19*
Žihárec	**3,45***	*1,44*	**2,34***	*0,94*	1,67	*0,61*	0,64	*0,24*	**2,29***	*0,47*	1,09	*0,17*
Piešťany	**2,74***	*1,17*	**2,04***	*0,92*	1,34	*0,55*	-0,55	*-0,21*	1,54	*0,33*	0,38	*0,06*
Dolný Hričov	**3,30***	*1,70*	**2,96***	*1,36*	1,91	*0,84*	-0,02	*-0,01*	**3,01***	*0,49*	**2,17***	*0,33*
Nitra	**2,84***	*1,27*	**2,44***	*1,09*	1,05	*0,48*	0,03	*0,01*	1,74	*0,35*	0,77	*0,12*
Hurbanovo	**2,93***	*1,17*	**2,34***	*1,06*	1,37	*0,60*	0,69	*0,26*	**2,50***	*0,50*	0,87	*0,19*
Dudince	**3,11***	*1,13*	**2,53***	*1,06*	1,84	*0,70*	0,82	*0,30*	**2,16***	*0,44*	0,36	*0,07*
Banská Bystrica	**3,08***	*1,18*	**2,16***	*0,91*	1,42	*0,61*	-0,74	*-0,21*	1,52	*0,36*	1,32	*0,24*
Sliač	**3,31***	*1,42*	**2,79***	*1,25*	1,74	*0,76*	-0,40	*-0,11*	1,20	*0,22*	1,19	*0,19*
Poprad	**3,56***	*1,41*	**3,90***	*1,55*	1,90	*0,85*	0,10	*0,03*	1,47	*0,34*	1,71	*0,37*
Telgárt	**2,76***	*1,04*	**3,16***	*1,27*	1,30	*0,59*	-1,20	*-0,46*	0,07	*0,03*	0,28	*0,04*
Rimavská Sobota	**2,77***	*0,97*	**2,81***	*1,30*	1,81	*0,68*	-0,49	*-0,17*	0,79	*0,13*	-0,72	*-0,10*
Košice	**2,83***	*1,09*	**3,68***	*1,65*	**2,04***	*0,82*	0,55	*0,20*	**2,54***	*0,56*	-0,64	*-0,11*
Tisinec	**2,54***	*1,13*	**3,93***	*1,97*	**2,81***	*1,20*	1,22	*0,46*	1,77	*0,39*	-0,69	*-0,15*
Milhostov	1,81	*0,67*	**3,38***	*1,39*	1,15	*0,43*	0,03	*0,01*	1,15	*0,22*	**-2,41***	*-0,42*
Kamenica n. Cirochou	**3,98***	*1,83*	**3,09***	*1,43*	**3,03***	*1,21*	1,09	*0,42*	**3,18***	*0,67*	**3,15***	*0,53*

* $p < 0.05$

The assessment of the average annual duration of sunshine also shows an increase (Figure 3 – 7). During the decade 1971 - 1980 it reached values from 1400 hours in the north to 1900 hours in the south. In the current decade (2011 - 2020), the average annual values start at the level of 1700 hours in the north to 2200 hours in the south of Slovakia. From a comprehensive perspective, we can say that the average increase in sunshine compared to 1971-1980 and the last decade 2011-2020 is 19.3 % (an increase of 323 hours on average). The lowest percentage increases in sunshine were recorded in Rimavská Sobota 11 % (181 hours) and Trebišov 11.2 % (196 hours) and the highest were in Kamenica nad Cirochou 28 % (455 hours), Bratislava Airport 26.6 % (457 hours), Dolný Hričov 24.5 % (352 hours), Poprad 24.4 % (395 hours) and Tisinec 23.4 % (357 hours) other localities represented an average increase of 17.9 %, which represents a value of 309 hours.

 https://doi.org/10.15414/2022.9788055225029

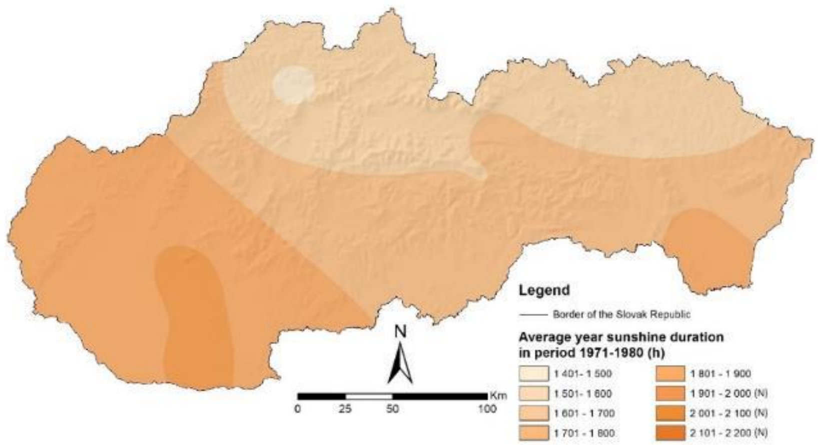


Figure 3 Average year sunshine duration in period 1971 – 1980 in hours (*N – not available)

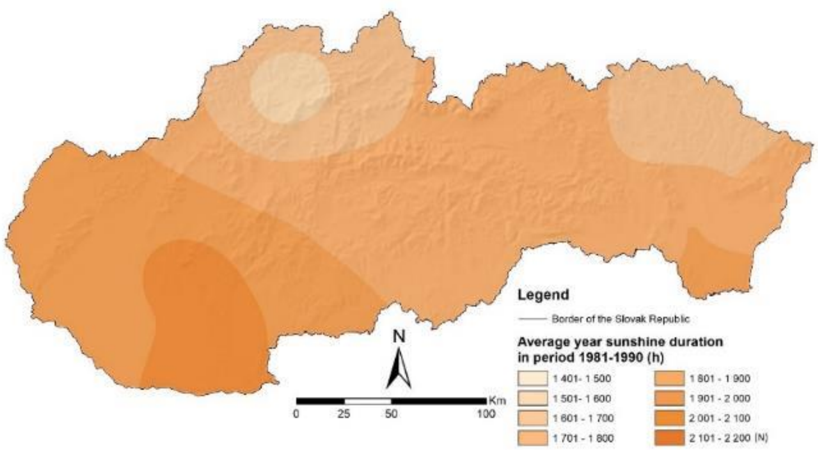


Figure 4 Average year sunshine duration in period 1981 – 1990 in hours (*N – not available)

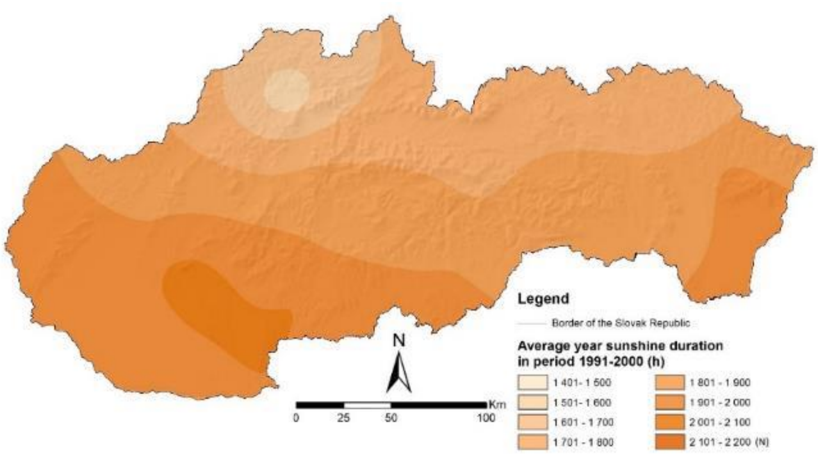


Figure 5 Average year sunshine duration in period 1991 – 2000 in hours (*N – not available)

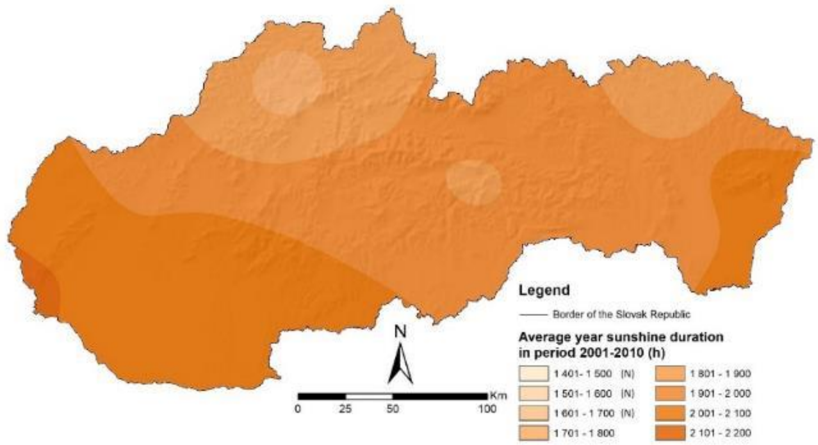


Figure 6 Average year sunshine duration in period 2001 – 2010 in hours (*N – not available)

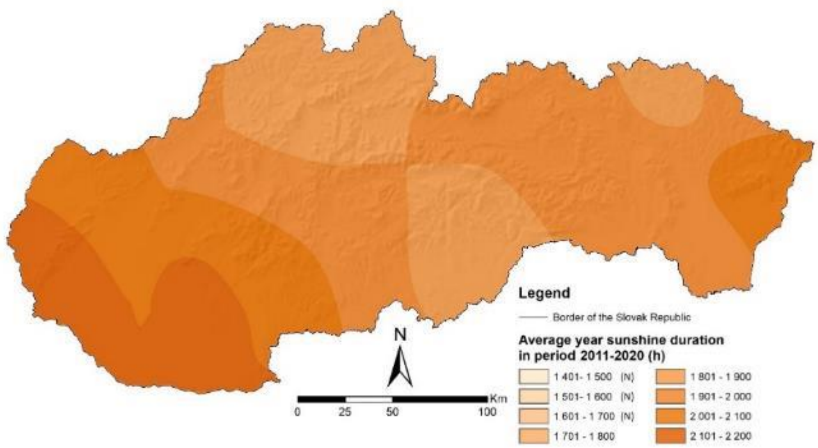


Figure 7 Average year sunshine duration in period 2011 – 2020 in hours (*N – not available)

Few authors deal with changes in the sunshine duration. Most of them deal with the intensity of sunlight. In Europe, the sunshine duration was studied in Italy and especially in Poland. Manara et al. (2015) claim that the increase in the length of sunshine is mainly from the 80s. There is also a significant increase in the length of sunshine in Poland (Bartoszek et al., 2020; Matuszko et al., 2015), which confirms our results. The U.S. sunshine duration database shows little evidence for a significant trend in solar forcing at the earth's surface during the twentieth century (Stanhill, Cohen, 2005). Analysis of data from about 200 meteorological observing stations shows significant decreases in percent of possible sunshine duration over much of China for the period 1954 – 1998 (Kaiser, Qian, 2002).

Conclusions

In our work we deal with the sunshine duration and Mann-Kendall analysis of sunshine in the months during the period 1971 - 2020. The results show that a statistically significant increase in the sunshine duration is in April, June, July, and August. The ten-year average also shows an increase in the number of hours. While for the period 1971 - 1980 the average annual values range from 1400 to 1900 $h.year^{-1}$, in the last decade 2011-2020 the length of sunshine is 1700 - 2200 $h.year^{-1}$. The sunshine duration also affects other climatological indicators such as precipitation and air temperature, which have also changed significantly in recent decades.

Acknowledgment

This publication was supported by the Operational Program Integrated Infrastructure within the project: Demand-driven research for the sustainable and inovative food, Drive4SIFood 313011V336, cofinanced by the European Regional Development Fund; by the Cultural and Educational Grant Agency no. KEGA 031SPU-4/2021 and by the Grant Agency of SUA in Nitra no. 19-GASPU-2021

References

AL BUHAIRI, M. H. 2010. Analysis of Monthly, Seasonal and Annual Air Temperature Variability and Trends in Taiz City - Republic of Yemen. In Journal of Environmental Protection, vol. 1, 401-409. DOI 10.4236/jep.2010.14046.

ALHAJI, U. U. et al. 2018. Trend Analysis of Temperature in Gombe State Using Mann Kendall Trend Test. In Journal of Scientific Research & Reports, 20(3): 1-9. ISSN: 2320-0227.

BARTOSZEK, K. et al. 2020. Trends in sunshine duration in Poland (1971–2018). In International Journal of Climatology, vol. 41, pp. 73-91. https://doi.org/10.1002/joc.6609.

BREZIANSKÁ, K. – VITKOVÁ, J. 2015. Analýza bezzrážkových období a ich vplyv na zásobu vody v pôde na Záhorskej nížine (Analyse of Periods Without Precipitation and their Influence on Soil Water Storage at Záhorská Lowland). In Acta Hydrologica Slovaca, 16 (TC1), 260-266.

ČIMO, J. 2019. Klimatická zmena a jej dopad na teplotné pomery Slovenska (habilitačná práca) [Climate change and its impact on the temperature conditions in Slovakia (associate professor thesis). 140 p.

ČIMO, J. et al. 2012. Praktická biometeorológia [Practical biometeorology]. SPU. Nitra. 201 p. ISBN 978-80-552-0771-1.

GOCIC, M. – TRAJKOVIC, S. 2013. Analysis of changes in meteorological variables using Mann-Kendall and Sen's slope estimator statistical tests in Serbia. In Global and Planetary Change, vol. 100, pp. 172-182, ISSN 0921-8181. https://doi.org/10.1016/j.gloplacha.2012.10.014.

HAMED, K. H. 2008. Trend detection in hydrologic data: The Mann–Kendall trend test under the scaling hypothesis. In Journal of Hydrology, vol. 349, issue 3-4, pp. 350-363. https://doi.org/10.1016/j.jhydrol.2007.11.009.

HAVLÍČEK, V. et al. 1986. Agrometeorologie [Agrometeorology]. Státní zemědělské nakladatelství. Praha. 264 p. [In Czech].

KENDALL, M. G. 1975. Rank Correlation Methods. Griffin, London.

LIBISELLER, C. – GRIMVALL, A. 2002. Performance of partial Mann-Kendall tests for trend detection in the presence of covariates. In ENVIRONMETRICS, vol 13, pp. 71-84. https://doi.org/10.1002/env.507.

MANARA, V. et al. 2015. Sunshine duration variability and trends in Italyfrom homogenized instrumental timeseries (1936–2013). In Journal of Geophysical Research: Atmospheres, vol. 120, pp. 3622-3641. https://doi.org/10.1002/2014JD022560.

MANN, H. B. 1945. Nonparametric tests against trend. In Econometrica, vol. 13, pp. 245-259.

MATUSZKO, D. et al. 2015. Relationship between sunshine duration and air temperatureand contemporary global warming. In International Journal of Climatology, vol. 35, pp. 3640-3653. https://doi.org/10.1002/joc.4238.

ÖNÖZ, B. – BAYAZIT, M. 2012. Block bootstrap for Mann–Kendall trend test of serially dependent data. In HYDROLOGICAL PROCESSES, vol. 26, pp. 3552–3560. https://doi.org/10.1002/hyp.8438.

SEN, P.K. 1968. Estimates of the regression coefficient based on Kendall's tau. In J. Am. Stat. Assoc., 63, pp. 1379-1389.

ŠPÁNIK, F. – REPA, Š. 1978. Agroklimatická charakteristika suchých rokov 1947 a 1976 v Nitre [Agroclimatic characteristics of the dry years 1947 and 1976 in Nitra]. In Acta Fytotechnica. [In Slovak].

ŠPÁNIK, F. et al. 2002. Agroklimatické a fenologické pomery Nitry (1991-2000) [Agroclimatic and phenological conditions of Nitra (1991-2000)]. SPU. Nitra. [In Slovak].

ŠÚTOR, J. et al. 2011. Vplyv bezzrážkových období na dynamiku zásob vody v zone aerácie pôdy (Effect of the Time Periods Without Precipitation on Water Storage Dynamics in the Aeration Zone of the Soil). In Acta Hydrologica Slovaca, 12(1), 22-28.

Wikipedia. 2022. Slovakia. [cit. 2022-04-05]. Available online: https://en.wikipedia.org/wiki/Slovakia (accessed on 1 June 2022).

World Meteorological Organization. 2010. Manual on the Global Observing System (WMO-No. 544), Volume I. Geneva. ISBN 978-92-63-10544-8.

World Meteorological Organization. 2018. Guide to Instruments and Methods of Observation (WMO-No. 8), Volume I. Geneva. ISBN 978-92-63-10008-5.

ZHENG, X. et al. 2008. Long-term trends in sunshine duration over Yunnan-Guizhou Plateau in Southwest China for 1961–2005. In GEOPHYSICAL RESEARCH LETTERS, vol. 35, L15707, https://doi.org/10.1029/2008GL034482.

ZELEŇÁKOVÁ, M. et al. 2017. Precipitation Trends over Slovakia in the Period 1981–2013. Water, 9, 922. https://doi.org/10.3390/w9120922.

REPEL, A. et al. 2021. Long-Term Analysis of Precipitation in Slovakia. Water, 13, 952. https://doi.org/10.3390/w13070952.

STANHILL, G. – COHEN, S. 2005. Solar Radiation Changes in the United States during the Twentieth Century: Evidence from Sunshine Duration Measurements. Journal of Climate, vol. 18, issue 10, pp. 1503 – 1512. https://doi.org/10.1175/JCLI3354.1.

KAISER, D.P. – QIAN, Y. 2002. Decreasing trends in sunshine duration over China for 1954–1998: Indication of increased haze pollution? Geophysical Research Letters, vol. 29, Issue 21, pp. 38-1 – 38-4. https://doi.org/10.1029/2002GL016057.

Contact address: Ing. Vladimír Kišš, PhD., Research Centre Agrobiotech, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, +421 37 641 5247, vladimir.kiss@uniag.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 03.05.2022
Received in revised form 13.05.2022
Accepted 25.05.2022

SENSITIVITY ANALYSIS AND ASSESSMENT OF THE PERFORMANCE OF THE HBV HYDROLOGICAL MODEL FOR SIMULATING RESERVOIR INFLOW HYDROGRAPH

Mitra Tanhapour[1], Kamila Hlavčová[2], Jaber Soltani[3], Anna Liová[4], Bahram Malekmohammadi[5]

[1]Department of Water Engineering, College of Aburaihan, University of Tehran, Tehran, IRAN

[2,4]Department of Land and Water Resources Management, Faculty of Civil Engineering, Slovak University of Technology, Bratislava, SLOVAKIA

[3]Department of Water Engineering, College of Aburaihan, University of Tehran, Tehran, IRAN

[5]School of Environment, College of Engineering, University of Tehran, Tehran, IRAN

Abstract

More precision prediction of the reservoir inflow is crucial for the design, management, and operation of the water resources systems. Efficient implementation of hydrological models depends on the selection of the convenient parameters of the model to predict streamflow. This research aims to investigate the performance of the HBV (Hydrologiska Byrans Vattenbalansavdelning) model for simulating the Dez dam reservoir inflow hydrograph using the cross calibration and validation approach. Accordingly, the recorded data during 2012-2019 was split into equal parts, and each of them was exerted in turn for both calibration and validation periods. Moreover, the local sensitivity analysis of the parameters was carried out for each calibration period to identify the most sensitive parameters and to assess the effect of cross calibration on the most sensitive parameters. Results represented the robust performance of the HBV model to simulate the reservoir inflow hydrograph. In addition, the most sensitive parameters identified by sensitivity analysis are relatively different together for each split of the observed data. Reliable prediction of the reservoir inflow provides the possibility to make decisions easier for reservoir operation under extreme events conditions.

Keywords: HBV model, reservoir inflow hydrograph, sensitivity analysis, cross calibration and validation

Introduction

More accurate prediction of the reservoir inflow is one of the main prerequisites for making various strategies concerning the adaptation of reservoirs in flood conditions and hydroelectric energy generation (Ramaswamy and Saleh, 2020), design of corresponding structures (Valipour et al. 2013), water balance (Alley, 1985), and water supply management (Fleming et al. 2002). Since uncertain processes such as precipitation, temperature, and nonlinear watershed responses influence streamflow variations (Londhe and Charhate, 2010), it is difficult to have a reliable streamflow prediction. Accordingly, precise streamflow estimation has vital importance for hydrologists and water system managers (Wagena et al. 2020).

Hydrological models are one of the most critical tools to investigate the response of the watershed in association with the streamflow simulation (Singh and Saravanan, 2020). These models simulate the river streamflow by describing the physical processes of the watershed through empirical equations and parameters and by combining hydrological and meteorological data (Jain et al. 2018). During the past decades, the HBV model, as one of the hydrological models, has been widely used to simulate flood hydrographs (Hlavcova et al. 2005; Reynolds et al. 2020) and streamflow (Ayaz Fateh et al. 2018) over the world due to its reliability, robustness, and simplicity (Toum et al. 2021; Reynolds et al. 2020).

Successful application of the hydrological models depends on how their parameters are calibrated. Hydrological models have many parameters, and it is necessary to estimate them during the model calibration process (Liu et al. 2018). Generally, model calibration is the estimation of parameters values by comparing model output with the observed data through evaluation criteria like Nash-Sutcliffe and etc. (Moriasi et al. 2007). However, estimating many parameters is difficult due to the uncertainty of parameters that are not directly measurable in the field. Hence, it is essential to identify key parameters using parameters sensitivity analysis (Ma et al. 2000). Sensitivity Analysis

 https://doi.org/10.15414/2022.9788055225029

(SA) is an approach to determine the percentage of the variations in model output through evaluation criteria according to the changes in model parameters. Therefore, SA provides this possibility to more easily perform model calibration by determining the most sensitive parameters.

The reliability of the hydrological models is examined by comparing the observed and simulated data using evaluation criteria in both calibration and validation periods. The values of evaluation criteria are variable with sampling variations of observed data for calibration and validation periods (Liu et al. 2018). Although some researchers proposed a structure for splitting data into calibration and validation periods (Moriasi et al. 2007; Liu et al. 2018), there isn't any standardized method in this regard (Liu et al. 2018). Klemeš (1986) described the cross calibration and validation approach and revealed that when long observed data is available, it can be split into equal parts. Each part should be employed in turn in calibration and validation periods. Thus, in order to investigate the reliability of the model, it is required to be determined the model efficiency quantitatively for different calibration and validation periods. Accordingly, the aim of this research is to evaluate the performance of the HBV model for simulating reservoir inflow hydrograph using cross calibration and validation method. In addition, sensitivity analysis of the model parameters was performed to find the most sensitive parameters for each split of recorded data.

Material and Methods

Case study and data

Dez dam basin has been located in the south-western of Iran at the latitude of 32°35’N to 34°07’N and the longitude of 48°20’ to 50°20’E. It consists of the connection of the Bakhtiari and Sezar rivers. Figure 1 represents the location of the Dez dam basin. The daily discharge of the Taleh-Zang station, located at the reservoir entrance, was applied to simulate reservoir inflow.

A set of variables, e.g., precipitation, temperature, Potential Evapotranspiration (PET), and discharge, were used as input data at the daily timescale. The precipitation data was uniformly obtained over a Dez basin using the IDW interpolation method in the GIS and Python environments. The uniform temperature data was defined all over the basin by interpolation between the temperature and height of the synoptic stations. The PET was calculated based on Lawry-Johnson's method. The observed records were available during 2012 – 2019. They split into the same parts for calibration and validation of the HBV model.

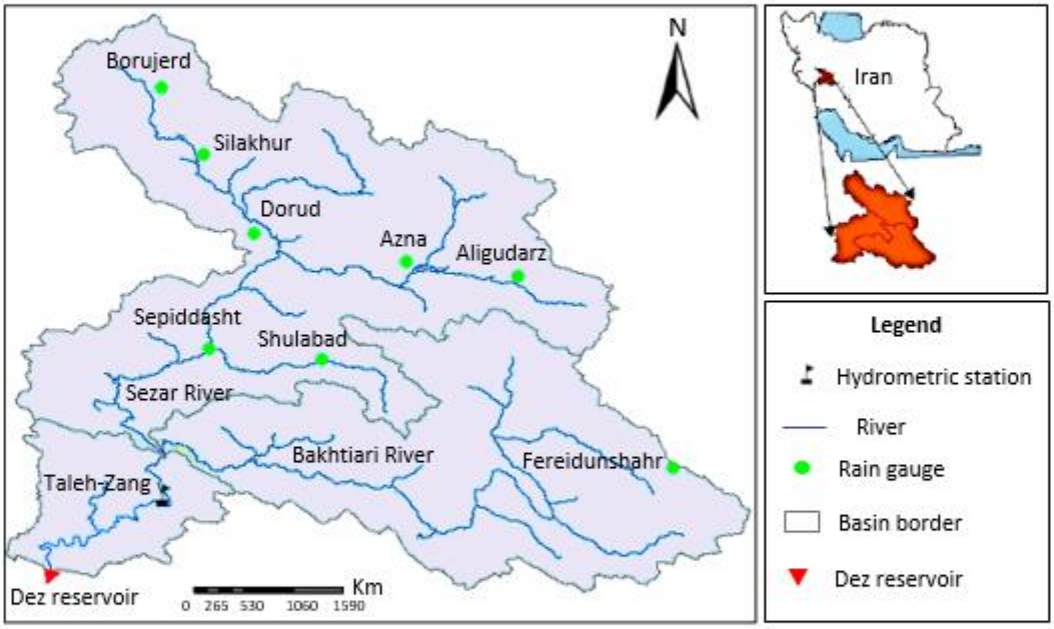


Figure 1 The location of the Dez dam basin

HBV model

HBV model is one of the conceptual hydrological models. In this research, the HBV model was developed in the MATLAB environment. The Harmony search optimization algorithm was used to calibrate the model. The HBV model comprises three sub-models, e.g., snow accumulation and melt, soil moisture, and runoff response. Figure 2 illustrates the structure of this model.

The model calculates runoff based on the parameters shown in the snow and soil moisture sub-models in Figure 2 (see legend). The calculated runoff converts to the discharge in the watershed outlet using the runoff response sub-model. The runoff response involves two storage zones, the upper zone with two outlets (Q0 and Q1) and the lower zone with one outlet (Q2). They are coupled together by constant percolation (perc). When the water level exceeds a threshold limit (L) in the upper zone, runoff is rapidly triggered in the upper part of the upper zone (Q0), while the response of the other outlets is slow. The parameters K_0, K_1, and K_2 are the recession coefficients to control runoff associated with the response functions of the upper zone and lower zone (Parra et al. 2018). Finally, the HBV model uses the triangular weight function (MAXBAS) for routing the produced runoff at the watershed outlet.

 https://doi.org/10.15414/2022.9788055225029

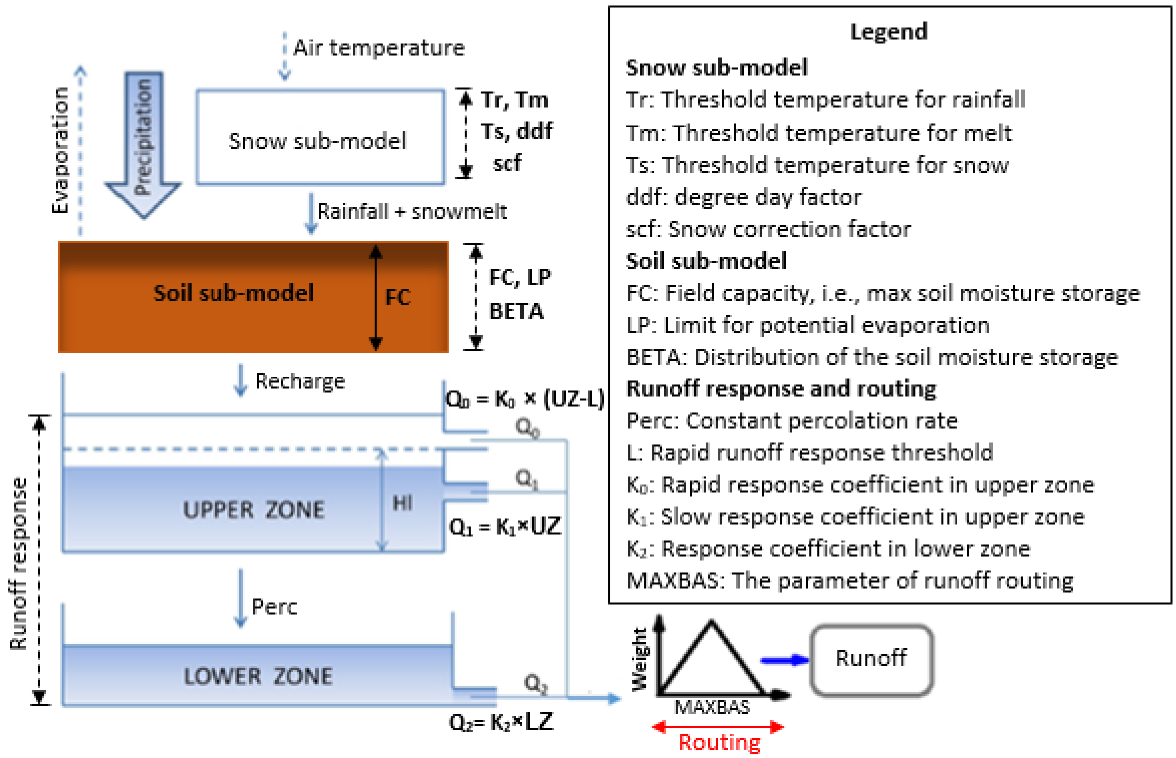


Figure 2 Structure of the HBV model, its parameters and relationships (Ding et al. 2016)

<u>Evaluation criteria</u>

The performance of the HBV model was assessed using Nash-Sutcliffe Efficiency (NSE), Mean Absolute Error (MAE), and $BIAS$ which their equations are as follows:

$$NSE = 1 - \frac{\sum_{i=1}^{n}(Q_{sim}-Q_{obs})^2}{\sum_{i=1}^{n}(Q_{sim}-\overline{Q}_{obs})^2} \quad (1)$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|Q_{sim} - Q_{obs}| \quad (2)$$

$$BIAS = \frac{1}{n}\sum_{i=1}^{n}(Q_{sim} - Q_{obs}) \quad (3)$$

Where Q_{sim} is the simulated discharge; Q_{obs} is the observed discharge with the average represented by $\overline{Q}_{obs}$; n is the number of records. The more the NSE index is closer to one and the MAE and $BIAS$ indices are closer to zero indicate the better model's performance.

 https://doi.org/10.15414/2022.9788055225029

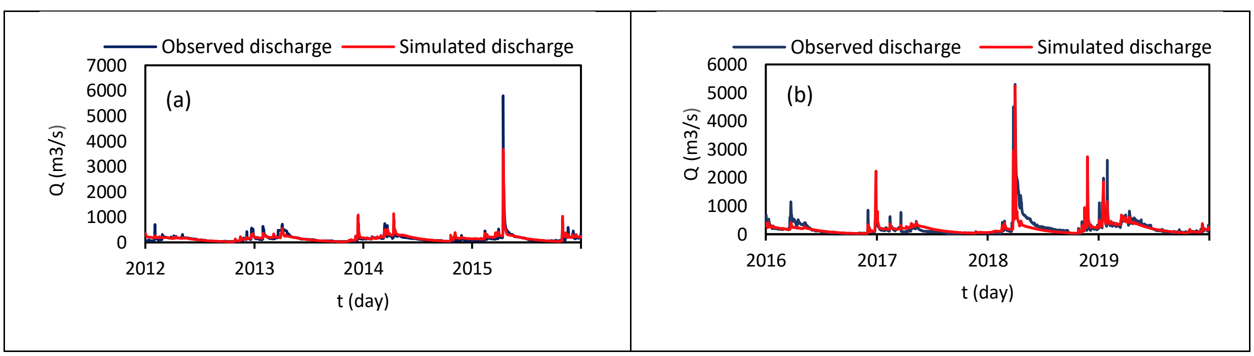
Sensitivity analysis

Sensitivity analysis (SA) is an approach to determining which one of the parameters most affects the model results. In this research, the effect of each parameter on the model output was separately determined by keeping the other parameters constant. For this purpose, the values of the parameters were increased and decreased by 20% of their initial values, and the NSE and MAE criteria were selected as the objective function for SA.

Results and discussion

Simulation of the reservoir inflow hydrograph

The results of simulating inflow hydrograph were presented using a graphical plot (Figure 3) and statistical criteria (Table 1). Throughout this part (results and discussion), the first data split refers to the model calibration period during 2012-2015, and the second data split denotes the model calibration period in 2016-2019. According to Figure 3, it was found that simulated inflow hydrographs for the first split of data (parts (a) and (b)) have more consistency with the observed inflow hydrographs compared to the second split of data (parts (c) and (d)). Generally, for both splits of data, the calibration results indicate more agreement than the validation results. Moreover, the HBV model represents more efficient results in simulating base flows compared to the peak flows, and the model underestimates most peak flows in the calibration and validation periods.



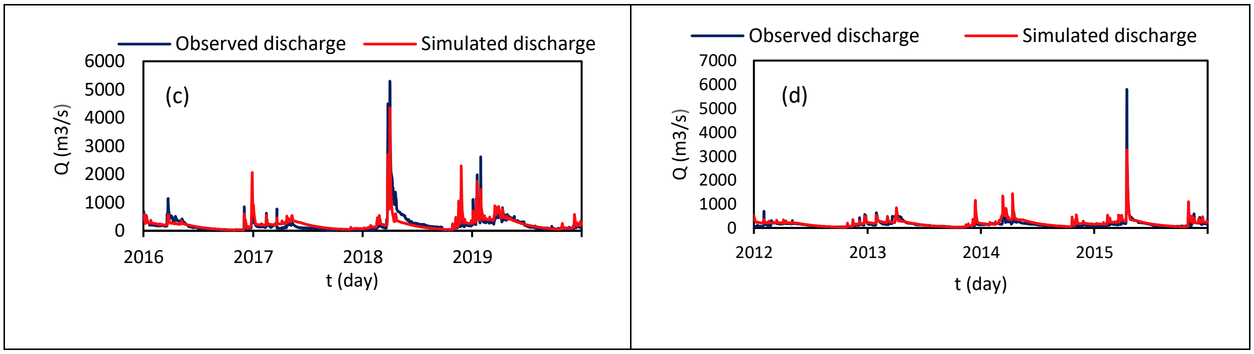


Figure 3 Comparison of the simulated and observed reservoir inflow hydrograph using the HBV model. (a) and (c): calibration periods; (b) and (d): validation periods.

A set of statistical criteria to investigate the performance of the HBV model are shown in Table 1. The NSE indicator is varied from 0.69 to 0.8 for both calibration and validation periods, representing the validity of the HBV model to predict inflow hydrograph. It demonstrates that the simulated and observed inflow hydrographs have a robust agreement. Similarly, the error evaluation indices (MAE and BIAS) in this table indicate a little difference between the observed and predicted inflow hydrographs.

Table 1 Evaluation criteria of the HBV model for the calibration and validation periods

Evaluation criteria	Calibration (2012-2015)	Validation (2016-2019)	Calibration (2016-2019)	Validation (2012-2015)
NSE	0.8	0.71	0.75	0.69
MAE (mm/day)	0.05	0.09	0.1	0.07
BIAS (mm/day)	0.01	0.02	0.01	0.05

<u>Sensitivity analysis of the parameters</u>

The results of the parameters sensitivity analysis for the first data split (see part (a)) and the second data split (see part (b)) are shown in Figure 4. This figure demonstrates the maximum percentage of variations created in the NSE and MAE criteria, as objective functions, by increasing and decreasing the values of parameters by as much as 20 % of their initial values. The most sensitive parameters to generate runoff for the first data split (part (a)) respectively are L, maxbas, K1, scf, and BETA by considering the threshold limit around 19-20 % for NSE. The most sensitive parameters for the second data split (part (b)) respectively are Tr, BETA, ddf, L, and K2 by applying a threshold limit of relatively 11 % for NSE. Assessment of the effect of cross calibration on the most sensitive parameters represents that they are somewhat different from each other by changing the data used for calibration. This can be due to the difference in the flow characteristics of these two time periods in terms of magnitude and frequency of peak flows.

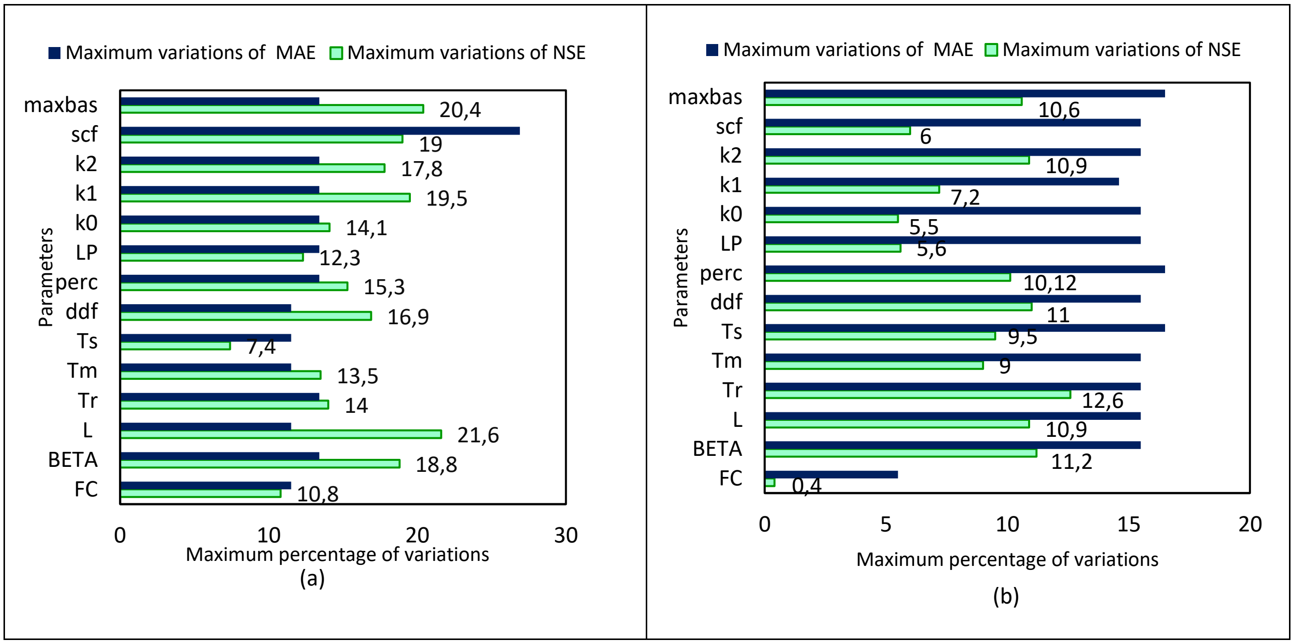


Figure 4 Sensitivity analysis of the HBV model parameters. (a) Calibration period: 2012-2015; (b) calibration period: 2016-2019

Conclusion

Applying better decision-making concerning the efficient operation of the reservoirs is possible based on an accurate reservoir inflow prediction. In this research, the performance of the HBV model was evaluated for simulating the Dez reservoir inflow hydrographs using the cross calibration and validation method. Then, the influence of cross calibration was investigated on the most sensitive parameters identified by sensitivity analysis. The outcomes of the present study revealed that the simulated inflow hydrographs are in strong agreement with the observed inflow hydrographs using HBV hydrological model. Moreover, by changing the calibration period, the most sensitive parameters determined by sensitivity analysis are rather different. The approach used in this research is efficient in increasing the reliability of the data split scheme.

Acknowledgment

This work has been funded by the VEGA grant agency under Contract No. VEGA 1/0782/21. The authors are grateful for their financial support.

References

ALI, Ayaz Fateh et al. 2018. Projection of future streamflow of the Hunza River Basin, Karakoram Range (Pakistan) using HBV hydrological model. Journal of Mountain Science, vol. 15, no. 10, pp.2218-2235.

ALLEY, William M. 1985. Water balance models in one-month-ahead streamflow forecasting. Water Resources Research, vol. 21, no. 4, pp.597-606.

DING, Jie et al. 2016. Estimation of instantaneous peak flows from maximum mean daily flows using the HBV hydrological model. Hydrological Processes, vol. 30, no. 9, pp. 1431-1448.

FLEMING, Nicholas et al. 2002. Forecasting Streamflow and Water Demand to Improve the Efficiency of Water Supply in South Australia. In Hydrology and Water Resources Symposium. Institution of Engineers, Australia, pp. 565-573. 0858257785.

HLAVČOVÁ, Kamila et al. 2005. An empirical method for estimating future flood risks for flood warnings. Hydrology and Earth System Sciences, vol. 9, no. 4, pp.431-448.

JAIN, Sharad Kumar et al. 2018. A Brief review of flood forecasting techniques and their applications. International Journal of River Basin Management, vol. 16, no 3, pp. 329-344.

KLEMEŠ, Vit. 1986. Operational testing of hydrological simulation models. Hydrological sciences journal, vol. 31, no. 1, pp.13-24.

LIU, Dedi et al. 2018. Statistics for sample splitting for the calibration and validation of hydrological models. Stochastic Environmental Research and Risk Assessment, vol. 32, no. 11, pp.3099-3116.

LONDHE, Shreenivas and CHARHATE, Shrikant. 2010. Comparison of data-driven modelling techniques for river flow forecasting. Hydrological Sciences Journal–Journal des Sciences Hydrologiques, vol. 55, no. 7, pp.1163-1174.

MA, Liwang et al. 2000. Root zone water quality model sensitivity analysis using Monte Carlo simulation. Transactions of the ASAE, vol. 43, no. 4, p.883.

MORIASI, Daniel N. et al. 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Transactions of the ASABE, vol. 50, no. 3, pp.885-900.

PARRA, Víctor et al. 2018. Identifying advantages and drawbacks of two hydrological models based on a sensitivity analysis: a study in two Chilean watersheds. Hydrological Sciences Journal, vol. 63, no. 12, pp.1831-1843.

RAMASWAMY, V. and SALEH, F. 2020. Ensemble Based Forecasting and Optimization Framework to Optimize Releases from Water Supply Reservoirs for Flood Control. Water Resources Management, vol. 34, no. 3, pp.989-1004.

REYNOLDS, J.E. et al. 2020. Robustness of flood-model calibration using single and multiple events. Hydrological Sciences Journal, vol. 65, no. 5, pp.842-853.

SINGH, Leelambar and SARAVANAN, Subbarayan. 2020. Evaluation of various spatial rainfall datasets for streamflow simulation using SWAT model of Wunna basin, India. International Journal of River Basin Management, pp.1-10.

TOUM, Ezequiel et al. 2021. The HBV. IANIGLA Hydrological Model. The R Journal, vol. 13, no. 1, pp.378-395.

VALIPOUR, Mohammad et al. 2013. Comparison of the ARMA, ARIMA, and the autoregressive artificial neural network models in forecasting the monthly inflow of Dez dam reservoir. Journal of hydrology, vol. 476, pp.433-441.

WAGENA, Moges B. et al. 2020. Comparison of short-term streamflow forecasting using stochastic time series, neural networks, process-based, and Bayesian models. Environmental Modelling & Software, vol. 126, p.104669.

Contact address: Jaber Soltani, Department of Water Engineering, College of Aburaihan, University of Tehran, Tehran, Iran, email: jsoltani@ut.ac.ir.

ARTICLE HISTORY:
Received 09.05.2022
Received in revised form 19.05.2022
Accepted 20.05.2022

EFFECT OF NORWAY SPRUCE FOREST DIEBACK ON SOIL WATER BALANCE: THE EXAMPLES FROM UPLAND AREAS OF THE CZECH REPUBLIC

Tomáš VICHTA, Štěpán NEUBAUER, Martin VALTERA, Ladislav HOLÍK, Ondřej FIDLER, Pavel SAMEC, Gabriela TOMÁŠOVÁ, Jiří VOLÁNEK, Aleš KUČERA, Miroslav ŠLACHETKA, Nikola ŽIŽLAVSKÁ, Marie BALKOVÁ

Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 1, 613 00, Brno, CZECH REPUBLIC

Abstract

This study focuses on the description of soil water balance under three different spruce monoculture conditions, nemaly living forest, disturbed forest with dead trees and after forest clear-cutting. Analysis was based on sampling instantaneous moisture in surface soil layers in a non-rainfall period and soil water content measurements from the last-half of 2021. We investigated both column daily soil moisture and its vertical distribution in invidual soil layers. Highest soil moisture was observed in the disturbed forest, the other sites generally having comparatively lower soil moisture, probably due to higher evapotranspiration and different soil properties.

Keywords: Forest decline, Soil moisture, Forest hydrology, Land cover

Introduction

Soil moisture is very important for the development and stability of forest ecosystems. An understanding of soil moisture variation is essential for studying other hydrological, biological or chemical soil processes, such as water movement, microbial activity or carbon sequestration (Gao et al. 2019; Kutílek, 1978; Ridolfi et al. 2003; Vavříček et al. 2017; Zarlenga et al. 2018). An important factor affecting the dynamics of moisture is vegetation condition. In addition, vegetation can also influence soil physical properties (Haghighi et al. 2010). The removal of tree canopies, for example, can result in increased surface and air temperatures, increased soil moisture in the topsoil and a decrease in air humidity (Hesslerová et al. 2018; Špulák et al. 2021).

In Central Europe, recent disturbance to Norway spruce (*Picea abies* (L.)) stands has been attributed to droughts in 2003, 2015, 2018 and 2019 (Hari et al. 2020; Mezei et al. 2017; Kornhuber et al. 2019; Seidl et al. 2011). Such drought events can lead to losses in productivity and increased tree mortality or associated secondary damages caused by biotic stressors such as bark beetle (*Ips typographus* (L.)) (Brasseur et al. 2017; Schuldt et al. 2020; Senf et al. 2020; Zang et al. 2014). However, our understanding of forest soil responses to drought-induced tree mortality is far from complete (Allen et al. 2015; Breshears et al. 2005), while information on the effects of tree dieback disturbance on changes in sites characteristics (especially air and soil temperature and moisture) are even more scarce (Kopáček et al. 2020).

In this study, we assess the significance of different post-disturbance management conditions on forest regeneration and parallel effects linked with the soil moisture regime in three forest types: conventional clear-cut forests, declining stands with cover and healthy (living) uncut forests. These data will also be used as a background for future environmental studies focused on evaluating the impact of the ongoing wave of large-scale Norway spruce forest decline on soils and on recovery of forest soils following bark-beetle infestation.

Material and methods

Study sites

This study was performed at one spruce monoculture in Bohemia (Benešov) and three (Vranov, Velká bítes, Cerná hora) in Moravia (Czech Republic). The sites were all situated at altitudes of 370 to 540 m a.s.l. on southeast to northeast exposures with an inclination of 0 – 10°. The main soil types are classified as Haplic Cambisol or Luvic Cambisol (WRB, 2014) on a bedrock of crystalline hard rocks with an admixture of Quaternary sediments in the upper part of the solum. The majority of the localities are covered by pure stands dominated by Norway spruce aged 50 to 80 years. Average annual temperatures range from 7.5 to 9.3 °C, and average annual precipitation from 590 to 630 mm (ČHMÚ, 2022).

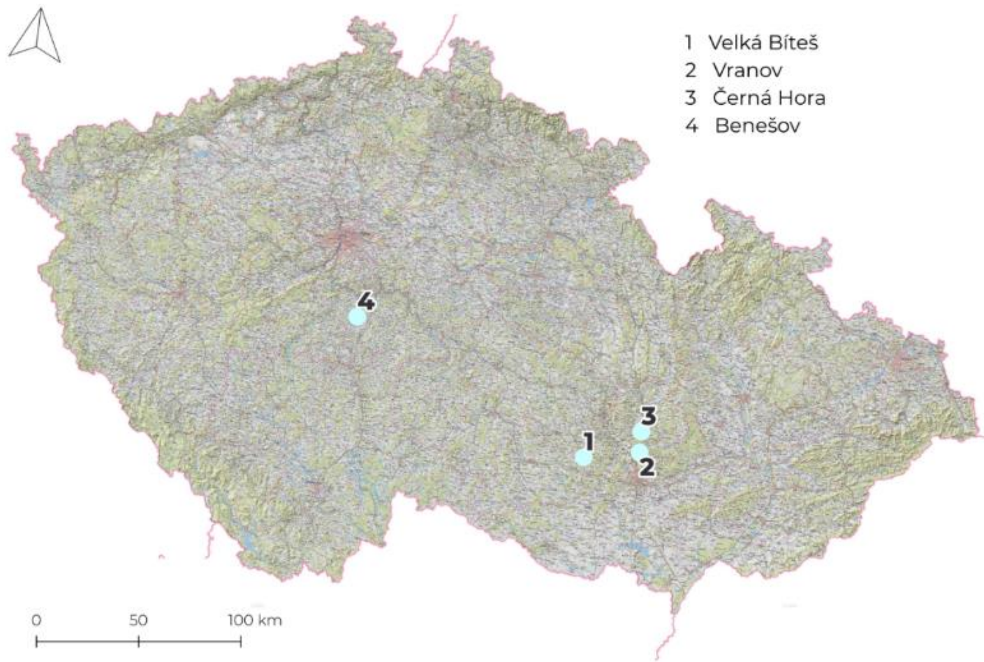


Figure 1 Location of the experimental sites

Experimental design and field measurements

A desing strategy was set up in order to ensure that each study locality (see Fig. 1) included three treatments (min. area 500 m^2) representing (L) living forest, (D) disturbed forest with dead trees and (C) clear-cut sites (Fig. 2), each with similar soil and meteorological conditions. The research plots were established in the first-half of 2021 using the methodology of Fidler, et al. (2021).

At each plot, soil samples were obtained using two different sampling protocols. The first focused on vertical differences in instantaneous moisture content in the forest floor and topsoil. In order to ensure representative sampling, soil samples were collected over four days in a non-rainfall period (second week of September 2021), i.e. collections were performed between rewetting periods, two days after the last rain event, to ensure that rapid water movement in the soil had ceased (Sumner, 1999). Moisture was then determined by the gravimetric method in the laboratory. A total of 648 soil samples were taken (4 localities × 3 plots × 9 replicates × 6 profile layers - L, F+H, 0–5, 0–10, 10–20 and 20–30 cm), the design being based on that of the ICP Forests

Manual for sampling and analysis of soil (Cools et al. 2016). Values were recorded automatically once each hour throughout the study period.

Figure 1 Stand condition: living forest (left), disturbed forest with dead trees (middle) and clear-cut sites (right). (Photos: Tomáš Vichta)

The second protocol established the vertical dynamics of soil water in the soil column and individual soil layers during the autumn/winter of 2021 (September to December), this period being representative of wet seasons when the soil is replenished with rainwater. Due to cost restrictions, this was only performed at two sites (Velká Bíteš and Vranov; see Table 1 for basic soil characteristics). The soil water regime was measured using 5TM TDR sensors (Decagon Devices Inc., USA) at three depth profiles, i.e. 10, 30 and 60 cm. Again, values were recorded automatically once each hour throughout the study period.

Table 1 Soil parameters of sites used to assess vertical dynamics of soil water: BD = bulk density, TP = total porosity, WRC = water retencion capacity, CFC = coarse-fragment content, SOM = organic matter content. L = living forest, D = disturbed forest with dead trees, C = clear-cut sites.

Velká Bíteš									
Stand condition		L			D			C	
Depth (cm)	10	30	60	10	30	60	10	30	60
BD (g/cm^3)	1.41	1.61	1.63	1.53	1.73	1.53	1.49	1.78	1.72
TP (% vol.)	43.68	35.90	38.14	38.40	32.44	40.41	40.68	30.64	33.19
WRC (% vol.)	27.68	26.58	25.53	36.71	27.20	28.14	27.81	20.93	19.35
CFC (% of total soil dry mass)	0.09	0.03	5.32	0.00	0.14	0.00	4.47	14.54	24.06
SOM (% of total soil dry mass)	2.91	2.46	2.05	2.51	1.63	2.78	3.37	1.50	1.82
Vranov									
Stand condition		L			D			C	
Depth (cm)	10	30	60	10	30	60	10	30	60
BD (g/cm^3)	1.31	1.46	1.54	1.47	1.54	1.70	1.26	1.55	1.70
TP (% vol.)	49.21	40.23	37.64	43.17	38.40	33.16	50.13	36.68	31.49
WRC (% vol.)	32.77	25.19	9.88	37.13	28.25	28.74	45.95	25.15	25.23
CFC (% of total soil dry mass)	0.02	2.56	0.12	0.10	0.02	0.00	0.02	0.78	0.60
SOM (% of total soil dry mass)	2.49	2.16	1.39	3.92	2.33	2.41	3.98	2.22	2.30

Data proccesing and statistical analysis

Hourly values for vertical differences in instantaneous moisture and vertical soil water dynamics were aggregated into daily average values. Subsequently, the average values for the entire soil column were also calculated as a weighted average for individual soil depths. Differences in instantaneous soil content for forest floor and topsoil were statistically evaluated using the Student's t-test, while the non-parametric Kruskal-Wallis test (Kruskal et al. 1952) was applied to soil water regime datasets due to high variance in the data. All tests were performed at a significance level of 5 % (i.e. $p < 0.05$) using the Statistica software package v.12.

Results and discussion

Vertical distribution of instantaneous soil moisture in forest floors and topsoil across different spruce stand treatments

On average, soil moisture at each site was twice as high in the L and F+H organic soil layers than in the 0-10, 10-20 and 20-30 cm mineral layers (Fig. 3).

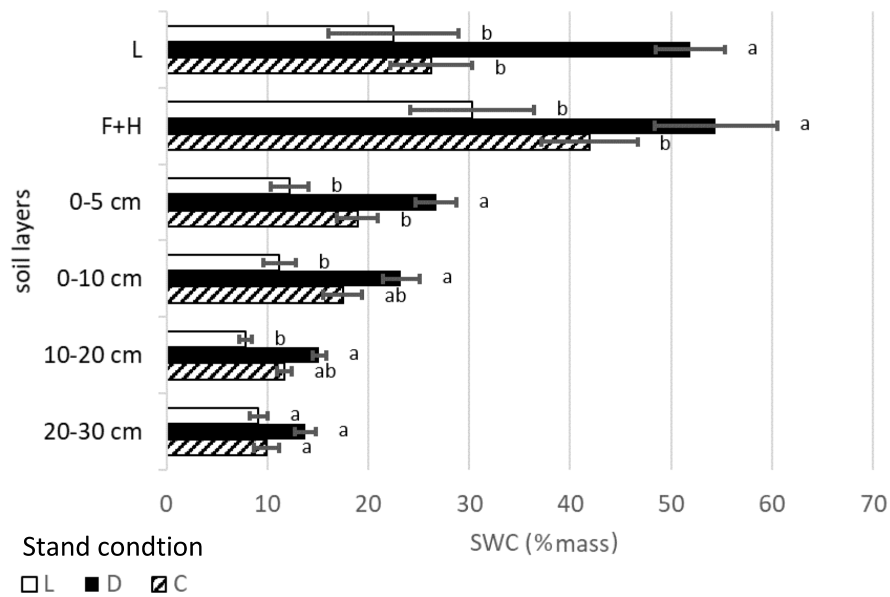


Figure 2 Box plots depicting the vertical distribution of instantaneous soil water content for all stand treatments (n=4; Vranov, Velká Bíteš, Černá Hora and Benešov) and soil layers. L = living forest, D = disturbed forest with dead trees, C = clear-cut sites.

Highest soil moisture was recorded in the disturbed forest with dead trees, with greatest differences exhibited in the organic layers and the 0 – 5 cm layer. There was no significant difference in soil moisture values between living forest plots and clear-cut plots. Likewise, while there was no significant difference in moisture in different soil levels in living forest plots and clear-cut plots; however, moisture was lower for each soil layer in living forest sites.

Soil water distribution in different spruce stand types

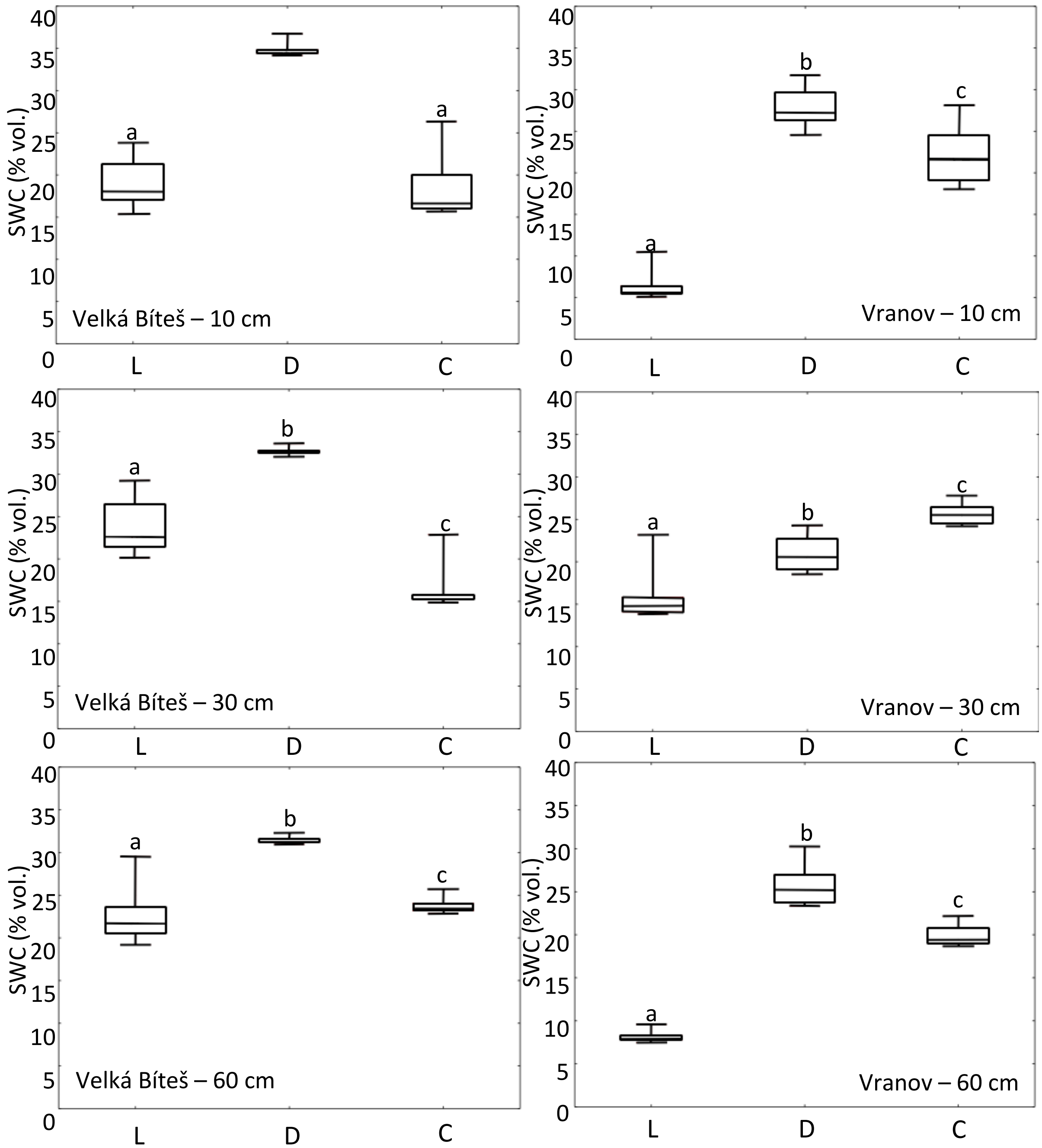


Figure 3 Box plots depicting the vertical soil water content dynamics for all stand treatments (n=2); site. L = living forest, D = disturbed forest with dead trees, C = clear=cut sites.

Both Velká Bíteš and Vranov showed a similar distribution of soil water content (SWC) within the soil column, with both localities characterised by high SWC at the disturbed site, followed by clear-cut sites then living forest sites (Figure 4). At Velká Bíteš, similar differences were observed at living and clear-cut sites, with no significant difference in SWC at 10 cm, but significantly higher SWC at 30 cm in living forest sites but significantly higher SWC at 60 cm in clear-cut sites (Figre 4). In contrast, SWC values for each profile at Vranov were significantly lower at living forest sites then clear-cut sites, with maximum SWC values at 30 cm.

Both the Velká Bíteš and Vranov localities were characterised by an overall highest SWC at disturbed sites, followed by clear-cut then living forest sites, with both localities showing clear differentiation between disturbed sites and other sites (Figure 5). However, overall SWC values for the entire column were significant different between clear-cut and living forest sites, with SWC higher in living forest site at Velká Bíteš and SWC higher at clear-cut sites at Vranov.

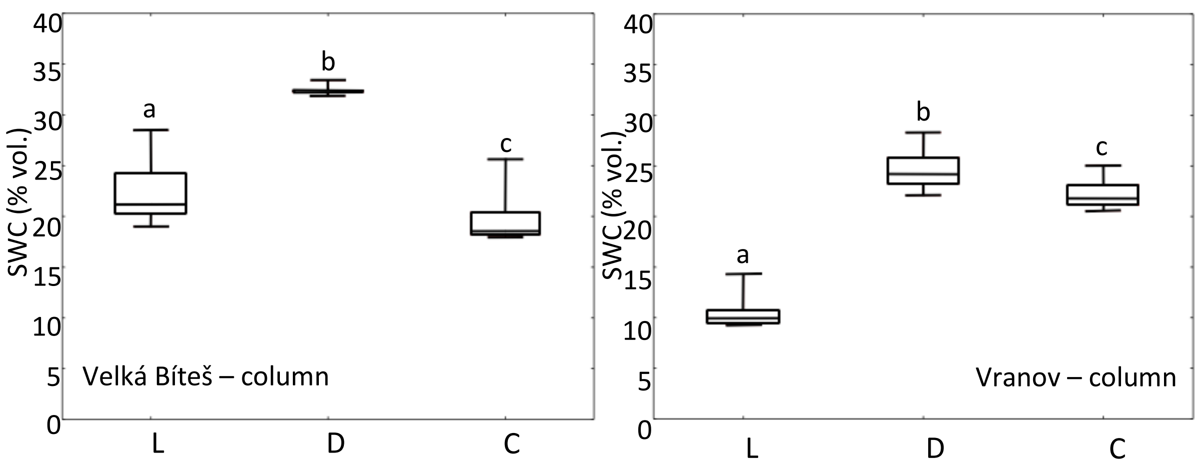


Figure 4 Box plots of average soil water content in the soil column for each site. L = living forest, D = disturbed forest with dead trees, C = clear-cut sites.

Discussion

Overall, our study showed that disturbed stands were generally wetter than either clear-cut or living spruce forest stands. Living forest stands were characterised by high evapotranspiration rates, suggesting that any disturbance to the forest canopy results in a reduction in the amount of water intercepted and utilised through transpiration (Aussenac, 2000; Kopáček et al. 2020; Wood et al. 2008). Impacts of forest disturbance on SWC have been shown to be particularly significant in the upper forest soil layer (Keenan et al. 1993; Kopáček et al. 2020); and indeed, in our own study, an increase in instantaneous soil moisture was only found in disturbed stands with dead trees, the difference in moisture content between living forest and clear-cut sites being statistically non-significant in all forest floor and topsoil layers.

While similar patterns were also observed in SWC vertical dynamics at different depths, the results were influenced by the different soil properties found at Vranov and Velká Bíteš, with higher quantities of rock fragments at 30 and 60 cm at Velká Bíteš resulting in a lower soil retention capacity after clear-cutting (Table 1). Wiekenkamp et al. (2016) showed that the occurrence of preferential pathways in forest ecosystems can cause non-sequential reactions in soil moisture sensors. In this study, we observed a similar sensor reaction at different depths at both at Vranov and Velká Bíteš at the start of SWC monitoring. Consequently, subsequent samples for instantaneous soil moisture were performed according to Sumner (1999) (see Experimental design and field measurements) and the hourly SWC values were aggregated into daily values (see Proccesing data and statistical analysis). The microrelief at all sites may also have biased SWC measurements in the same way due to concentration of rainwater infiltration in depressions (Juřička et al. 2022), the surface not being completely flat at all sites.

In addition to decreased evapotranspiration, a loss of canopy trees due to mortality increases solar radiation and wind at the ground’s surface, which further increases soil evaporation and transpiration (Anderegg et al. 2012; Geiger et al. 1995). As evapotranspiration in living forest stands is usually higher than that in post-disturbance soils, this generally means that disturbed soils have elevated soil moisture levels (Bearup et al. 2014; Beudert et al. 2018). Indeed, Kopáček et al. (2020) showed that, in undisturbed natural mountain forests, soil moisture increased after tree dieback, and that levels remained high and relatively stable in such forests for five to six years after. A similar period of approx. four to five years has also been documented for restoration of mountain forests after clear-cutting (Adams et al. 1991). The loss of evapotranspiration from tree surfaces following canopy loss and the increase in water input to soils with decreasing altitude (Kopáček et al. 2020) together are also likely to contribute to elevated run-off in disturbed forests (e.g. see Adams et al. 1991; Anderegg et al. 2012; Beudert et al. 2018; Kopáček et al. 2020). However, while such conditions are relatively well researched in natural mountain forests, there have been relatively few studies to date comparing soil water regimes in relation to different types of land use and land cover (Niu et al. 2015).

Conclusions

Norway spruce is now one of the dominant tree species found in Europe. In recent years, there have been numerous cases of spruce dieback in Central Europe. In this study, we found that disturbed spruce forests with dead trees generally had higher soil moisture levels than living forests and clear-cut sites, with neither of the latter sites differing significantly from each other across localities. This was possibly caused by differences in the physical properties of soils at the sites. In order for our results to be generalisable for similar regions, we suggest that further studies are needed covering a broad range of site conditions. This is particularly important, given the topicality of spruce decline over recent years.

Acknowledgments

This research was supported by an Internal Grant from Mendel University in Brno, registration no.: IGA LDF_VT_2021006. We thank all owners and management companies, namely Lesy České republiky, s. p., Lesy města Velká Bíteš s .r. o., Školní lesní podnik Masarykův les Křtiny, that provided the forest plots for this research. We also acknowledge the expert comments of a reviewer and the corrections of Kevin Roch, who both helped to improve the quality of this paper.

References

ADAMS, P.W. et al. 1991. Long-term patterns in soil moisture and revegetation after a clearcut of a Douglas-fir forest in Oregon. In Forest Ecology and Management, vol. 41, no. 3-4, pp. 249-263. ISSN 0378-1127.

ALLEN, C.D. et al. 2015. On underestimation of global vulnerability to tree mortality and forest die-off from hotter drought in the Anthropocene. In Ecosphere, vol. 6, no. 8, pp. 1-55. ISSN 2150-8925.

ANDEREGG, W.R. et al. 2013. Consequences of widespread tree mortality triggered by drought and temperature stress. In Nature climate change, vol. 3, no. 1, pp. 30-36. ISSN 1758-678X.

ANON. 2022. Měsíční a roční data dle zákona 123/1998 Sb. [cit. 2022-04-18]. Available on internet: https://www.chmi.cz/historicka-data/pocasi/mesicni-data/mesicni-data-dle-z.-123-1998-Sb.

AUSSENAC, G. 2000. Interactions between forest stands and microclimate: ecophysiological aspects and consequences for silviculture. In Annals of forest science, vol. 57, no. 3, pp. 287-301. ISSN 1297-966X.

BEARUP, L.A. et al. 2014. Hydrological effects of forest transpiration loss in bark beetle-impacted watersheds. In Nature Climate Change, vol. 4, no. 6, pp. 481-486. ISSN 1758-678X.

BEUDERT, B. et al. 2018. Natural disturbance by bark beetle offsets climate change effects on streamflow in headwater catchments of the Bohemian Forest. In Silva Gabreta, vol. 24, pp. 21-45. ISSN 1211-7420.

BRESHEARS, D.D. et al. 2005. Regional vegetation die-off in response to global-change-type drought. In Proceedings of the National Academy of Sciences, vol. 102, no. 42, pp. 15144-15148. ISSN 1091-6490.

BRASSEUR, G.P. et al. 2005. Klimawandel in Deutschland: Entwicklung, Folgen, Risiken und Perspektiven. Springer Nature. 348 p. ISBN 978-3-662-50396-6.

COOLS, N. et al. 2016. Part X: Sampling and Analysis of Soil. Version 2020-1. In: UNECE ICP Forests Programme Co-ordinating Centre (ed.): Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. Thünen Institute of Forest Ecosystems, Eberswalde, Germany, 29 p + Annex [cit. 2022-04-18]. ISBN 978-3-86576-162-0. Available on internet: [http://www.icp-forests.org/manual.htm]

FIDLER, O. et al. 2021. Dieback environment from the forest soil perspective - 1st year project report. SilvaNet – WoodNet 2021. 26.11.2021 - 26.11.2021, Brno. In SilvaNet – WoodNet 2021: Proceedings Abstracts of Student Scientific Conference. Brno: Mendel university in Brno, 25-26. ISBN 978-80-7509-814-6.

GAO, L. et al. 2019. The role of sampling strategy on apparent temporal stability of soil moisture under subtropical hydroclimatic conditions. In Journal of hydrology and hydromechanics, vol. 67, no. 5, pp. 260-270. ISSN 0042-790X.

HAGHIGHI, F. et al. 2010. A study of the effects of land use changes on soil physical properties and organic matter. In Land Degradation and Development, vol. 21, no. 5, pp. 496-502. ISSN 1099-145X.

HARI, V. et al. 2020. Increased future occurrences of the exceptional 2018–2019 Central European drought under global warming. In Scientific reports, vol. 10, no. 1, pp. 1-10. ISSN 2045-2322.

HESSLEROVÁ, P. et al. 2018. The effect of forest disturbance on landscape temperature. In Ecological engineering, vol. 120, pp. 345-354. ISSN 0925-8574.

GEIGER, R. et al. 1995. The Climate near the Ground; Vieweg+Teubner Verlag: Wiesbaden, Germany. 528 p. ISBN 978-3-322-86584-7.

IUSS Working Group WRB. 2014. World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports No. 106. Rome, Italy. 203 p. ISBN: 978-92-5-108369-7.

JUŘIČKA, D. et al. 2022. The role of pit-mound microrelief in the redistribution of rainwater in forest soils: a natural legacy facilitating groundwater recharge? In European Journal of Forest Research, vol. 141, no. 2, pp. 321-345. ISSN 612-4669.

KEENAN, R.J. et al. 1993. The ecological effects of clear-cutting. In Environmental Reviews, vol. 1, no. 2, pp. 121-144. ISSN 11818700.

KRUSKAL, W.H. et al. 1952. Use of ranks in one-criterion variance analysis. In Journal of the American statistical Association, vol. 47, no. 260, pp. 583-621. ISSN 01621459.

KUTÍLEK, M. 1978. Vodohospodářská pedologie, Alfa Bratislava. Bratislava. 296 p. SNTL 04-721-78.

KOPÁČEK, J. et al. 2020. Changes in microclimate and hydrology in an unmanaged mountain forest catchment after insect-induced tree dieback. In Science of the Total Environment, vol. 720, no. 137518. pp. 1-12. ISSN 0048-9697.

KORNHUBER, K. et al. 2019. Extreme weather events in early summer 2018 connected by a recurrent hemispheric wave-7 pattern. In Environmental Research Letters, vol. 14, no. 5, pp. 1-14. ISSN 17489326.

MEZEI, P. et al. 2017. Storms, temperature maxima and the Eurasian spruce bark beetle Ips typographus—An infernal trio in Norway spruce forests of the Central European High Tatra Mountains. In Agricultural and Forest Meteorology, vol. 242, pp. 85-95. ISSN 0168-1923.

NIU, C.Y. et al. 2015. Analysis of soil moisture condition under different land uses in the arid region of Horqin sandy land, northern China. In Solid Earth, vol. 6, no. 4, pp. 1157-1167. ISSN 2169-9356.

RIDOLFI, L. et al. 2003. Stochastic soil moisture dynamics along a hillslope. In Journal of Hydrology, vol. 272, no. 1-4, pp. 264-275. ISSN 2214-5818.

SCHULDT, B. et al. 2020. A first assessment of the impact of the extreme 2018 summer drought on Central European forests. In Basic and Applied Ecology, vol. 45, pp. 86-103. ISSN 1439-1791.

SEIDL, R. et al. 2011. Adaptation options to reduce climate change vulnerability of sustainable forest management in the Austrian Alps. In Canadian Journal of Forest Research, vol. 41, no. 4, pp. 694-706. ISSN 0045-5067.

SENF, C. et al. 2020. Excess forest mortality is consistently linked to drought across Europe. In Nature communications, vol. 11, no. 1, pp. 1-8. ISSN 2041-1723.

ŠPULÁK, O. et al. 2021. Topsoil Moisture Depletion and Recharge below Young Norway Spruce, White Birch, and Treeless Gaps at a Mountain-Summit Site. In Forests, vol. 12, no. 7, pp. 1-22. ISSN 1999-4907.

SUMNER, M.E. (ed.). 1999. Handbook of soil science. CRC press. 631 p. ISBN 13: 9780849331367.

VAVŘÍČEK, D. et al. 2017. Základy lesnického půdoznalství a výživy lesních dřevin. Lesnická práce. Kostelec nad Černými lesy. 362 p. ISBN 978-80-7458-103-8.

WIEKENKAMP, I. et al. 2016. Spatial and temporal occurrence of preferential flow in a forested headwater catchment. In Journal of hydrology, vol. 534, pp. 139-149. ISSN 2214-5818.

WOOD, P.J. et al. (ed.). 2008. Hydroecology and ecohydrology: past, present and future. John Wiley and Sons. 464 p. ISBN 978-0-470-01017-4.

ZANG, C. et al. 2014. Patterns of drought tolerance in major European temperate forest trees: climatic drivers and levels of variability. In Global change biology, vol. 20, no. 12, pp. 3767-3779. ISSN 1354-1013.

ZARLENGA, A. et al. 2018. Spatial variability of soil moisture and the scale issue: a geostatistical approach. In Water Resources Research, vol. 54, no. 3, pp. 1765-1780. ISSN 1944-7973.

Contact address: Ing. Tomáš Vichta, Mendel University in Brno, Faculty of Forestry and Wood Technology, Department of Geology and Soil Science, Zemědělská 1, 613 00, Brno, Czech Republic, +421 723 462 534, tomas.vichta@mendelu.cz.

ARTICLE HISTORY:
Received 22.04.2022
Received in revised form 13.05.2022
Accepted 13.05.2022

SATURATED HYDRAULIC CONDUCTIVITY OF SANDY SOIL UNDER APPLICATION OF TWO DIFFERENT BIOCHAR TYPES

Lucia TOKOVÁ[1], Natália BOTKOVÁ[1,2], Justína VITKOVÁ[1], Peter ŠURDA[1], Lenka BOTYANSZKÁ[1], Peter RONČÁK[1], Ján GADUŠ[3]

[1]Institute of Hydrology, Slovak Academy of Sciences in Bratislava, SLOVAKIA

[2]Institute of Landscape Engineering, Slovak University of Agriculture in Nitra, SLOVAKIA

[3]Institute of Environmental Management, Slovak University of Agriculture in Nitra, SLOVAKIA

Abstract

In this research, we evaluated the application effect of two different biochar types, one made from willow at a pyrolysis temperature of 520 °C and the other from grain husks and paper fiber sludge at 550 °C, on the saturated hydraulic conductivity of sandy soil. Mixtures of sandy soil and biochar were prepared in laboratory conditions with a biochar ratio of 20 $t.ha^{-1}$ in the Kopecky cylinders. All 3 treatments (with biochar particle size: > 2 mm, 125 µm – 2 mm and < 125µm) were prepared in 3 replicates for each biochar. These prepared mixtures were compared with the control treatment (without amendments), which was also prepared in 3 replicates. The results clearly indicate that both used types of biochar reduced hydraulic conductivity compared to pure sand, but a statistically significant reduction ($p < 0.05$) was observed only for the finest fraction of biochar (< 125 µm). The results further indicate a significantly lower hydraulic conductivity of the soil on treatments with biochar from willow (at 520 °C) compared to treatments with biochar from grain husks (at 550 °C).

Keywords: willow biochar, grain husks biochar, saturated hydraulic conductivity, sandy soil

 https://doi.org/10.15414/2022.9788055225029

Introduction

Improvement of water retention in the landscape within the soil profile is often discussed topic especially in a relation to climate change mitigation. Some studies suggest that biochar can improve quality of degraded soils (Ndor et al., 2015; Karim et al., 2020) and the soil water regime (Hardie et al., 2013; Castellini et al., 2015).

Biochar is a carbon rich product made from biomass by pyrolysis process that takes place at high temperatures ranging from 300 °C up to 1000 °C under low oxygen or no oxygen conditions (Lehmann and Stephen, 2015). Biochar addition to soils potentially affects various soil properties, and these effects are dependent on biochar derived from different input materials and pyrolysis conditions (Lei and Zhang, 2013).

Biochar as a soil amendment can increase crop productivity (Aydin et al., 2020), potentially by improving the soil hydrological properties (Toková et al., 2020). Biochar can also increase soil moisture (Novak et al., 2012), soil water holding capacity, plant available water content (Blanco–Canqui, 2020) and change hydraulic properties of the soil (Makó et al., 2020). Biochar is predicted to cause sandy soils to drain slower (Lim et al., 2016) and clay rich soils to drain more rapidly. However, past results have not been consistent, likely due to confounding factors such as biochar characteristics (i.e., input material type, pyrolysis temperatures), application rates, and soil characteristics.

Given the importance of hydraulic conductivity in determining the partitioning of precipitation between infiltration and overland flow, which impacts water storage in the subsurface and thus plant available water, it is necessary to understand the effects of biochar on the hydraulic properties of different soil types.

The main aim of our study was to evaluate the effect of two different biochar types, produced at similar pyrolysis temperatures (from willow at 520 °C and from grain husks at 550 °C) on the saturated hydraulic conductivity of sandy soil. Another aim was to study the effect of different surface areas of used biochar on the saturated hydraulic conductivity of the soil.

Material and methods

The experiment was conducted in the laboratory of the Institute of Hydrology SAS in 2021 to assess the effect of biochar on soil hydraulic conductivity. The location of soil samples was 48° 22' 16.91" N, 16° 59' 34.44" E, and altitude 155 m above sea level. The area selected for soil sampling was a sand pit with no vegetation near the Plavecký Štvrtok (Western Slovakia).

Laboratory experiment preparation

Particle size distribution of soil was measured by the hydrometer method (Velebný, 1981). It consists of 91 % sand, 7.5 % silt and 1.5 % clay, so it is classified as sand (Velebný, 1981). The soil was sieved to a fraction with a particle diameter size ≤ 2 mm, which was used in further research.

The particle size of produced biochar was 0 – 10 mm. For the purposes of experiment, coarse biochar was homogenized using a hammer mill and sieved to a fraction with a particle size 2 mm – 125 µm.

Mixtures of sandy soil and biochar were prepared in laboratory with a biochar application rate of 20 $t.ha^{-1}$ in Kopecky cylinders with a volume of 100 cm^3. Overall, three treatments, representing different particle size (PS) fractions (PS > 2 mm, PS 125 µm – 2 mm and PS < 125 µm), were prepared for each type of biochar. For each treatment were prepared 3 samples of soil and biochar mixtures. These prepared mixtures were compared with the control treatment (without amendments), which was prepared in 3 replicates as well.

Characteristics of used biochar

The first type of biochar used in this experiment (WB), was made from willow cultivar Tordis ((*Salix schwerinii* x S. *viminalis*) x S. *viminalis*) in the UNYPIR reactor, which is part of the AgroBioTech center of the Slovak University of Agriculture in Nitra. The basic chemical properties of this biochar are listed in Table 1. WB was produced at pyrolysis temperature of 520 °C.

The second type of biochar (GHB), was made from sludge paper fibers with grain husks in a Pyreg reactor (Pyreg GmbH, Görhe, Germany). The basic chemical properties of this biochar are listed in Table 1. GHB was produced at pyrolysis temperature of 550 °C.

 https://doi.org/10.15414/2022.9788055225029

Table 1 Chemical properties of both types of biochar used in the laboratory experiment

	C	H	N	S
	%	%	%	%
WB	81.58	2.53	0.91	0.31
GHB	53.1	1.84	1.4	0.08

C – carbon, H – hydrogen, N – nitrogen, S – sulfur

Determination of saturated hydraulic conductivity of soil

Saturated hydraulic conductivity of the soil (K_{sat}) was determined on prepared mixtures of sandy soil and biochar in Kopecky cylinders (100 cm^3) for all treatments of the laboratory experiment. Each treatment was made in three replications, so 21 samples were measured in total. We performed 3 measurements of K_{sat} on each soil sample, which means that we had 9 values of K_{sat} for each treatment.

K_{sat} of sandy soil was determined using a falling-head method (Igaz et al., 2017) (Figure 1) according to the equation:

$$K_{sat} = \frac{L}{t} \, . \ln\frac{H_2}{H_1}$$ (Equation 1 source: Antal and Igaz, 2012)

where: L – soil cylinder height (cm), t –time of water level decrease from height H_2 – H_1 (s), H_2 – initial water level in the extension (cm), H_1 – the height of the water in the extension after the drop

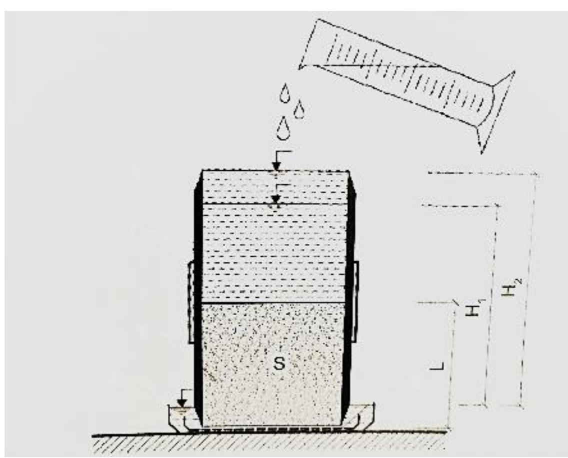


Figure 1 Scheme of falling-head system for saturated hydraulic conductivity measurement

Statistical analysis

Statistical analysis of the biochar effect on the K_{sat} of the sandy soil was done using one–way analysis of variance (ANOVA). The significant treatments at $p < 0.05$ were determined by the least significance difference (LSD) test. All analyses were performed in Statgraphics Centurion XV.I software (Statpoint Technologies, Inc., Warrenton, VA, USA).

Results and discussion

The results clearly show that the application of biochar at a dose of 20 $t.ha^{-1}$ to sandy soil reduces its saturated hydraulic conductivity (K_{sat}) (Table 2). An interesting observed phenomenon was the gradual reduction of K_{sat} by reducing the particle size of biochar (Figure 2), while a statistically significant reduction ($p < 0.05$) compared to the control was recorded only in treatments where biochar with the finest particles (< 125 µm) was applied (Table 2). From the results can be stated, that reducing the particle size of biochar, or by reducing its surface area, K_{sat} also decreases more in sandy soil.

Table 2 Impact of two different types of biochar on the saturated hydraulic conductivity of sandy soil. Different letters (a, b, c) indicate treatment means, which are significantly different at $p < 0.05$ according to least significance difference test.

	Mean (n = 9)	Standard deviation (n = 9)	Comparison to control
	$cm.h^{-1}$		%
Control	48.36^{c}	10.10	
WB >2mm	39.71^{bc}	4.43	- 17.88
WB 125µm – 2mm	34.59^{bc}	2.30	- 28.47
WB <125µm	8.89^{a}	4.57	- 81.61
GHB >2mm	47.94^{c}	3.15	- 0.86
GHB 125µm – 2mm	45.24^{bc}	4.98	- 6.45
GHB <125µm	18.96^{a}	2.11	- 60.79

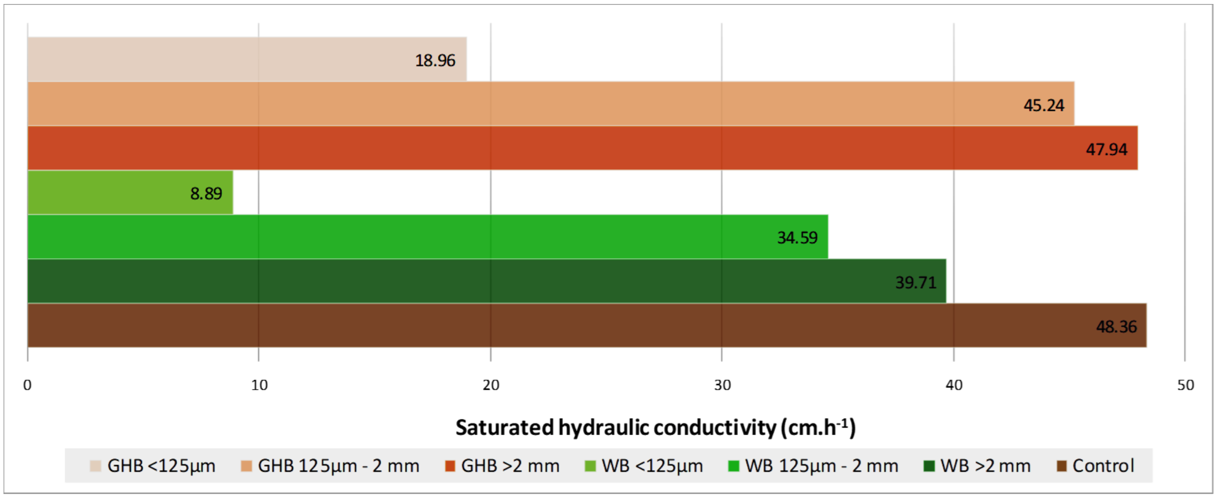


Figure 2 Impact of two different types of biochar on the saturated hydraulic conductivity of sandy soil

Some of the authors, such as Lehmann and Stephen (2015), Lim et al. (2016) and Dan et al. (2015) report, that biochar in sandy soils causes slower water run–off. Our results on the decrease in K_{sat}, due to the application of biochar, are therefore in line with previous work in this area.

The results also show, that by using willow biochar (WB 520 °C), K_{sat} decreased more than when using husk biochar (GHB 550 °C) (Figure 2). We believe that the difference in hydraulic properties was not due to the different pyrolysis temperature of the biochars used (difference 30 °C), but in the type of input material used. This statement is confirmed by Das et al. (2021), who states that the resulting properties of biochar are more affected by the type of input material than by the pyrolysis temperature itself. In our laboratory experiment, two types of raw materials were used, which could affect the hydraulic properties of the resulting biochar.

Conclusion

Our results successfully evaluated the impact of biochar on saturated hydraulic conductivity (K_{sat}) of sandy soil. The results of our study confirmed, that by reducing the size of the biochar particles, the K_{sat} decreases more and at the finest biochar fraction (< 125 µm) we recorded a statistically significant reduction (*$p < 0.05$*) of K_{sat} at both biochar treatments compared to control. The difference between the WB (willow biochar) and GHB (sludge paper+grain husks biochar) was also significant. At the same biochar particle size, lower K_{sat} values were found for biochar made from willow. Our results confirmed that the input material from which biochar is made, has an effect on the change in the K_{sat} of sandy soil. In the context of climate change, the application of biochar to sandy soils is a suitable tool to reduce subsurface runoff and to increase water retention in the landscape.

Acknowledgment

This research was created with financial support from the project of the Scientific Grant Agency VEGA 2/0155/21.

References

ANTAL, J. – IGAZ, D. 2012. Aplikovaná agrohydrológia. SPU. Nitra. 210 p. ISBN 978–80–552–0731–5.

AYDIN, E. et al. 2020. Potential of biochar to alternate soil properties and crop yields 3 and 4 years after the application. In Agronomy [online], vol. 243–244, pp. 175–182. Available on internet: https://doi.org/10.3390/agronomy10060889.

BLANCO–CANQUI, H. 2020. Does biochar improve all soil ecosystem services? In Bionergy [online], vol. 13, no. 4, pp. 291–304. Available on internet: https://doi.org/10.1111/gcbb.12783.

CASTELLINI, M. et al. 2015. Impact of biochar addition on the physical and hydraulic properties of a clay soil. In Soil and Tillage Research [online], vol. 154, pp. 1–13. Available on internet: https://doi.org/10.1016/j.still.2015.06.016.

DAN, T. et al. 2015. Experimental study of influence of biochar on different texture soil hydraulic characteristic parameters and moisture holding properties. In Polish Journal of Environmental Studies, vol. 24, pp. 1435–1442.

DAS, S. K. et al. 2021. Compositional heterogenity of different biochar: Effect of pyrolysis temperature and feedstocks. In Journal of Environmental Management [online], vol. 278, pp. 1–12. Available on internet: https://doi.org/10.1016/j.jenvman.2020.111501

HARDIE, M. et al. 2013. Does biochar influence soil physical properties and soil water availablity? In Plant and Soil [online], vol. 376, pp. 347–361. Available on internet: https://doi.org/10.1007/s11104-013-1980-x.

IGAZ, D. et al. 2017. Základné merania v hydropedológií. SPU. Nitra. 110 p. ISBN 978–80–552–1686–7.

KARIM, MD. R. et al. 2020. Biochar effects on soil physiochemical properties in degraded managed ecosystems in northeastern Bangladesh. In Soil Systems [online], vol. 4, no. 4, pp. 69. Available on internet: https://doi.org/10.3390/soilsystems4040069.

LEHMANN, J. – STEPHEN, J. 2015. Biochar for environmental management: Science, technology and implementation. 2nd ed. Rontledge, Taylor and Francis Group. London. 928 p. ISBN 978–0–415–70415–1.

LEI, O. – ZHANG, R. J. 2013. Effects of biochars derived from different feedstocks and pyrolysis temperatures on soil physical and hydraulic properties. In Journal of Soils and Sediments [online], vol. 13, pp. 1561–1572. ISSN 1439–0108. Available on internet: https://doi.org/10.1007/s11368-013-0738-7

LIM, T.J. et al. 2016. Predicting the impact of biochar additions on soil hydraulic properties. In Chemosphere [online], vol. 142, pp. 136–144. Available on internet: https://doi.org/10.1016/j.chemosphere.2015.06.069.

MAKÓ, A. et al. 2020. Soil physical properties affected by biochar addition at different plant phaenological phases. Part II. In International Agrophysics [online], vol. 34, pp. 1–7. Available on internet: https://doi.org/10.31545/intagr/115285.

NDOR, E. et al. 2015. Effects of biochar on soil properties and organic carbon sink in degraded soil of Southern Guinea Savanna Zone, Nigeria. In International Journal of Plant and Soil Science, vol. 4, pp. 252–258.

NOVAK, J. M. et al. 2012. Biochars impacts on soil moisture storage in an ultisol and two ardisols. In Soil Science, vol. 177, no. 5, pp. 310–320.

TOKOVÁ, L. et al. 2020. Effect of biochar application and re–application on soil bulk density, saturated hydraulic conductivity, water content and soil water availability in a silty loam Haplic Luvisol. In Agronomy [online], vol. 10, no. 7, pp. 1005. Available on internet: https://doi.org/10.3390/agronomy10071005.

VELEBNÝ, V. 1981. Hydropedológia – učebná pomôcka na cvičenie. SVŠT. Bratislava. 173 p. ISBN 85–341–81.

Contact address: Ing. Lucia Toková, PhD., Slovak Academy of Sciences, Institute of Hydrology, Dúbravská cesta 9, 841 04 Bratislava, +421–2–32293516, tokova@uh.savba.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 25.04.2022
Received in revised form 11.05.2022
Accepted 13.05.2022

IMPACT OF CLEMENTINE PEELING AS A NATURAL FERTILIZER ON PLANT PHOTOSYNTHESIS

Lenka BOTYANSZKA[1], Peter SURDA[1], Justina VITKOVA[1], Lucia TOKOVA[1], Natalia BOTKOVA[1,2]

[1]Institute of Hydrology SAS, SLOVAKIA

[2]Institute of Landscape Engineering SUA, SLOVAKIA

Abstract

Approximately 30 – 40 % of food waste is generated during food processing, which may include peels, bark, stems, seeds, shells, bran, moldings, and cuttings. Such waste can be used as a natural fertilizer highly rich in phenols, essential oils, ions, vitamins, etc. Clementine peels were powdered and applied as a natural fertilizer at a 5 % concentration to three different plants. Measurement of the effect of peel powder as a natural growth fertilizer was performed on wheat, barley, and tomato plants. The parameter measured was chlorophyll fluorescence parameter Fv/Fm. The measurement was performed after fertilizer application at weekly intervals. The difference in Fv/Fm reduction was demonstrated only in the tomato variant compared to the control, in other variants, the peel powder had little to no effect.

Keywords: clementine peels, fertilizers, chlorophyll fluorescence

Introduction

Every year, by-products from the food industry are produced in large quantities around the world (Torres-León et al., 2018). Approximately 30 – 40 % of food waste is generated during food processing (Helkar, et al., 2016). Food wastes from vegetable processing include peels, rinds, stalks, seeds, shells, bran, pomace, and trimmings. Citrus (Rutaceae) is the most economically important tree fruit crop in the world. For mandarins production, China leads, being the largest producer with 19.0 million tons, covering 57 % of world production, followed at a distance by Spain (7 %), Japan, Morocco, Egypt, Turky, and Brazil (around 3 % each) (Zhong and Nicolosi, 2020).

Clementines have significant success in Europe. A clementine (Citrus × clementina) is a tangor, a citrus fruit hybrid between a willowleaf mandarin orange (C. × deliciosa) and a sweet orange (C. × sinensis), is one of the most important crop varieties of Citrus in the Mediterranean area (Loizzo, *et al*., 2018). Clementine fruits grow on different continents, and Spain represents the major European producer. Clementines need a mild climate, as constant as possible throughout the growing season. They are sensitive to temperature changes, especially those caused by cold winds (Leporini, *et al*., 2020).

Citrus fruits provide benefits for human health based which are related to the presence of bioactive compounds including vitamin C, carotenoids, phenolics, and essential oils (Leporini *et al*., 2020). Most citrus fruits are processed to make juices; however, a large amount of citrus waste is generated, including peels, segmental membranes, and seeds. It is estimated that worldwide production of 15 million tons of citrus waste per year (Jeong *et al*., 2021). Due to low costs and easy availability, citrus fruit residues that are discarded as waste should rather be considered as a potential source of nutrients. In fact, these by-products are rich in bioactive substances, e.g. fiber, polyphenols, and other bioactive compounds. Therefore, these by-products are considered renewable (Abou Baker, *et al*., 2021). However, it is questionable how waste after processing (clementine peels) affects the soil and cultivated plants. Therefore, we focused on their addition to the soil.

Material and methods

<u>Soil</u>

Agro NATURA the substrate for the whole garden is a mixture based on peat, coconut fiber, clay, natural limestone, and organic fertilizer. The nitrogen-phosphorus-potassium (10-4-4) nutrient ratio contains an organic fertilizer to start growth. The unique structure ensures optimal aeration to accelerate root growth, has high water absorption and consequently the ability to provide excellent water supply to plants.

 https://doi.org/10.15414/2022.9788055225029

Collection and processing of clementine Fruit Peels

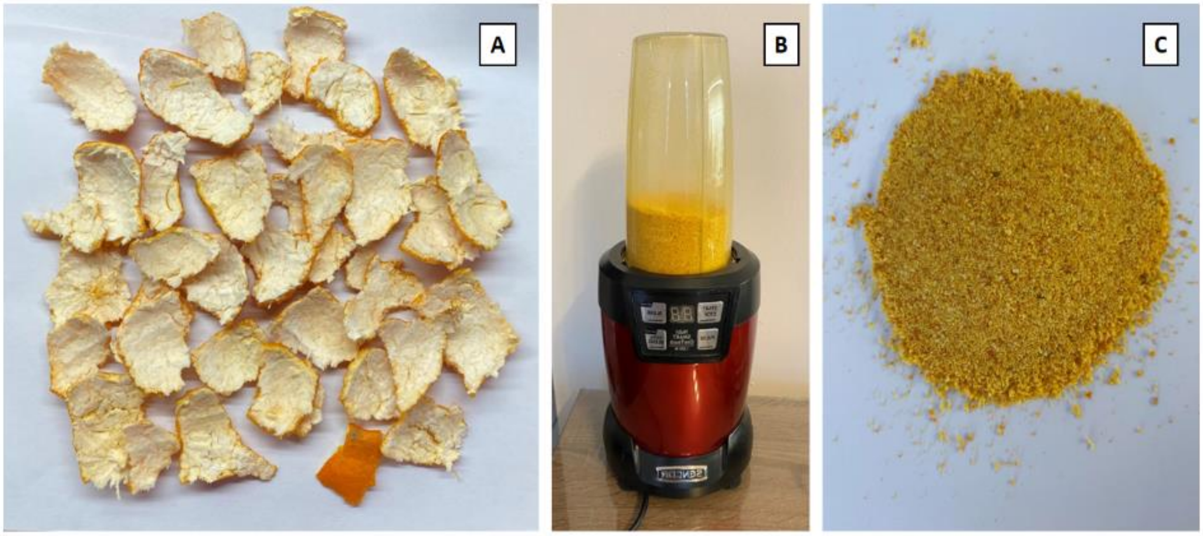


Figure 1 Landscape A. clementines peel, B. processing of skins with a mixer, C. processed peels (Botyanszka, 2022)

Clementine fruits were bought in an ordinary shop and subsequently peeled. The fresh peels were cut into small pieces approx. 5 cm and air-dried at room temperature for 14 days (Figure 1 A). The dried fruit peels were ground to a powder (Figure 2 B, C).

Application clementine peel powder in the soil

Were applied to the soil 3g amounts of peel powder, which represented 5 % of the total soil (table 1.). The powder was mixed with the soil for uniform distribution. Three plant types and controls were maintained for each formulation. After 12 days of growth in control soil, young plants of wheat, barley and tomato were planted into pots with different concentrations of peel powder. Each pot own one plant and water was poured regularly. Results were observed after 30 days of inoculation.

Table 1 Quantity of peel powder used for the preparation of variants

<table>
<tr><th>plant/ concentration</th><th>C</th><th>3g = 5%</th></tr>
<tr><td>Wheat</td><td rowspan="3">60g soil</td><td rowspan="3">57g soil + 3g powder</td></tr>
<tr><td>Barley</td></tr>
<tr><td>Tomato</td></tr>
</table>

Source: Botyanszka, 2022

<u>Chlorophyll Fluorescence mesurments</u>

The electron transport of photosystem II (PSII) is affected by stress, which could be examined by fast chlorophyll fluorescence in plants. The change in photosynthetic was attributed was determined by OJIP and light response curve calculations by using FluorPen FP 110/D (Photon system, Czech Republic). The measurement was done to the same leaf after 15 minutes of dark adaptation. The parameter we used was the measurement of the ratio of variable to maximal fluorescence (Fv/Fm), with maximal values of 0.85 equaling an 85 % efficiency of the conversion of absorbed light into photochemistry.

Figure 2a Measurement of based experiment (Botyanszka, 2022)

Results and discussion

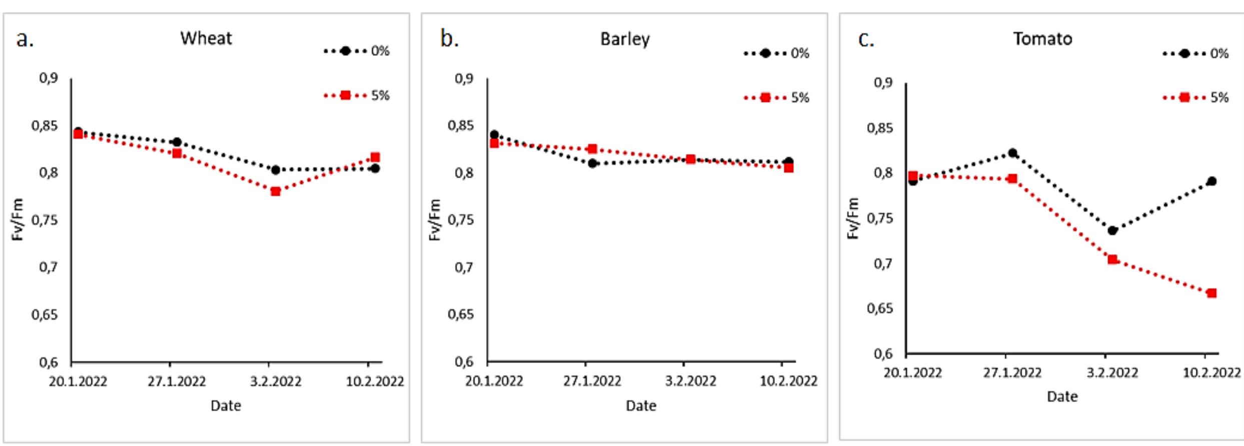


Figure 2b Measurement of based experiment (Botyanszka, 2022)

The effect of the peel on Fv/Fm was in some variants significant where the average Fv/Fm across 3 variants ranged from 0.79 to 0.82 in control and 0.74 to 0.82 in 5 % concentration (Table 2). The tomato variant showed more reduction in Fv/Fm than others but the average Fv/Fm decreased due to the addition of peels was only 0,02 of the control value (Table 2).

However, the mean Fv/Fm value in control plants was 0.81, which is very close to the well-established maximum value of unstressed C3 leaves of 0.835 (Demmig and Björkman 1987).

Table 2 The effect of clementine peel on the chlorophyll fluorescence parameter Fv/Fm of young plants wheat, barley, and tomato

20.1.2022			
plant	%	Fv/Fm (Mean)	SD
Wheat	0	0,843 a	0,012
Wheat	5	0,841 a	0,005
Barley	0	0,840 a	0,010
Barley	5	0,832 a	0,017
Tomato	0	0,791 a	0,011
Tomato	5	0,798 a	0,010
27.1.2022			
plant	%	Fv/Fm (Mean)	SD
Wheat	0	0,832 a	0,005
Wheat	5	0,821 a	0,011
Barley	0	0,810 a	0,017
Barley	5	0,825 a	0,003
Tomato	0	0,823 b	0,003
Tomato	5	0,794 b	0,041
3.2.2022			
plant	%	Fv/Fm (Mean)	SD
Wheat	0	0,803 ab	0,014
Wheat	5	0,781 a	0,024
Barley	0	0,814 a	0,003
Barley	5	0,814 a	0,008
Tomato	0	0,737 b	0,014
Tomato	5	0,704 a	0,028
10.2.2022			
plant	%	Fv/Fm (Mean)	SD
Wheat	0	0,805 a	0,015
Wheat	5	0,817 a	0,003
Barley	0	0,812 ab	0,006
Barley	5	0,805 a	0,009
Tomato	0	0,791 b	0,030
Tomato	5	0,667 a	0,080

Source: Botyanszka, 2022

Many studies have addressed the impact research on different types of agricultural or food industry waste and their appropriate use to improve soil fertility, improve microbial activities, strengthen agricultural production, and mitigate climate change (Dahunsi, *et al*., 2021; Anastopoulos, *et al*., 2019; Gómez-Muñoz, *et al*., 2017; Qaryouti, *et al*., 2015; Deng, *et al*., 2012). Most fruit peels contain different macro and microelements, vitamins, glucose, fructose, minerals, organic acids, cellulose, hemicellulose, pectin, enzymes, flavonoids, essential oils, and pigments (Debernardi-Vázquez, *et al*., 2020). Some fruit peels such as citrus varieties may be used as natural insecticides to kill the pest (e.g. nematodes, aphids, and thrips) (Buss and Park-Brown, 2002). At the same time, they should act as beneficial to enhance microbes. There are very few publications regarding the formulation of fruit peel and its utilization for plant growth. Mercy*, et al*. (2014) state the formulation applied soil contains an approximately tenfold number of microorganisms per ml than control soil. However, it remained questionable whether the application of such an amount to the soil would not be toxic to the plants.

The application of the peels did not have a significant effect on the maximum quantum efficiency of PSII photochemistry during the entire tested period in wheat. As with wheat, the effect on barley was minimal, which was statistically confirmed. Tomatoes showed a decrease in the maximum quantum efficiency of PSII photochemistry, with the lowest value at 5 % averaging 0.67 equalling a 67 % efficiency of the conversion of absorbed light into photochemistry

We conclude that the 5 % peels content impact identified by our phenotypic evaluation based on Fv/Fm wasn't relevant in terms of reduced quantum efficiency of photosystem II photochemistry in the wheat and barley variant but caused a decrease in the tomato variety. Therefore, although clementine peels can be used as alternative and effective nutrients, it is necessary to take into account the type of plant and the concentration of the peels. And in the next phases of the research, the effect of the clementine peel as a natural fertilizer was to be supported by several parameters of chlorophyll fluorescence.

Conclusions

From the previous results of this study, it can be concluded that under the same conditions of the three plant variants, the addition of Clementine peels at 5 % concentration had the greatest effect on the photochemical activity of photosystem II in tomato plants.

Acknowledgment

This work was supported by the Slovak Scientific Grant Agency VEGA 2/0155/21.

References

ABOU BAKER, D. H. et al. 2021. Citrus Peels as a Source of Bioactive Compounds with Industrial and Therapeutic Applications. In *Phenolic Compounds-Chemistry, Synthesis, Diversity, Non-Conventional Industrial, Pharmaceutical and Therapeutic Applications. IntechOpen.*

ANASTOPOULOS, I. et al. 2019. Valorization of agricultural wastes could improve soil fertility and mitigate soil direct N2O emissions. In *Journal of environmental management*, vol. 250, pp. 109389.

BUSS, E. A. – PARK-BROWN, S. G. 2006. *Natural products for insect pest management*. University of Florida IFAS Extension: Florida. pp. 1– 5.

DAHUNSI, S. O. et al. 2021. Crop performance and soil fertility improvement using organic fertilizer produced from valorization of Carica papaya fruit peel. In *Scientific reports*, vol. 11, no. 1, pp. 1-16.

DEBERNARDI-VÁZQUEZ, T. D. J. et al. 2020. Composting of byproducts from the orange (Citrus sinensis (L.) Osbeck) and sugarcane (Saccharum spp. hybrids) agroindustries. In *Ingeniería e Investigación*, vol. 40, no. 3, pp. 81-88.

DEMMIG, B. – BJÖRKMAN, O. 1987. Comparison of the effect of excessive light on chlorophyll fluorescence (77K) and photon yield of O2 evolution in leaves of higher plants. In *Planta*, vol. 171, no. 2, pp. 171-184.

DENG, G. F. et al. 2012. Potential of Fruit Wastes as Natural Resources of Bioactive Compounds. In *International Journal of Molecular Sciences*, vol. 13, no. 7, pp. 8308-8323.

GÓMEZ-MUÑOZ, B. et al. 2017. Nitrogen turnover, crop use efficiency and soil fertility in a long-term field experiment amended with different qualities of urban and agricultural waste. In *Agriculture, ecosystems & environment*, vol. 240, pp. 300-313.

HELKAR, P. B. et al. 2016. Review: Food industry by-products used as a functional food ingredients. In *International journal of waste resources*, vol. 6, no. 3, pp. 1-6.

JEONG, D. et al. 2021. Recent advances in the biological valorization of citrus peel waste into fuels and chemicals. In *Bioresource Technology*, vol. 323, pp. 124603.

LOIZZO, M. R. et al. 2018. Investigating the in vitro hypoglycaemic and antioxidant properties of Citrus× clementina Hort. juice. In *European Food Research and Technology*, vol. 244, no. 3, pp. 523-534.

LEPORINI, M. et al. 2020. Impact of extraction processes on phytochemicals content and biological activity of Citrus× clementina Hort. Ex Tan. leaves: New opportunity for under-utilized food by-products. In *Food Research International*, vol. 127, pp. 108742.

LEPORINI, M. et al. 2020. Citrus× clementina hort. juice enriched with its by-products (Peels and Leaves): Chemical composition, in vitro bioactivity, and impact of processing. In *Antioxidants*, vol. 9, no. 4, pp. 298.

MERCY, S. et al. 2014. Application of different fruit peels formulations as a natural fertilizer for plant growth. In *International Journal of Scientific & Technology Research*, vol. 3, no. 1, pp. 300-307.

QARYOUTI, M. et al. 2015. Effect of using raw waste water from food industry on soil fertility, cucumber and tomato growth, yield and fruit quality. In *Scientia Horticulturae*, vol. 193, pp. 99-104.

TORRES-LEÓN, C. et al. 2018. Food waste and byproducts: An opportunity to minimize malnutrition and hunger in developing countries. In *Frontiers in Sustainable Food Systems*, vol. 2, pp. 52.

ZHONG, G. – NICOLOSI, E. 2020. Citrus origin, diffusion, and economic importance. In GENTILE, A. - LA MALFA, S. - DENG Z. (Eds.), *The Citrus Genome*, Springer, Cham, pp. 5-21.

Contact address: Ing Lenka Botyanszká, PhD., Institute of Hydrology, Slovak Academy of Sciences, Dúbravská cesta 9, 841 04 Bratislava, Slovakia, E-mail: botyanszka@uh.savba.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 30.04.2022
Received in revised form 22.06.2022
Accepted 25.06.2022

POSSIBILITIES OF REVITALIZATION OF PUBLIC SPACES

Vendula MORAVCOVÁ, Jana MORAVCOVÁ

Faculty of Agriculture and Technology, University of South Bohemia in Ceske Budejovice, CZECH REPUBLIC

Abstract

Public spaces have a very important role in modern life, especially in greater cities. The environment of modern cities is often polluted by heavy traffic, which includes exhalations, dust, and noise. Many cities look for solution how to make centres more suitable for inhabitants, especially by reduction of traffic and building places for recreation and leisure time. At the same time there is an effort to expand urban greenery on the stone and concrete streets and make city environment more comfortable especially in hot summer days. For this work there was chosen city of Ceske Budejovice in South Bohemia and some projects, which are prepared for revitalisation of some public spaces. Especially there were chosen plans of revitalisation of city park Dukelska, main square and old town of Ceske Budejovice.

Keywords: public space, revitalisation, Ceske Budejovice

Introduction

Public spaces have been an integral part of all urbanized areas since their inception. In general, these are areas that are freely accessible to the public and are usually owned by the state or local governments (Madanipour, 2006). The first delimitation of public space appears in ancient Greece, when public space is delimited in the form of the so-called agora. In further development, these places were transformed into medieval markets, squares, etc. Depending on the size of the settlements, we also encounter the delimitation of public spaces for economic use in the form of, for example, municipal orchards or municipal pastures. At present, public space is mainly connected with aspects of social life and commonly used space (Nissen, 2008). Public space, unlike private space, has a legal framework that is defined by public law and public institutions. In the legislation of the Czech (or Czechoslovak) Republic, the concept of public space appears for the first time in the Act on Local Fees (Act No. 565/1990 Coll.). Within the framework of this regulation, public space is exhaustively defined as the areas of squares, marketplaces, roads, parks and public greenery, including other freely publicly accessible places. The amendment to the Czech Act on Municipalities (Act No. 128/2000), which, after deletion from the Act on Local Fees in 2004, is practically the only legal regulation of this area, is similar to the definition. The definition of the term has become practically customary over time, and several ambiguities and disputes arise within this framework, which concern, for example, the interiors of buildings accessible to the public, etc.

Siebel and Wernheim (2003) added four aspects to the definition of public space that distinguish public spaces from private spaces. It is about:

• the legal dimension, where public spaces are under the "supervision" of legislative restrictions that users must comply with,

• a functional dimension, where, according to the authors, public spaces serve mainly the needs of the market and politics,

• the social dimension, where the public space gives the impression of anonymity but on the other hand places a strong emphasis on the aspect of user behaviour,

• material dimension, where public space usually uses a different design and material spectrum than private spaces.

However, the last-mentioned aspect of the design and materials used in public spaces poses the biggest problem in planning the use of these areas in spatial planning. Public spaces have always been a "showcase" of municipalities, and municipalities have presented their face to the outside in the form of modern period design works and the use of structural elements (Lofti and Mousazadeh, 2020). At present, however, many of these spaces no longer meet current requirements for use and layout on the one hand and design on the other. The same is true for green areas of public parks, where age is mainly influenced by the health and longevity of plantings and furniture (Cudny, 2016). However, the revitalization of these public spaces encounters inconsistent currents of opinion and thought, both between the management of individual municipalities and residents, who, as users of the space, should be included in the planning as

 https://doi.org/10.15414/2022.9788055225029

much as possible. Particularly problematic is the "nostalgic" behaviour of residents who have the current face of public spaces associated with experiences and memories of their lives (Subiza Pérez, 2021). This fact, combined with natural human conservatism and reluctance to accept change and a lack of understanding of certain new needs of the present and the generation, leads to a very slow process of revitalizing public spaces in cities and towns (the situation is slightly simpler here). The changes created and revitalization actions have subsequently become a frequent target of criticism from the dissatisfied part of the population and, in many cases, also the target of vandalism (San Juan et al., 2017).

Material and methods

Ceske Budejovice is the South Bohemian regional town with population of 94 229 people (Czech statistical office, 2022). Its origin dates in 1264 and during the centuries the city has undergone many changes. The greatest changes have taken place in 19th century when the city walls were removed, and the old town and the surroundings became one unit. Many changes in appearance of the city centre meant construction of new buildings in 20th century in the style of Art Nouveau, romanticism, and socialist realism. Important change for the appearance of the city centre was new paving of central square in 1938 which was accompanied with removing trees and trams (City Council of Ceske Budejovice, 2022).

Although the city has historical prize, proximity of two rivers (Vltava and Malse), plenty of urban greenery all around the centre and many pubs, cafeterias, and other possibilities for meeting of citizens, public spaces are not suitable for their use, especially in summer months. Main problem of the city centre is heavy traffic and lack of shadow. Although there is plenty of parks, greenery is often neglected and equipment of relax zones is outdated and often damaged.

The three main parts on which the article is focused on are:

- Premysl Otakar II. Square and its surrounding

This part of city is the heart of historical core. For centuries it was centre of trade, place for markets and meeting of citizens. Nowadays the road lining of the square serves as roundabout and shortcut for cars and as parking lot for residents, employees of town hall and city visitors. Central part of the square is used mainly for seasonal markets especially during Easter and Christmas. For the rest of the year the square is empty. The nearby Krajinska street is one of the main streets, which leads to Premysl Otakar II. Square. Historically it was one of the most important streets of the city. On

 https://doi.org/10.15414/2022.9788055225029

her beginning there was one of the city gates, which was torn down in 1867. Today it is connector between Marianske square and Premysl Otakar square, which is used mainly in the traffic jam, as a shortcut, what means heavy traffic load for the historical core.

- Dukelska Park

One of the biggest plans for revitalization of public spaces is park Dukelska on the edge of old city. This park lies along the Malse River and could be beautiful place for relaxation, meeting, and outside activities for close school. Nowadays this place is not suitable because of old rusty facilities, potentially dangerous trees which are mostly in very bad condition, unmaintained mostly poisonous or thorny shrubs (*Taxuss baccata, Berberis vulgaris*) especially around the playground, which serve as shelter for homeless people. One of the biggest problems of Dukelska Park is lane, which is combined for walkers and cyclists, what is reason of many accidents and disagreements in this place.

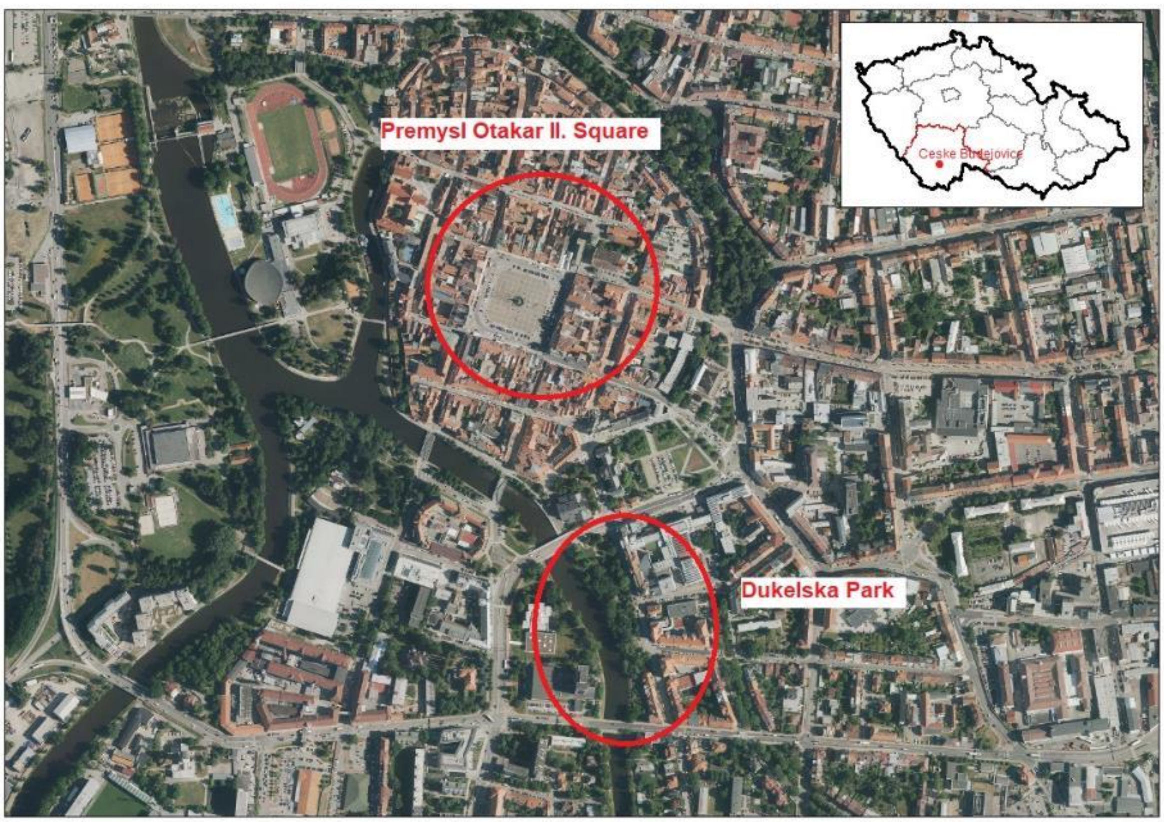


Figure 1 The localization of the places of interest

Authors are trying to find in this article an answer to two research questions:

RQ1: How do revitalization interventions of public spaces differ according to their type?

RQ2: Do residents perceive the proposed changes in individual parts of the city in the same way?

As described above as the basic material for the study, two representatives were selected from many urban revitalization projects, namely the area of public space in the form of a square and a representative of the blue-green infrastructure in the form of a large park area. As a basis for the study, studies of revitalizations of selected parts were used, the analysis of which provided answers to the first research question.

Structured interview with the city's residents, visitors and entrepreneurs who own or have leased establishments around then served as another source of information. The total amount of questioners held in both localities were 240. These interviews were conducted at several dates in the summer of 2021 for the revitalization of Dukelska Park, directly at the site of the planned event, and at several dates in the spring of 2022 for the revitalization of the central square, either through online meetings or personal interviews and questionnaires. Opinions on revitalization actions were also collected through social media such as Facebook, etc. Questionnaire surveys focus mainly on the following issues:

1. How do you perceive the current state of the assessed area

2. How do you perceive the traffic situation (operation of cars / passenger transport by bike or scooter) and possibilities for parking plots

3. What are the possibilities of living in the assessed area (shopping, gastronomy, culture, sports) and which part needs to be changed in this area

4. How do you perceive urban furniture in the studied areas

5. What do you perceive the so-called blue-green infrastructure in the locality (representation of vegetation, its condition, possibilities of water resources, possibilities of cooling in the summer months…)

The evaluation of these questionnaires then provided information to answer the second research question. Analysis and plans of revitalization of city parts were prepared in cooperation with design office and city of Ceske Budejovice.

 https://doi.org/10.15414/2022.9788055225029

Results and discussion

During last 20 years the situation is improving and urban spaces are being revitalized. First part was revitalization of pedestrian zone Lannova Street in 2006, when there were planted new trees with benches in the shadow and there were build water elements. Other part of revitalization took place in 2019, when waterfront on the confluence of rivers Malse and Vltava was opened, and old rusty railing was removed. In 2021 there was introduced project to build benches above water surface. Currently, several new activities are planned for the revitalisation of the wider city centre, especially regarding the involvement of the blue-green infrastructure and also in connection with the development of the new city master plan. From many smaller projects, two significant larger scale projects have been selected for this study.

RQ1:

Based on the study of the revitalization of the two types of public spaces selected within the city, information related to the most necessary planned interventions was first extracted from the plans and sorted.

<u>The Premysl Otakar II. Square and its surroundings</u> (Figure 2)

This plan is currently considered by city officials to be paramount, and this revitalization should be the most significant action of the outgoing city council term. It should be noted that the revitalisation action will be the largest only in terms of importance and not in terms of financial significance. The revitalization plan for the site is aimed at reducing traffic in the city centre, building a new pedestrian zone, and expanding the restaurants and cafes on the perimeter of the square where additional outdoor seating would be allowed. There is also a plan for the placement of potted trees, floral arrangements, and new benches to provide ample places to meet and relax in the shade and cooling climate of the square, where temperatures can reach 60°C in summer. Potted greenery was chosen for ease of maintenance and to protect the historic ceramic paving of the central part of the square. The main intention is to close the entire northern part of the square to traffic. The other three quarters will be used as parking spaces for residents, visitors, and City Hall staff.

 https://doi.org/10.15414/2022.9788055225029

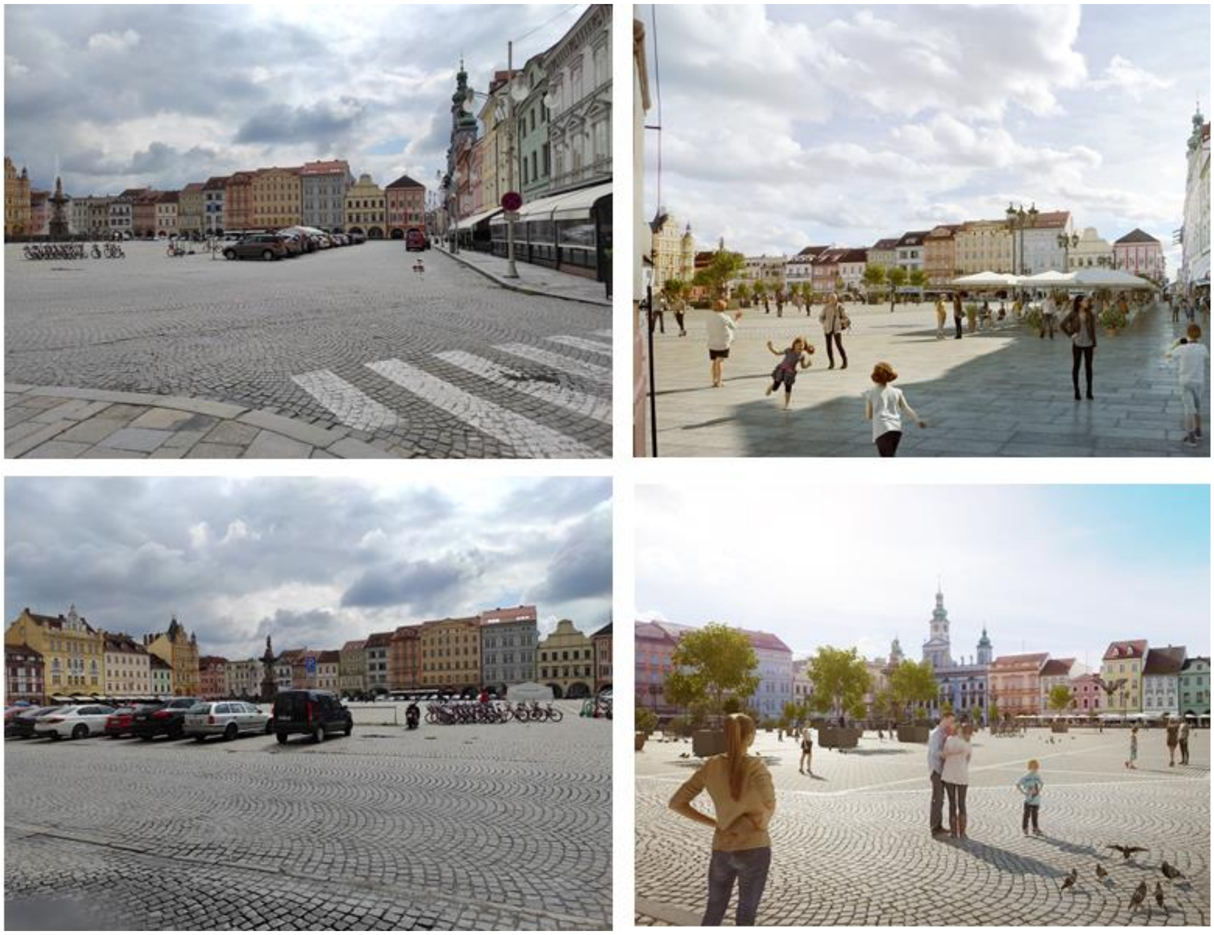


Figure 2 Premysl Otakar II. Square – actual state and planned revitalization

The nearby Krajinska Street has many cafes and shops selling cosmetics, fashion, and jewellery. This was the main reason for the plan to turn this adjacent area into a pedestrian shopping area with outdoor seating on the central street line, complete with potted greenery. Besides Krajinska Street, there are other streets in the old town of České Budějovice that are planned for revitalization. The main reason for this is their current condition and the prevention of increased traffic after the closure of Krajinska Street. These streets include Hroznova and Biskupska streets. New paving and bollards for non-residential vehicles are planned for these streets.

 https://doi.org/10.15414/2022.9788055225029

Dukelska Park (Figure 3)

In contrast to the typical space of the central square, Dukelska Park is part of the public greenery of the outer edge of the central part of the old town. The revitalisation follows the successfully implemented plans for the restoration of the original green areas in the belt of the former walls (Na Sadech Park) and the larger forest park loosely connected to the wider city centre to the south-east. The revitalisation of Dukelska Park is part of the development of the city's blue-green infrastructure under the Water in the City banner, which aims to connect the public green spaces and watercourses that surround the entire urban conservation core. These areas are also part of the city's rapidly developing transport infrastructure focused on personal transport in the form of cycling and the increasingly popular use of electric scooters. The revitalisation plan for Dukelska Park is thus based mainly on the restoration of green spaces and the separation of pedestrians and cyclists.

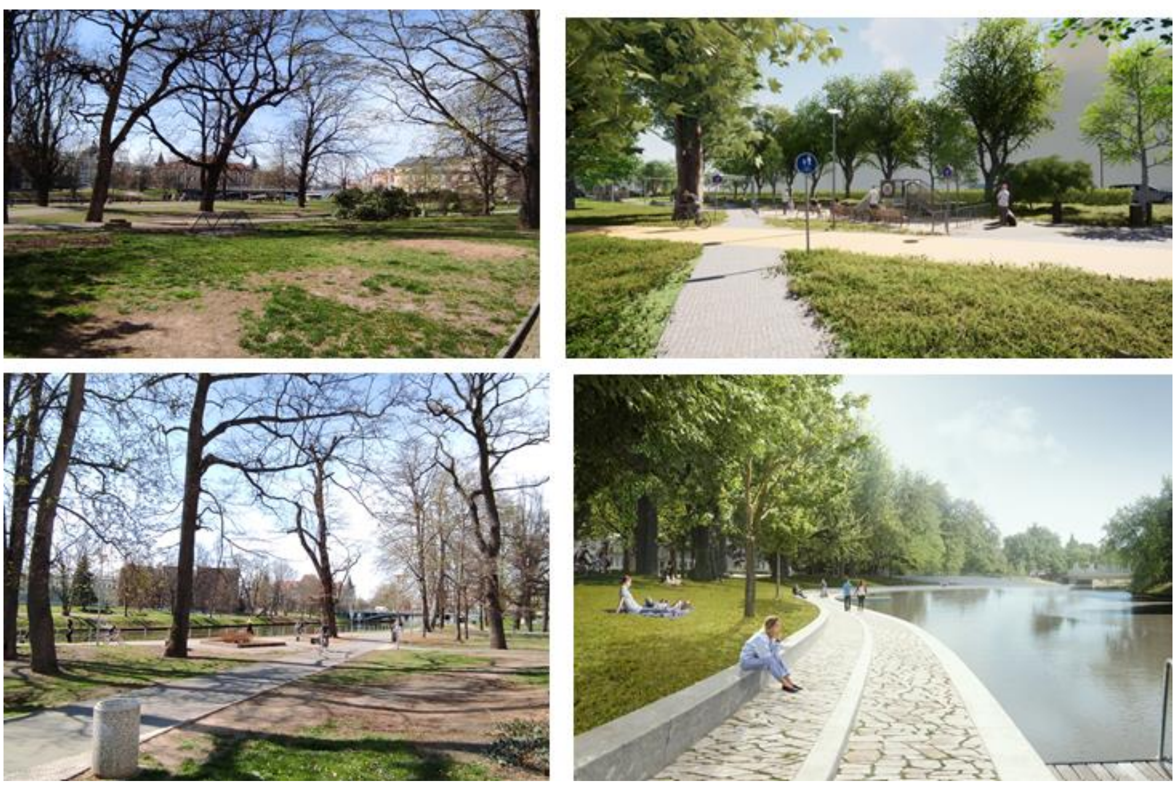


Figure 3 Dukelska park – actual state and planned revitalization (Park Dukelska, 2022)

Given the presence of the main cycle route, the requirement was to maintain both routes. The restoration of the park greenery consists in the removal of old dangerous trees, mainly hollowed out fir trees and old bushes. This removed greenery will be replaced with new trees. During the revitalisation of the park the rusty railings along the river will be removed. Another part of the park restoration is the construction of a new playground and new facilities for gathering and relaxation. There were several projects for the revitalization, but the concept presented by the Rusina Frei Company was ultimately selected. These concepts were selected through a competitive process in 2021 and the first citizen meetings were also held at this time. Currently, as part of the revitalization, old hazardous foliage has been removed

After comparing the two designs, a summary table (Table 1) was created comparing the changes that the areas in question are to undergo and what activities must be used to revitalize both types of public spaces.

Table 1 Comparison of the revitalisation activities in both places

	Premysl Otakar II. Square	Dukelska park
Adjustment of traffic intensity	✓	✓
Adjustment of parking spaces	✓	x
Adaptation and completion of urban furniture	✓	✓
Creating conditions for sport/recreation	x	✓
Creating conditions for relaxation / gastronomy	✓	x
Addition of water elements	x	✓
Access to water bodies	x	✓
Replenishment of growing greenery	x	✓
Replenishment of decorative greenery	✓	✓

It is clear from the summary that in the case of public space in the form of large paved areas (similar to the Premysl Otakar II. Square site), the focus is mainly on commercial activities and modification of conditions for these activities (parking options, reduction of road capacity for transit traffic, etc.). The designers are particularly concerned with the issue of making the environment more attractive for potential investors and traders and with the possibility of making the environment more attractive, especially for leisure activities related to gastronomy and shopping. Aspects of blue-green infrastructure are completely neglected and in practice these elements are added only on a very limited scale, mainly in the form of potted flowers that can be moved and replaced. The water component (in this case represented by the presence of a central fountain) is only supplemented in the form of small design misters. An example of a similar concept can also be found in the town of Hostomice, where directly in the tender documentation for the revitalisation project the sentence "The revitalisation will not, however, mean a radical transformation of the square from an urban planning point of view, rather it will be about highlighting the functions that are perceived as positive and, on the contrary, eliminating the functions that are perceived as negative" (Hostomice City, 2022). Among the larger cities in the Czech Republic, a similar approach can be mentioned in the municipality of Melnik or the recently completed part of the revitalisation of Wenceslas Square in Prague. In contrast, the councillors of the city of Jihlava took a conceptually different path (Jihlava City, 2022), where, in an architectural competition, virtually all the design translators supported the presence of green infrastructure directly in the central space of the square, in the form of mature tree vegetation that will provide sufficient shade and background for residents and visitors. However, this concept is rather unique in the environment of historic cities. The fact that central spaces in villages tend to be protected on grounds of historical value and conservation also argues against the use of this concept. The city of České Budějovice has already had experience with this type of revitalisation, as can be demonstrated by the changes that one of the most important pedestrian zones in the city, Lannova Street, has undergone, where the original traffic artery has over time become a modern shopping avenue, unfortunately again without significant elements of blue-green infrastructure, where most of the water features and greenery are concentrated only in small isolated islands at both ends of the mentioned street.

As far as the revitalisation of the park area is concerned, there is a virtually expected trend for revitalisation to focus mainly on the issue of improving the condition of the vegetation, addressing the health of the old tree vegetation and replacing inappropriate park landscaping with more modern and newer features. What makes the revitalisation of Dukelska Park unique is the involvement in the Water in the City activity, where the aim is to connect the landscaped riverbed to the parkland and make the shoreline more accessible and open to passers-by. This concept is familiar from many locations where park landscaping is immediately adjacent to riverbanks. Examples are cities such as Prague, Brno, or world capitals such as Passau, Linz, London, or Paris. The architects of Passau were also inspired by these concepts. Another area that this revitalisation has to address is the addition of elements for recreational and sporting activities, which is unusual in a park of such a small scale, and it was quite a challenge for the designers to fit all the elements into the park area. However, this was an absolute necessity, not only because of the heavily urbanised surroundings, but also because of the proximity of the primary school, the secondary industrial school and the kindergarten and nursery school, where the pupils of these schools use the park for various activities related to teaching and leisure time. This phenomenon is also related to the issue of traffic, which is not a standard part of the revitalisation of green infrastructure elements in cities. Dukelska Park is located on the transit route of the urban cycle path, which connects the southern residential areas of the city with the centre and further with the areas of collective housing and the university in the north-western part of the city. However, due to the sparse network of paved roads in the park area, there are often collisions between users of the cycle path and pedestrians, e.g., children and dog walkers. Given the limited capacity of the park, this challenge is also quite crucial for the architects and is quite unique in the scale of similar park areas. It was inspired by the revitalisation of the nearby Na Sadech Park area, where this problem was solved by two parallel roads on both sides of the park area, thus separating the routes for both user groups.

RQ2:

The second task of this study is to address the issue of the views of users of the revitalised areas on the current state of the environment and on the upcoming changes within the newly developed proposals. As described in the methodology individual respondents were asked five basic questions. The answers to each question will be presented separately for each of the areas under consideration.

1. How do you perceive the current state of the assessed area

a) In the case of the central square, the well-known phenomenon of conservatism in spatial planning was fully manifested by the individual respondents. Like what Atkinson and Moon (1994) describe in their publication, the inhabitants of any part of an urbanised area are used to what is in front of their eyes daily and are practically not open to accept any change, even when presented with proper argumentation and historical context, with few exceptions. A similar phenomenon was observed during the questionnaire survey in the central Premysl Otakar II. Square. The town's inhabitants, business users and visitors agree that the square in its current form is unique (especially because of its regular shape with an uninterrupted area of over 1 ha and the centrally located Baroque fountain) and is an attraction for all its users. Virtually no changes are required in its appearance and the internal organisation of the area.

b) In the case of Dukelska Park, the opinion is not so clear, and the users of the area do not clearly agree on the need to maintain the current form of the park. Certainly, in the case of the guided interviews, opinions are also expressed that correspond to similar case studies such as those described by Colomb and Tomaney (2021), where users refer to the fact that the area has been used in the same way for a long time and they remember it practically unchanged, e.g. from the time of their youth, but many users see the need for change especially with regard to safety (danger of falling trees and branches or safety of traffic on the cycle and pedestrian path). While in the central square area the conservatism of the users is shown in almost 100 % of cases in the evaluation of Dukelska Park, this is more of a minority opinion of rather older users of the park (about 15 %). Especially the younger population sees the need for change just regarding safety.

<u>2. How do you perceive the traffic situation (operation of cars / passenger transport by bike or scooter) and possibilities for parking plots</u>

a) The perception of the traffic situation in the central square is very contradictory among the inhabitants and users of the area. It is not possible to trace a clear prevailing opinion in the answers of the different groups. On the question of transit traffic through the square, the majority of respondents agreed that transit traffic should be maintained in order to be able to enter and exit the ring road around the perimeter of the square. The architects' ambitious plan to make it impossible to drive around the entire area, and the desire to reduce traffic to only two of the four sides of the plaza and to address the surrounding areas through retractable bollards only at certain times of the day, was opposed by virtually all residents and tenants of surrounding properties. Similarly, the issue of parking in the subject areas is perceived by residents and occupiers of adjacent properties. This group would like to see 100 % of all parking spaces retained, irrespective of other public interests in the form of recreational areas or green infrastructure areas of the town, and their use restricted to selected groups of residents who have very close links to properties around the assessment areas, to the exclusion of virtually all other users of parking spaces. Similar experiences are described in e.g., Clements (2019) However, this view is opposed by an equally large group of residents who do not have such a close connection to the central square but use e.g., the adjacent shopping and cultural facilities or nearby gastronomic establishments. The behaviour of these public space users is also characterised in the model solution provided by Guo et al. (2013). While these public space users agree with the first group on the need to make the whole area of the square available for traffic, they also demand the preservation of the possibility to use paid parking spaces anytime and anywhere. There is little support for the original plan to exclude traffic from the centre, following the example of nearby Austrian and German border towns.

b) The traffic situation around revitalization of the park area does not address the issue of car traffic or parking spaces at all but focuses on collision situations of pedestrians and individual traffic

 https://doi.org/10.15414/2022.9788055225029

in the form of cycling. In recent years, the new phenomenon of electric scooters has also come to the fore, particularly in the form of shared scooters. In the guided interviews, virtually all respondents agree on the need to address the traffic situation in the area, particularly regarding the safety of children attending nearby junior schools. What individual respondents disagree on is the possibility of traffic regulation. The views of the individual respondents are closely related to the mode of transport preferred by the individual. Respondents, mainly older residents who use the park for walking and often for dog walking, prefer to divert the cycle path completely away from the park area, or a compromise solution with a cycle route on the outer edge of the park area. Respondents who, on the other hand, use the park only for transit on the bike path also prefer to separate the pedestrian and transit areas, but for the purposes of the bike path they would prefer the most direct and shortest route possible, motivated by time savings. This issue, accurately reflecting the survey results, is also aptly summarized in Campos-Sánchez et al. (2019).

3. What are the possibilities of living in the assessed area (shopping, gastronomy, culture, sports) and which part needs to be changed in this area

a) Given that the area of the square is in the heart of the urban core, the residents, and users of the area experience virtually no serious deficiencies related to leisure activities in the area. Minor differences can be found in the interviews with the operators of unit shops and catering establishments. They mainly agree that the supply is limited by the previously described traffic phenomenon. This phenomenon is described by many authors e.g., Parmar et al. (2020). The business respondents argue that most potential customers are not willing to walk to the outlets and prefer to choose competing outlets with self-parking. This so-called 15-minute phenomenon is also described, for example, in the study by Moreno et al. (2021). Interestingly, the same respondents who argue for the need for very close parking for customers in the previous question on parking options wanted to preserve parking spaces in the downtown for the unqualified use of residents and business owners or tenants, not for the use of visitors. Some of them even cited in their arguments on traffic to prevent these potential visitors from entering the central plaza area and adjacent streets.

b) The issue of leisure activities in the case of the revitalisation of the park area is practically one of the main points of the Dukelska Park revitalisation. This is one of the basic requirements of the revitalisation project. The respondents, again according to the age structure, agree on the need to create facilities for playgrounds, sports opportunities but also possibly for recreation in connection with the riverbank. Virtually none of the respondents see the need to establish facilities in the form of catering or social facilities such as public toilets. Opinions on the various elements to be implemented at the site vary, as already indicated, according to how the respondents use the park area. What is considered necessary by mothers with children or the younger generation (i.e., areas for sports or children's play) is often considered distracting by older citizens and especially seniors, but they also mostly see these areas as important for e.g. the needs of nearby schools.

4. How do you perceive urban furniture in the studied areas

a) The issue of urban furniture is perceived as completely negligible in the centre. Respondents agree that there is no need to add any additional elements in the form of benches, lighting elements, rubbish bins, etc. in this area. The main argument against these elements is mainly the concern of residents that if any resting places were to be placed beyond the existing benches near the central fountain, it would lead to the gathering of maladjusted residents and homeless people. Virtually all respondents, regardless of their connection to the site, agree that elements of the city's furniture are often damaged and dirty, including the sheltered spots on the edges of the square. An interesting point of conflict within the interviews regarding the elements located in the square and surrounding streets is the use of various advertising banners and signs. This issue is evaluated exactly opposite by the group of businessmen who use the surrounding buildings for commercial activities and the ordinary users of the city centre. Azumah et al. (2021) describe a similar view of this problematic phenomenon in their study.

b) The issue of the location of urban furniture in the revitalized park area is very crucial, unlike the first area under consideration. Virtually all respondents except for a few residents who use the area only as a transit space agree on the need to significantly improve the amenities of the park area compared to the current situation. Currently, there are only a few benches in poor condition and a few trash cans. The lighting fixtures on site are also inadequate and partially non-functional. This fact leads virtually all the respondents to the conclusion that this part of the park area needs to be considerably strengthened, especially in connection with the newly proposed recreation and sports areas and children's playgrounds. Particularly older residents and then women, regardless of age, identify public lighting as a very important element, which would increase the safety of the park area, especially at night and in winter during low light conditions. Residents argue mainly from the experience of other park areas in České Budějovice, where the safety situation has improved in some parts of the areas with the introduction of better lighting.

5. What do you perceive the so-called blue-green infrastructure in the locality (representation of vegetation, its condition, possibilities of water resources, possibilities of cooling in the summer months...)

a) The area of the square for the use of the blue-green infrastructure is strongly limited by the monument protection of the paved central part of the area which currently prevents any earthworks in this part, including the planting of tree vegetation. Conversations with the users of this central area were therefore conducted at a rather hypothetical level. However, an unexpected result of these interviews was the discovery that practically even if the monument protection were lifted and there was a possibility of greening the central area of the square, most residents and users (approximately 85 %) would not welcome this and would be against it. The argument most often cited is the issue of conservation as described by Atkinson and Moon (1994), where there are virtually no longer any survivors of the tree vegetation that still existed in the early 1920s. Century originally lined the central fountain. The second argument is the possibility that the vegetation and shaded areas would attract the attention of the homeless and vandals. In this context, the possible Water Infrastructure features have also been mentioned, but the argument against them is virtually the same and the residents are not convinced of their necessity even by the arguments in the form of thermal images from the summer season. Virtually all interviewees agree that it is better not to visit the square area on these hot days than to change it in any way.

b) In the park area, the issue of blue-green infrastructure is completely different. The parkland is traditional in the area and will be maintained in the future. There are contradictions on only two of the points addressed in this issue. The first point is the issue of tree revegetation, and the second issue is the accessibility of the riverbank and the connection of the park area to the Water Level. On the issue of restoration of tree vegetation, the phenomenon of traditionalism (Colomb and Tomaney, 2021) has again manifested itself, with older generations in particular clinging to the preservation of trees that they often know from the time they were planted. This argument was most often counterbalanced by the fact that revegetation and establishment of new areas will only give way to those individuals that are not in good health or, due to their age and species composition, there is no prospect of long-term involvement in the restored parkland. The second controversial issue, namely the accessibility of the water surface, has been a topic of discussion in Ceske Budejovice, especially on social networks, since the Water in the City initiative was launched, when the city administration decided to connect the terrestrial part of the city with the watercourses that cross the city. The main argument I in the described questioning is the safety of the users of the areas. A significant group of residents (70 % of the respondents) is concerned about accidents and potentially dangerous situations, especially for young children, when the riparian edge will be loosely connected to pavement areas and rest areas. The concerns of these respondents have been partially satisfied by moving the play elements of the playgrounds and sports fields to parts of the park that are not directly adjacent to the river. Consequently, Part I of these respondents agreed with the remaining group that the accessibility of water features, particularly in the summertime, can be a welcome benefit to park users.

Conclusions

The revitalization of public spaces is an integral part of city development. Because of many different opinions there is necessity to look for compromise between progress and original state and make dialog with citizens.

Acknowledgment

This study was prepared in cooperation with company of urban planning StudioMap and city of Ceske Budejovice.

References

ACT ON LOCAL FEES No. 565/1990 Coll.

ACT ON MUNICIPALITIES No. 128/2000 Coll.

ATKINSON, R. – MOON, G. 1994. Urban Planning under Conservatism. Urban Policy in Britain. Public Policy and Politics. Palgrave: London. 306 p.

AZUMAH, D. M. Y. et al. 2021. Visual Pollution Through Excessive Outdoor Advertisements. In: Marketing Communications in Emerging Economies, Volume I, Cham: Palgrave Macmillan. 193-228.

CAMPOS-SÁNCHEZ, F. et al. 2019. Evidence of green areas, cycle infrastructure and attractive destinations working together in development on urban cycling. Sustainability, 11.17. 4730.

CARMONA, M. 2021. Public places urban spaces: The dimensions of urban design. Routledge. 672 p. ISBN 978-1856178273.

CITY COUNCIL Ceske Budejovice. 2022. Access from: www.c-buedjovice.cz. [Cited 20.4.2022].

CLEMENTS, R. 2019. Parking and the City. Planning Theory & Practice, 20:3. 456-465.

COLOMB, C. – TOMANEY, J. 2021. Spatial planning, nationalism and territorial politics in Europe. Regional Studies, 55:1. 101-114.

CUDNY, W. 2016. Festivalisation of urban spaces: Factors, processes and effects. New York: Springer, 165 p. ISBN 978-3-319-31997-1.

CZECH STATISTICAL OFFICE. 2022. Access from: www.czso.cz. [Cited 20.4.2022].

GUO, L. et al. 2013. Modeling parking behavior under uncertainty: a static game theoretic versus a sequential neo-additive capacity modeling approach. Networks and Spatial Economics, 13.3. 327-350.

HOSTOMICE CITY. 2022. Access from: https://www.hostomice.cz/Revitalizace-namesti. [Cited 20.4.2022].

JIHLAVA CITY. 2022. Access from: https://www.cka.cz/cs/souteze/vysledky/revitalizace-masarykova-namesti-v-jihlave. [Cited 20.4.2022]

LOTFI, H. – MOUSAZADEH, H. 2020. Restoration of open spaces around urban rivers and their role in the quality of life and security of citizens (Case study: Alangdareh River, Gorgan). Human Geography Research, 52.1. 199-219.

MADANPOUR, A. 2006. Public Spaces of European Cities. Nordisk Arkitekturforskning, 1. 7-16.

MORENO, C. et al. 2021. Introducing the "15-Minute City": Sustainability, resilience and place identity in future post-pandemic cities. Smart Cities, 4(1). 93-111.

NISSEN, S. 2008. Urban Transformation: From Public and Private Spaces to Spaces of Hybrid Character. Sociologický časopis / Czech Sociological Review, 44 (6). 1129-1149.

Park Dukelska. 2022. Access from: www.dukelska-cbudejovice.cz. [Cited 20.4.2022].

PARMAR, J. et al. 2020. Study on demand and characteristics of parking system in urban areas: A review. Journal of Traffic and Transportation Engineering, 7.1. 111-124.

SAN JUAN, C. et al. 2017. Restoration and the city: the role of public urban squares. Frontiers in psychology, 8. 2093.

 https://doi.org/10.15414/2022.9788055225029

SIEBEL, W. – WEHRHEIM, J. 2003. Security and the Urban Public Sphere. Deutsche Zeitschrift für Kommunalwissenschaften 42/1. 19-46.

SUBIZA-PÉREZ, M. 2021. Exploring psychological restoration in favorite indoor and outdoor urban places using a top-down perspective. Journal of Environmental Psychology, 78. 101706.

Contact address: Ing. Vendula Moravcova, University of South Bohemia in Ceske Budejovice, Faculty of Agriculture and Technology, Department of Landscape Management, Studentska 1668, 37005 Ceske Budejovice, Czech Republic, +420 728 647 401, moravv@fzt.jcu.cz.

https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 25.04.2022
Received in revised form 24.05.2022
Accepted 25.05.2022

A REVIEW OF HUMIC SUBSTANCES AS BIOSTIMULANTS IN THE CULTIVATION OF ROOT VEGETABLES

Júlia FABIANOVÁ[1], Miroslav ŠLOSÁR[1]

[1]Slovak Agriculture University in Nitra, SLOVAKIA

Abstract

Humic substances are obtained by humification of dead organic materials. These substances have stimulating effects on horticultural crops, thus ensuring yield optimization. The potential of humic substances in agricultural practice has been studied in many studies. The aim of the research is to reveal the effectiveness, mechanisms and side effects on the selected groups of agricultural and horticultural crops. In the literature review, we present the results of research tasks that investigated the relationship between humic substances and root vegetables. Most studies observed that humic substances have positive effects on increasing yield, as well as quality (vitamin C, carotenoids, content B, Mn, Zn, Fe, N, P, K, carbohydrates, refractometric dry matter, proteins) of cultivated species. Humic substances can also be used in seed treatment methods or as substances capable of binding heavy metals in the soil with favorable results.

Keywords: humic substances, biostimulant, root vegetable

Introduction

Root vegetables belong to the most important groups of vegetables in the world. Within cultivating technology of this group, it is possible to use a high degree of mechanization, which allows the grower to reduce the degree of manual work. These species are suitable for ready-to-eat consumption but also for processing. The most important and grown species include carrot, parsley, celery, beetroot, but also lesser-known species as radish, rutabaga, turnips, black salsify etc. (Petříková et al. 2012).

In an effort to ensure a sufficient supply of food for the human population, the agricultural sector is looking for ways how to increase the production of agricultural crops with regard to human health and the environment. From 2000 to 2018, the population grew by 24.2 %. However, vegetable production in this period increased by only 17.2 % (FAO 2022). The use of industrial fertilizers can lead to the optimization of the produced amount of vegetable crops, but their use has a significant negative effect on the environment and human health. Industrial fertilizers used in conventional and integrated vegetable production systems contain phosphates, nitrates, ammonium, and potassium salts which are considered as a potential source of natural radionuclides and heavy metals. The use of these fertilizers can cause soil, water and atmosphere contamination, and the accumulation of heavy metals in plants which are part of the food chain (Savci 2012). In the last three decades, several technological innovations have been proposed to increase the sustainability of agricultural production systems through a significant reduction in synthetic agrochemicals such as pesticides and fertilizers. The use of natural plant biostimulants would be a promising environmentally friendly innovation (Colla and Rouphael 2015).

Biostimulants are products stimulating the natural processes of plants. They are not considered as a source of nutrients because they are supplied to the soil in small quantities. The stimulation of crop growth and productivity after application of plant biostimulants is caused by effect of bioactive substances on primary or secondary metabolism, leading to a wide range of biochemical, physiological, and molecular reactions (Rouphael and Colla 2020). It was found that biostimulants affect various metabolic processes, such as photosynthesis, respiration, ion uptake and nucleic acid synthesis. They further increase nutrient availability, improve plant metabolism, water retention, and increase chlorophyll production, affect soil properties and the activity of soil microorganisms etc. (Shubha et al. 2017). Several authors divide biostimulants into two basic categories: microbial and non-microbial biostimulants. These two groups include other subcategories that have been defined by their main effective composition:

- *Microbial biostimulants* - humic and fulvic acids, useful microorganisms, N-fixing bacteria (*Rhizobium, Azotobactera, Azospirillum*) arbuscular mycorrhizal fungi.
- *Non-microbial biostimulants* - hydrolysates of animal and plant proteins, seaweed extracts, Si, chitosan, inorganic compounds, phosphite (Du Jardin 2015; Gómez-Merino and Trejo-Télez 2015; Han et al. 2021 Pichyangkura and Chadchawan 2015; Rouphael and Colla 2020).

Humic substances are considered as main organic constituents of soils and sediments (Schintzier 1978). Sources of these substances are degraded and decomposed biological materials. From a chemical aspect, they are substances composed of small molecules linked by weak bonds (Piccolo 2001). They are characterized by being extremely resistant to degradation (Stevenson 1994). The molecular structure of these substances is markedly different from any group of soil compounds (García et al. 2019). Humic substances are composed of structures with hydrophobic and hydrophilic properties, fulvic acids are defined as associations of small hydrophilic molecules; humic acids are formed by associations of predominantly hydrophobic compounds (Canellas et al. 2015), which determine, for example, solubility and susceptibility of humic substances to biodegradation and affect their sorption potential (Kobierski et al. 2018).

Humic substances are divided into the three groups because of their respective solubility in acidic/alkaline medium:

- humins - insoluble in water,
- humic acids - soluble in medium with pH> 2,
- fulvic acids - soluble in water (Lehmann and Kleber 2015).

Humic substances (HS), including fulvic and humic acids, are major components of organic carbon in the soil and aquatic ecosystems, and probably belong to the most abundant organic molecules (Pédro et al. 2010). Due to their high nutrient content, they are the main components of organic fertilizers. However, due to the stabilization in humus-clay aggregates and their naturally low rate of mineralization in the soil, they are not suitable as a direct source of nutrients for plants. Thus, the increased plant growth in response to the addition of HS does not appear to be directly related to the nutrient content of the HS, but to its interactions with plant cells. They play a key role in soil because they are important in many chemical reactions of soil complex (Stevenson 1994). They significantly affect plant functions, namely the bioavailability of nutrients, the processes of carbon and oxygen exchange between the pedosphere and the atmosphere, or the transformation and transport of toxic substances (Piccolo and Spiteller 2003). In addition, humic substances in soil affect physiology of plants, composition and activity of soil microorganisms (Varanini and Pinton 2000).

Plant responses to humic substances are affected by:

- the plant species,

 https://doi.org/10.15414/2022.9788055225029

- ontogenetic phase of plant development,
- method and speed of HS application,
- source HS,
- prevailing management and environmental conditions (Trevisan et al. 2010).

The activity of humic substances depends on their structure. Humic and fulvic acids, characterized by a great diversity of functional groups, are considered as the most reactive humic substances, most of which are carboxyl groups (-COOH) and phenolic hydroxyl groups (-OH) (Pédrot et al. 2010). The electron transfer capacity (ETC) of soil HS is mainly dependent on the type and abundance of redox-active functional groups in their structure (Xi et al. 2018). Due to the presence of oxygen functional groups, HS improves plant nutrition by forming complex, stable bonds with micro- and macronutrients (Shah et al. 2018).

The supramolecular arrangement of HS promotes the properties of bioactivity, which results in the release of bioactive compounds such as phytohormones and derivatives of phytohormonal compounds. It can bind to plant cell receptors, thus stimulate plant growth and stress tolerance responses (Canellas and Olivares 2014). In 1998, Muscolo, Cutrupi and Nardi in their study published results which indicate that IAA (indole-3-acetic acid) is present in humic substances. Subsequently, Muscolo et al. (2007) state in their study that humic fraction with low relative molecular mass (Mr<3,500 Da), like IAA, interacts with cellular membranes in carrot cell cultures. Trevisan et al. (2010) explain that the „auxin activity" of humic substances mostly induces the formation of lateral roots. Already in 1990 Chen and Aviad observed that humic substances in nutrient solutions result in an increase in root length and stimulate the development of secondary roots. Pizzeghello et al. (2013) in their work demonstrate that humic substances also contain IPA (isopentenyladenosine) in physiologically active concentrations.

Material and methods

Based on many studies about activity of mechanisms of humic substances, several experiments have been realized on many species of vegetable. In the overview, root vegetable species were selected and the effect of humic substances or biotimulants based on humic substances on their qualitative and quantitative parameters.

 https://doi.org/10.15414/2022.9788055225029

Results and discussion

Fertilizers, adjuvants and biostimulants in horticulture could be applied in a different way. Dinu, Soare and Dumitru (2012) observed the reaction of carrot production to seeds soaking (6/12 hours) in humic acids solution. The total yield was increased about 14.7% (control=seeds moistened in water for 6 hours). 12 hours soaking proved to be more suitable; in this variant, yield was increased by 26.4% against to control variant.

Farag, Hussein and Hassan (2014) studied effect of priming treatment by humic acid and potassium silicate on improving stress tolerance to stress factor, specifically frost. Soaking was turned out to be effective. Seed soaking in humic acids and Na_2SiO_3 caused relief of freezing stress, stimulation of celery growth and proliferation.

El-Helaly (2018) states that foliar application of humic and fulvic acids was showed by significant increase in carrot yield. The effect of humic acids compared to fulvic acids was proved to be more effective. Fabianová et al. (2021) state that after the application of Agriful biostimulant, based on humic substances, carrot yield was also increased, as well as the content of carotenoids and vitamin C. The share in the non-marketable quality class was significantly decreased compared to the control variant. In Tursun, Akinci and Bozkurt's (2019) experiment, the application of humic acids, which were part of the Hoagland-Arnon solution with added boron, was not resulted in the increase of parsley growth parameters. However, this combination caused a significant increase in the content of microelements: B, Mn, Zn and Fe in the leaves.

On the contrary, El-Sayed, Hellal and Mohamed (2014) states that foliar application of humic substances in combination with super biophosphate on radish plants had statistically significant effect on fresh and dry weight of root and shoot, root length and diameter, as well as nutrient content and uptake. Similarly, according to Aisha et al. (2014), the growth properties, root yield and the proportion of proteins, N, P, K, carbohydrates and Fe content in turnip root tissues was increased due to the increasing dose of humic acid.

Humic substances are characterized by ability to bind metal ions, oxides, hydroxides, minerals and organic compounds (Trevisan et al. 2010). Therefore, they significantly affect the mobility and transport of metallic and organic contaminants in soil and water (Pédrot et al. 2010). Ondrasek, Rengel and Romic (2018) states that humic acid application caused higher uptake and distribution of trace metals (Cd, Zn, Cu a Mn,) in radish root.

Conclusions

Humic substances have been shown to be effective for optimizing yield and quality of root vegetables. They are suitable and effective in seed treatment, as well as in foliar application or drip irrigation. From the performed experiments, it is resulting that humic substance application increases the plant resistance to abiotic stresses. Humic substances can ensure an increase in crop-forming and quality parameters for carrots, parsley, celery, radish and turnip. It can also be argued that humic substances have remedial effects on contaminated soils.

Acknowledgment

KEGA 018SPU-4/2020 Development of Theoretical Knowledge and Practical Skills of Students for Teaching of Subject Vegetable Production.

References

AISHA, H. A. et al. 2014. Effect of various levels of organic fertilizer and humic acid on the growth and roots quality of turnip plants (Brassica rapa). In Current Science International [online], vol. 3, no.1, pp. 7-14 [cit. 2022-02-18]. Available on internet: https://www.curresweb.com/csi/csi/2014/7-14.pdf.

CANELLAS, L.P. – OLIVARES, F.L. 2014. Physiological responses to humic substances as plant growth promoter. In Chemical and Biological Technologies in Agriculrture [online], vol. 1, pp. 3 [cit. 2022-03-10]. Available on internet: https://chembioagro.springeropen.com/articles/10.1186/2196-5641-1-3.

CANELLAS, P. L. et al. 2015. Humic and fulvic acids as biostimulants in horticulture. In Scientia Horticulturae [online], vol. 196, pp. 15-27 [cit. 2022-02-14]. Available on internet: https://doi.org/10.1016/j.scienta.2015.09.013.

CHEN, Y. – AVIAD, T. 1990. Effects of humic substances on plant growth. Humic substances in soil and crop sciences: Selected readings, Madison: Soil Science Society of America, pp. 161-186.

COLLA, G. – ROUPHAEL, Y. 2015. Biostimulants in horticulture. In Scientia Horticulturae [online], vol. 196, pp. 1-134 [cit. 2022-02-07]. ISSN : 0304-4238. Available on internet: DOI: 10.1016/j.scienta.2015.10.044.

DINU, M. et al. 2012. Effect of carrot seed wetting with biostimulating substances on crop production in early field. In Biologie Horti. Techno. Ingeria mediului [online], vol. 17, pp. 165-170 [cit. 2022-02-22]. Available on internet: https://www.researchgate.net/profile/Dinu-Maria-2/publication/291321204_Effect_of_carrot_seed_wetting_with_biostimulating_substances_on_crop_production_in_early_field/links/56ab1ac408aed814bde714c9/Effect-of-carrot-seed-wetting-with-biostimulating-substances-on-crop-production-in-early-field.pdf.

DOU, S. et al. 2020. Are humic substances soil microbial residues or unique synthesized compounds? A perspective on their distinctiveness. In Pedosphere [online], vol. 30, no. 2, pp. 159-167 [cit. 2022-02-13]. ISSN 1002-0160. Available on internet: https://doi.org/10.1016/S1002-0160(20)60001-7.

DU JARDIN, P. 2015. Plant biostimulants: Definition, concept, main categories and regulation. In Scientia Horticulturae [online], vol. 196, pp. 3-14 [cit. 2022-02-07]. ISSN 0304-4238. Available on internet: https://doi.org/10.1016/j.scienta.2015.09.021.

EL-HELALY, M. A. 2018. Effect of foliar application of humic and fulvic acids on yield and its components of some carrot (Daucus carota l.) cultivars. Journal of Horticultural Science & Ornamental Plants [online], vol. 10, no. 3, pp. 159-166 [cit. 2022-02-22]. Available on internet: DOI: 10.5829/idosi.jhsop.2018.159.166.

EL-SAYED, S. A. A. et al. 2014. Effect of Humic acid and phosphate sources on nutrient composition and yield of Radish grown in calcareous soil. In European International Journal of Science and Technology [online], vol. 3, no. 9, pp. 168-177 [cit. 2022-02-26]. Available on internet: https://www.eijst.org.uk/images/frontImages/gallery/Vol._3_No._9/18._168-177.pdf.

FABIANOVÁ, J. et al. 2021. The effect of soil biostimulant agriful on the selected quantitative and qualitative parameters of carrot (daucus carota subsp. Sativus (hoffm.) Arcang.). In Slovak Journal of Food Sciences [online], vol. 15, pp. 1120-1127 [cit. 2022-02-26]. Available on internet: https://doi.org/10.5219/1696.

FARAG, I. A. et al. 2014. Improvement Seedling Growth Of Celery (Apium graveolens L.) Using Humic Acid, Potassium Silicate And Low Gamma Irradiation Doses. In Zagazig Journal of Agricultural Research [online], vol. 41, no. 4, pp. 737-745 [cit. 2022-02-16]. Available on internet: https://inis.iaea.org/search/search.aspx?orig_q=RN:46055294.

GARCÍA, A. C. et al. 2019. Structure-property-function relationship of humic substances in modulating the root growth of plants: A review. In Journal of Environmental Quality [online], vol.

48, pp. 1622-1632 [cit. 2022-02-14]. Available on internet: https://doi.org/10.2134/jeq2019.01.0027.

GÓMEZ-MERINO, F. C. – TREJO-TÉLLEZ, L. I. 2015. Biostimulant activity of phosphite in horticulture. In Scientia Horticulturae [online], vol. 196, pp. 82-90 [cit. 2022-02-13]. ISSN 0304-4238. Available on internet: https://doi.org/10.1016/j.scienta.2015.09.035.

HAN, X. et al. 2021. Effects of phosphite as a plant biostimulant on metabolism and stress response for better plant performance in Solanum tuberosum. In Ecotoxicology and environmental safety [online], vol. 210, pp. 111873 [cit. 2022-02-11]. ISSN 0147-6513. Available on internet: https://doi.org/10.1016/j.ecoenv.2020.111873.

KOBIERSKI, M. et al. 2018. Humic substances and aggregate stability in rhizospheric and non-rhizospheric soil. In J Soils Sediments [online], vol. 18, pp. 2777-2789 [cit. 2022-02-15]. Available on internet: https://doi.org/10.1007/s11368-018-1935-1.

LEHMANN, J. – KLEBER, M. 2015. The contentious nature of soil organic matter. In Nature [online], vol. 528, no. 7580, pp. 60-68 [cit. 2022-02-15]. Available on internet: https://www.nature.com/articles/nature16069.

MUSCOLO, A et al. 2007. The auxin-like activity of humic substances is related to membrane interactions in carrot cell cultures. In Journal of Chemical Ecology [online], vol. 33, no. 1, pp. 115-129 [cit. 2022-03-04]. Available on internet: https://link.springer.com/article/10.1007/s10886-006-9206-9.

MUSCOLO, A. et al. 1998. IAA detection in humic substances. In Soil Biology and Biochemistry [online], vol. 30, no. 8-9, pp. 1199-1201 [cit. 2022-03-04]. Available on internet: https://d1wqtxts1xzle7.cloudfront.net/65785974/s0038-0717_2898_2900005-420210226-14311-kj5cav-with-cover-page-v2.pdf?Expires=1646916022&Signature=CW96xRiy8IVv0fi58HULPlED7JIXbr74wuNf2~VqLjxY-AKPkrfJxH9lDZ4kby~wP3n4rPoE2mtkPzWw0TfqqaMndc1yHtogeRmmM7xwb2E1vdPp6NqhHnapDIw3xV1cW3noGUejNmdtOUlSmKJLfWM0kzetEkruPTgDXJlH6tkwrN5QtN5wr8oI2BziMNu7BEsAIc53~xK5qthdnvfJke0qNIZhLComa9eug-UmwW70Neko7A6F4MzZVsiWbmQ407zhLnVcyd09fpexAqHiEwftpbDPnHN99vvS7NTeGhRlWz82wnW8AueFLawwKP-GKY8gZeAEe3ltjOUaNmNNyw__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA.

ONDRASEK, G. et al. 2018. Humic acids decrease uptake and distribution of trace metals, but not the growth of radish exposed to cadmium toxicity. Ecotoxicology and environmental safety [online], vol. 151, pp. 55-61 [cit. 2022-02-09]. Available on internet: https://doi.org/10.1016/j.ecoenv.2017.12.055.

PÉDROT, M. et al. 2010. Dynamic structure of humic substances: Rare earth elements as a fingerprint. In Journal of colloid and interface science [online], vol. 345, no. 2, pp. 206-213 [cit. 2022-02-15]. Available on internet: https://doi.org/10.1016/j.jcis.2010.01.069

PETŘÍKOVÁ, et al. 2012. Zelenina. Praha: Profi Press. 191 p. ISBN 978-80-86726-50-2.

PICCOLO, A. – SPITELLER, M. 2003. Electrospray ionization mass spectrometry of terrestrial humic substances and their size fractions. In Anal Bioanal Chem [online], vol. 377, pp. 1047-1059 [cit. 2022-03-04]. Available on internet: https://link.springer.com/article/10.1007/s00216-003-2186-5.

PICCOLO, A. 2001. The supramolecular structure of humic substances. In Soil science [online], vol. 166, no. 11, pp. 810-832 [cit. 2022-02-14]. Available on internet: https://journals.lww.com/soilsci/Abstract/2001/11000/THE_SUPRAMOLECULAR_STRUCTURE_OF_HUMIC_SUBSTANCES.7.aspx.

PICHYANGKURA, R. - CHADCHAWAN, S. 2015. Biostimulant activity of chitosan in horticulture. In Scientia Horticulturae [online], vol. 196, pp. 49-65 [cit. 2022-02-07]. ISSN 0304-4238. Available on internet: https://doi.org/10.1016/j.scienta.2015.09.031.

PIZZEGHELLO, D. et al. 2013. Isopentenyladenosine and cytokinin-like activity of different humic substances. In Journal of Geochemical Exploration [online], vol. 129, pp. 70-75 [cit. 2022-02-16]. Available on internet: https://doi.org/10.1016/j.gexplo.2012.10.007.

ROUPHAEL, Y. – COLLA, G. 2020. Biostimulants in agriculture. In Frontiers in plant science [online], vol. 11, pp. 40 [cit. 2022-02-07]. Available on internet: https://doi.org/10.3389/fpls.2020.00040.

SAVCI, S. 2012. An agricultural pollutant: chemical fertilizer. In International Journal of Environmental Science and Development [online], vol. 3, no. 1, pp. 73 [cit. 2022-02-07].

SCHNITZER, M. 1978. Humic substances: chemistry and reactions. In Developments in soil science [online], pp. 1-64 [cit. 2022-02-16]. Available on internet: https://doi.org/10.1016/S0166-2481(08)70016-3

SHAH, Z. H. et al. 2018. Humic substances: Determining potential molecular regulatory processes in plants. In Frontiers in plant science [online], vol. 9, pp. 263 [cit. 2022-03-07]. Available on internet: https://doi.org/10.3389/fpls.2018.00263.

SHUBHA, K. et al. 2017. Bio-stimulants: an approach towards the sustainable vegetable production. In Agriculturally important microbes for sustainable agriculture. Springer. Singapore, pp. 259-277. ISBN 978-981-10-5589-8.

STEVENSON, F. J. 1994. Organic forms of soil nitrogen. Humic Chemistry: Genesis, Composition, Reaction. New York: Wiley John., editor. pp. 59–95.

TREVISAN, S. et al. 2010. Humic substances biological activity at the plant-soil interface: from environmental aspects to molecular factors. In Plant signaling & behavior [online], vol. 5, no. 6, pp. 635-643 [cit. 2022-03-04]. Available on internet: https://doi.org/10.4161/psb.5.6.11211.

TREVISAN, S. et al. 2010. Humic substances induce lateral root formation and expression of the early auxin-responsive IAA19 gene and DR5 synthetic element in Arabidopsis. In Plant Biology [online], vol. 12, no. 4, pp. 604-614 [cit. 2022-03-04]. Available on internet: https://doi.org/10.1111/j.1438-8677.2009.00248.x.

TURSUN, T. et al. 2019. Determination of the effect of humic acid on growth and development parameters of parsley (Petroselinum sativum Hoffm.) grown in boron soil. In Notulae Botanicae Horti Agrobotanici Cluj-Napoca [online], vol. 47, no. 1, pp. 183-193 [cit. 2022-02-26]. Available on internet: https://doi.org/10.15835/nbha47111222.

VARANINI, Z. – PINTON, R. 2000. Direct versus indirect effects of soil humic substances on plant growth and nutrition. CRC Press: The rhizosphere, pp. 157-174. ISBN 9780429116698.

XI, B. et al. 2018. Responses of the electron transfer capacity of soil humic substances to agricultural land-use types. In RSC advances [online], vol. 8, no. 57, pp. 32588-32596 [cit. 2022-03-04]. Available on internet: DOI: 10.1039/C8RA04278K.

Contact address: Ing. Júlia Fabianová, Slovak University of Agriculture in Nitra, Horticulture and Landscape Engineering Faculty, Institute of horticulture, Tr. A. Hlinku 2, 949 76 Nitra, Slovakia, +421 917 373 587, xbedrichova@uniag.sk.

ARTICLE HISTORY:
Received 01.05.2022
Received in revised form 13.05.2022
Accepted 25.05.2022

ANTIBIOFILM ACTIVITY OF *SALVIA SCLAREA* ESSENTIAL OIL

Lucia GALOVIČOVÁ[1], Veronika VALKOVÁ[1,2], Petra BOROTOVÁ[1,2], Miroslava KAČÁNIOVÁ[1,3]

[1]Slovak Agriculture University in Nitra, SLOVAKIA

[2] AgroBioTech Research Centre, SLOVAKIA

[3]University of Rzeszow, POLAND

Abstract

The work aimed to evaluate the antimicrobial and antibiofilm activity of an essential oil *Salvia sclarea* against *Salmonella enterica*. Molecular profiles of biofilms on stainless steel and plastic surfaces after application of *S. sclarea* essential oil were evaluated using MALDI-TOF MS Biotyper. The essential oil showed only weak antimicrobial activity against gram-positive and gram-negative bacteria with 1.00-4.33 mm zones of inhibition. We detected mild to strong activity against yeast with zones of inhibition 5.33-10.00 mm. Mild activity with zones of inhibition 5.33 mm was detected against biofilm-producing bacteria. Based on the analysis of mass spectra and the constructed dendrogram, we found that the essential oil of *S. sclarea* affects the compactness of a polysaccharide matrix surrounding the bacteria in the form of a biofilm, thereby reducing their resistance, and disrupting the homeostasis of the biofilm. MALDI-TOF MS Biotyper was introduced as a suitable tool for biofilm analysis, which is a prerequisite for its use in food and clinical practice.

Keywords: MALDI-TOF MS Biotyper, biofilm, *Salvia sclarea,* antimicrobial activity

Introduction

The popularity of aromatic and medicinal plants is constantly growing due to increasing demand, as well as consumer interest in these plants for medicinal, culinary, and other anthropogenic uses. More and more informations are available on their health, food, and nutrition benefits (Falleh et al. 2020). The potential and benefits of aromatic and medicinal plants and their metabolites are confirmed. Many secondary metabolites are produced by these plants. Essential oils (EO) form a significant part of these metabolites (Hanif et al. 2019). EOs are volatile liquids that are obtained by an extraction from the aromatic plants. The extraction is performed by different methods depending on which part of the aromatic plant is processed (Sharma et al. 2021).

The genus *Salvia* is one of the most important and extensive genera of aromatic and medicinal plants of the Lamiaceae family and includes a large number of species widespread worldwide (Russo et al. 2013). Since ancient times, *Salvia sclarea* has been one of the most respected medicinal herbs originating from Mediterranean countries and is widely used in medicine and culinary (Durling et al. 2007), as well as in cosmetics, perfumery, and pharmaceutical industries (Kong, Zhang, Xiong 2010). Plants of this genus are known for their biological activities, such as antibacterial, antioxidant, antitumor, antidiabetic, antimicrobial, anxiolytic, sedative, and anti-inflammatory activities (Rajabi et al. 2014).

Salmonella is a genus of rod-shaped gram-negative bacteria belonging to the family Enterobacteriaceae (Su, Chiu 2007). The bacteria of the *Salmonella* spp. are intracellular pathogens and are considered one of the major foodborne pathogens worldwide. *Salmonella* infections are serious and can be life-threatening. Most of these infections are zoonotic, transmitted from healthy animal carriers to humans by consuming contaminated food (Jantsch, Chikkaballi, Hensel 2011).

The bacterial biofilm is formed by bacterial cells grouped into a structural population that is irreversibly attached to abiotic and biotic surfaces due to incorporation into an extracellular matrix self-generated using polymeric substances (Nahar et al. 2018). Biofilm formation is thought to increase the ability of pathogens, including *S. enterica*, to survive and remain in the environment (Low et al. 2019). In the food industry, the biofilms can be formed on food as well as surfaces that come into contact with food. The issue of biofilm formation in the food industry leads to contamination of processed foods, cross-contamination as well as contamination of the final product. As a result of contamination, products are degraded, which hurts economic benefits moreover the spread of food-borne diseases is occurred (Srey, Jahid, Ha 2013).

The work was aimed to evaluate the antimicrobial and antibiofilm activity of the essential oil *Salvia sclarea* against *Salmonella enterica*. we evaluated a molecular profile of biofilms on stainless steel and plastic surfaces after application of *S. sclarea* essential oil using MALDI-TOF MS Biotyper.

 https://doi.org/10.15414/2022.9788055225029

Material and methods

Microorganisms

Gram-positive microorganisms (*Listeria monocytogenes* CCM 4699, *Streptococcus pneumoniae* CCM 4501, *Staphylococcus aureus* subsp. *aureus* CCM 2461), gram-negative microorganisms (*Yersinia enterocolitica* CCM 5671, *Haemophilus influenzae* CCM 4457, *Escherichia coli* CCM 3954) and yeast (*Candida albicans* CCM 8186, *Candida tropicalis* CCM 8223, *Candida glabrata* CCM 8270) for analyses were obtained from the Czech collection of microorganisms. Bacterial strains forming the biofilm of *Salmonella enterica* and *Pseudomonas fluorescens* were obtained from chicken and fish samples. They were identified by 16S rRNA scanning and MALDI-TOF MS Biotyper.

Essential oil

Salvia sclarea essential oil (SSEO) was purchased from Hanus, s.r.o. (Nitra, Slovakia). It was prepared by steam distillation of fresh flowering stalk and leaves. It was stored in the dark at 4 °C throughout the analysis.

Disk diffusion method

The microorganisms were incubated in Mueller Hinton broth (MHB, Oxoid, Basingstoke, UK) at 37 °C for 24 hours for bacteria and Sabouraud Dextrose broth (SDB, Oxoid, Basingstoke, UK) at 25 °C for 24 hours for yeast. Microbial cultures were prepared in distilled water and adjusted with a densitometer to a 0.5 McFarland standard corresponding to 1.5×10^8 CFU/mL (Erba Lachema s.r.o., Brno, Czech Republic). 100 µL of bacterial culture was plated on Mueller Hinton agar (MHA). To detect antimicrobial activity, clean disks were subsequently used, which were impregnated with plant oil (10 µL per disk). The samples were incubated at 4 °C for 1-2 h, then at 37 °C for 18 – 24 h, respectively 48 h for bacteria and at 25 °C for 24 – 48 h for yeast. Antimicrobial activity was assessed by measuring the growth inhibition zone around the discs after incubation. Two antibiotics (cefoxitin, gentamicin; Oxoid, Basingstoke, UK) and one antifungal (fluconazole; Oxoid, Basingstoke, UK) were used as positive controls for gram-negative, gram-positive bacteria and yeast. Clean disks without essential oil served as a negative control. An inhibition zone above 10 mm was determined to be a very strong antimicrobial activity, inhibition zone above 5 mm was determined to be a mild activity, and inhibition zone above 1 mm was determined to be weak activity. Antimicrobial activity was measured three times.

Analysis of biofilm development phases and evaluation of molecular differences on different surfaces using MALDI-TOF MS Biotyper

The experiment was performed in 50 ml polypropylene tubes. Each tube contained 20 ml of MHB, a stainless steel plate, and a plastic plate. The inoculum was incubated in MHB at 37 °C for 24 hours. 100 µL of bacterial culture (0.5 McFarland standard corresponding to 1.5×10^8 $CFU.ml^{-1}$) was added to the polypropylene tubes. In the experimental group, MHB was enriched with 0.1-1 % vegetable oil. The prepared samples were placed on a shaker, with 45 ° inclination and a shaking speed of 170 rpm at 37 °C. Biofilm and planktonic cell samples were taken on days 3, 5, 7, 9, 12, and 14. Biofilm samples from the steel and plastic plates were taken with a sterile cotton swab and applied directly to a MALDI-TOF MS Biotyper plate. Planktonic cells were obtained by withdrawing 300 µL of culture medium. The medium was centrifuged in a microtube at 3000 g for 3 minutes. The supernatant was removed, and the pellet was resuspended in 30 µL of ultrapure water. The washing procedure was repeated 3 times. From the final suspension, 1 µL was applied to a MALDI-TOF MS Biotyper plate. Samples were applied to a metal 96-well MALDI plate (Bruker Daltonics, Germany) in quadruplicate. The loaded samples were covered with 1 µL of the α-cyano-4-hydroxycinnamic acid matrix (10 mg/mL) and dried at room temperature. After crystallization, the samples were analysed using a MALDI-TOF MicroFlex (Bruker Daltonics, Germany) using a linear and positive mode for the range m/z 200 – 2000 (Galovičová et al. 2021; Kačániová et al. 2020; Pereira et al. 2015).

Results and discussion

Disk diffusion method

Using the disk diffusion method, we detected weak antimicrobial activity in all gram-negative and gram-positive microorganisms (Table 1). Moderate antimicrobial activity was detected in biofilm-producing bacteria. SSEO had moderate to very strong activity against yeasts.

Öğütçü et al. 2008 tested the same gram-positive and gram-negative bacteria as we tested in our study and they detected inhibition zones smaller than 7 mm for all bacteria. The authors evaluated the inhibitory activity as weak which confirms our findings about weak antibacterial activity of SSEO. Ovidi et al. 2021 detected inhibition zones for *E. coli* (16.67 ± 1.53 mm) with a rating of very strong inhibitory activity and *P. fluorescens* (8.00 ± 1.00 mm) with moderate activity. Like the authors, we detected moderate activity against *P. fluorescens*, but we observed a different inhibitory effect against *E. coli*. Safaeian Laein et al. 2021 detected in *E. coli, S. aureus* and *C. albicans* medium to strong antimicrobial activity with zones of inhibition 7 – 13 mm. Our findings are consistent with the finding of strong SSEO inhibitory activity against *C. albicans*, but in our study, we found only weak inhibitory activity against *E. coli* and *S. aureus*.

Table 1 Antimicrobial activity *S. sclarea* essential oil

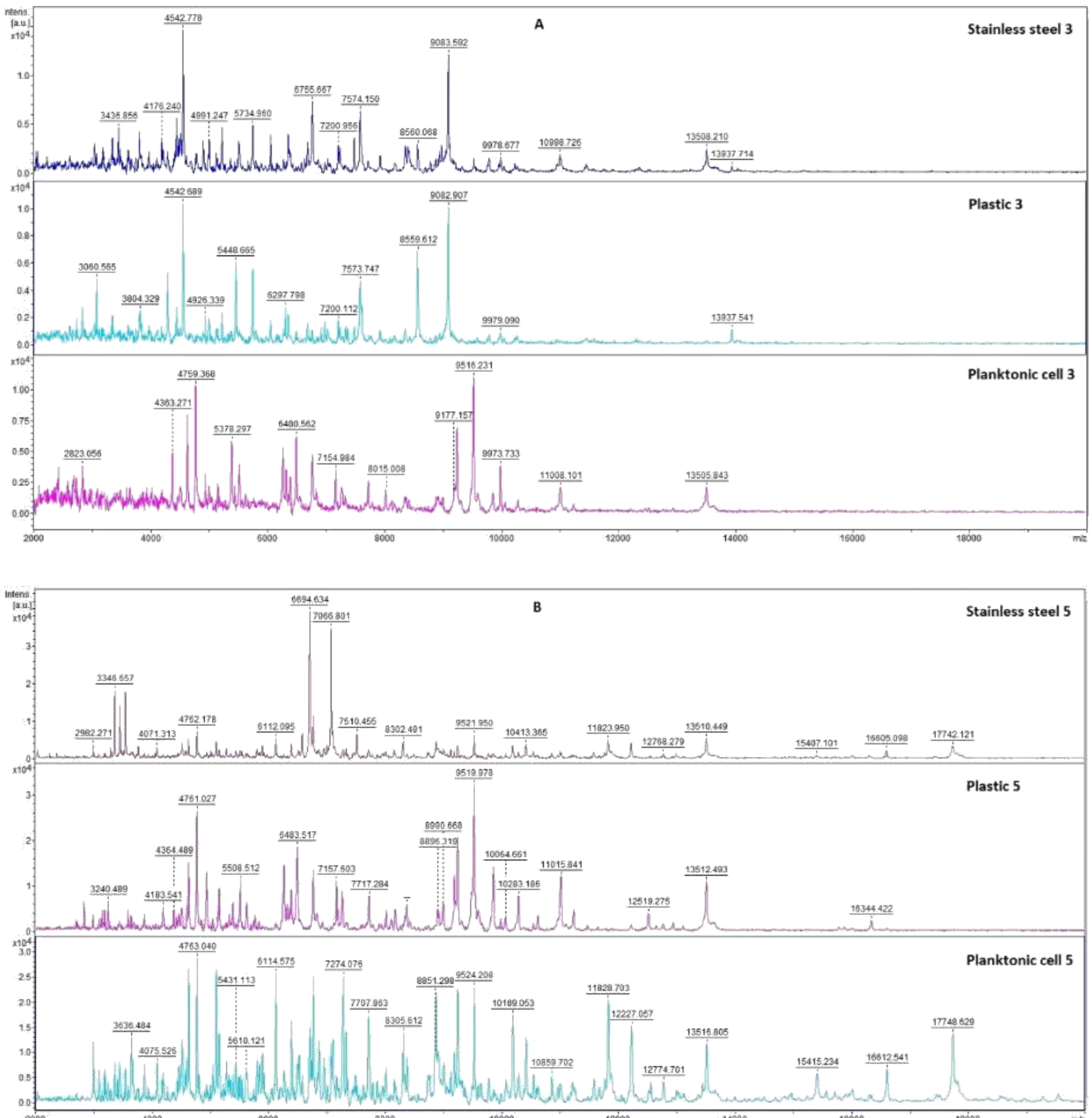
Microorganisms	Zone inhibition (mm)	Activity EO	ATB
Escherichia coli	4.33±0.58	*	22±1.00
Haemophilus influenzae	1.00±0.00	*	25±2.00
Yersinia enterocolitica	2.67±0.58	*	25±1.50
Streptococcus pneumoniae	2.33±0.58	*	27±2.00
Listeria monocytogenes	1.33±0.58	*	31±3.00
Staphylococcus aureus	2.33±0.58	*	31±1.00
Salmonella enterica-biofilm	5.33±0.58	**	28±0.50
Pseudomonas fluorescens-biofilm	5.33±0.58	**	26±2.00
Candida glabrata	5.67±0.58	**	31±3.00
Candida tropicalis	5.33±1.15	**	25±2.00
Candida albicans	10.33±1.15	***	31±1.00

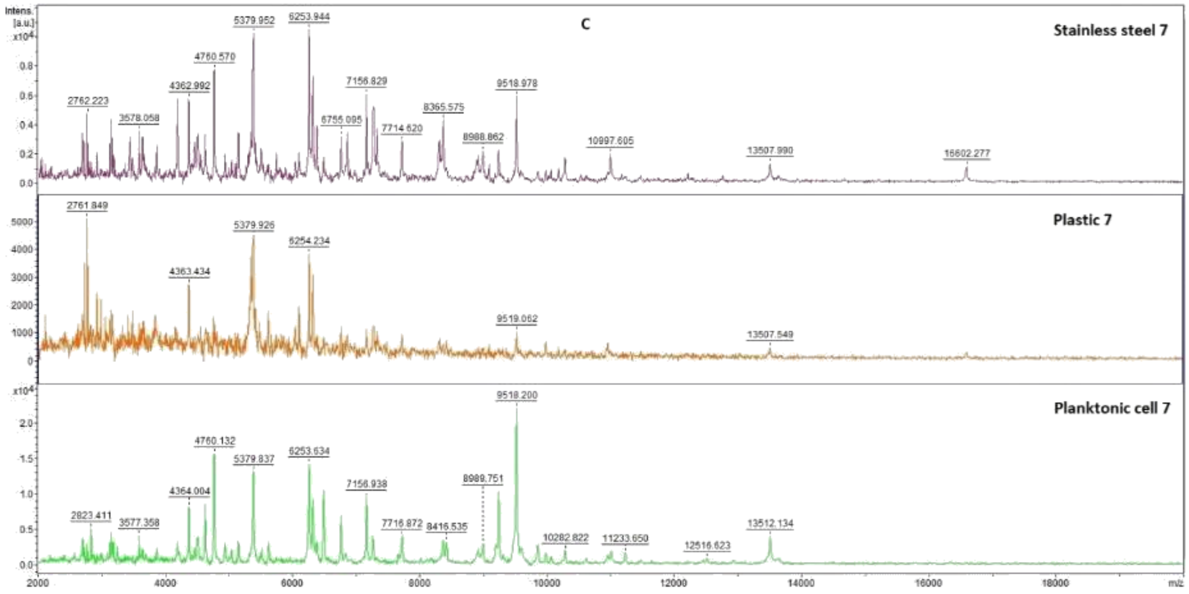
* Weak antimicrobial activity (zone 1–5 mm). ** Moderate inhibitory activity (zone 5–10 mm). *** Very strong inhibitory activity (zone > 10 mm), ATB—antibiotics, positive control (cefoxitin for G−, gentamicin for G+, fluconazole for yeast).

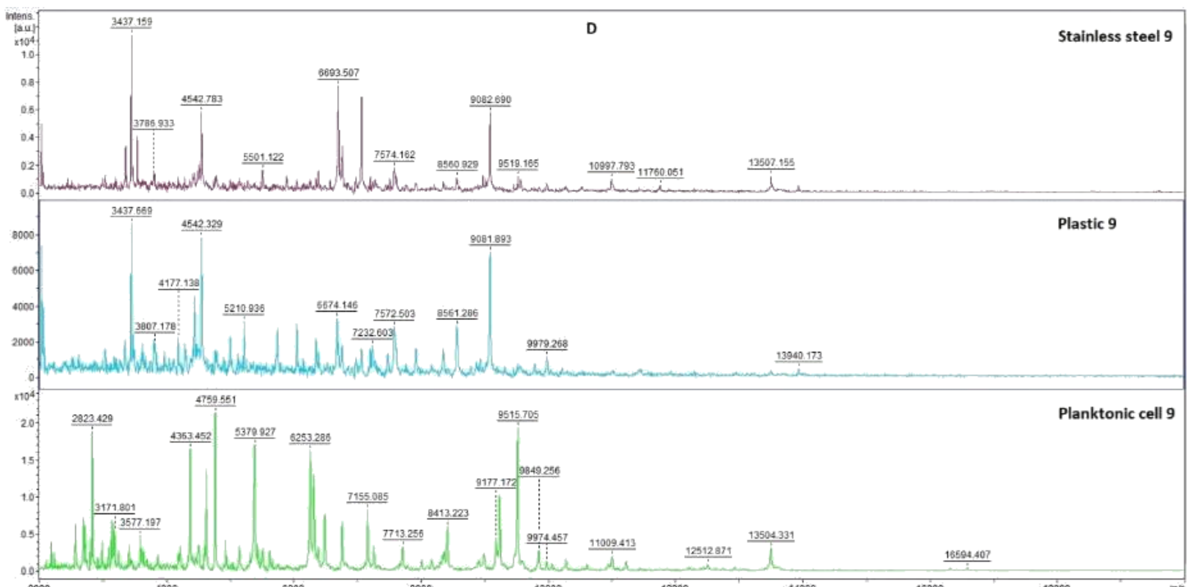
Analysis of biofilm development phases and evaluation of molecular differences on different surfaces using MALDI-TOF MS Biotyper

The effect of *Salvia sclarea* essential oil against biofilm-producing *Salmonella enterica* was evaluated by MALDI-TOF MS Biotyper mass spectrometry. The spectra of the control groups (planktonic cells and EO-untreated biofilm) developed in the same way (spectra not shown), thus the control planktonic cells were used as a control to compare the molecular changes of the biofilm.

Mass spectra during day 3 of the cultivation (Figure A) showed the same peaks, indicating the same protein production by young biofilms and control planktonic cells. At the protein level, no changes were observed in the bacterial cultures. The difference between the mass spectra of the biofilms on the tested surfaces (stainless steel and plastic) and the control sample occurred from day 5 (Figure B-F). With a predominance on the plastic surface. Changes in the protein profile of the biofilm treated with SSEO were visible. SSEO appears to affect the homeostasis of the bacterial biofilm formed on the stainless steel and plastic surfaces.




C
Stainless steel 7
Plastic 7
Planktonic cell 7
Intens. [a.u.]
x10⁴
m/z
5379.952
6253.944
4760.570
4362.992
7156.829
9518.978
2762.223
3578.058
6755.095
8365.575
7714.620
8988.862
10997.605
13507.990
16602.277
2761.849
5379.926
6254.234
4363.434
9519.052
13507.549
9518.200
4760.132
6253.634
5379.837
7156.938
8989.751
4364.004
2823.411
3577.358
7716.872
8416.535
10282.822
11233.650
12516.623
13512.134


D
Stainless steel 9
Plastic 9
Planktonic cell 9
Intens. [a.u.]
x10⁴
m/z
3437.159
6693.507
4542.783
9082.690
3786.933
5501.122
7574.162
8560.929
9519.165
10997.793
11760.051
13507.155
3437.669
4542.329
9081.893
4177.138
5210.936
6674.146
7572.503
8561.286
3807.178
7232.603
9979.268
13940.173
4759.551
2823.429
9515.705
4363.452
5379.927
6253.286
9849.256
9177.172
7155.085
8413.223
3171.801
3577.197
7713.256
9974.457
11009.413
12512.871
13504.331
16594.407

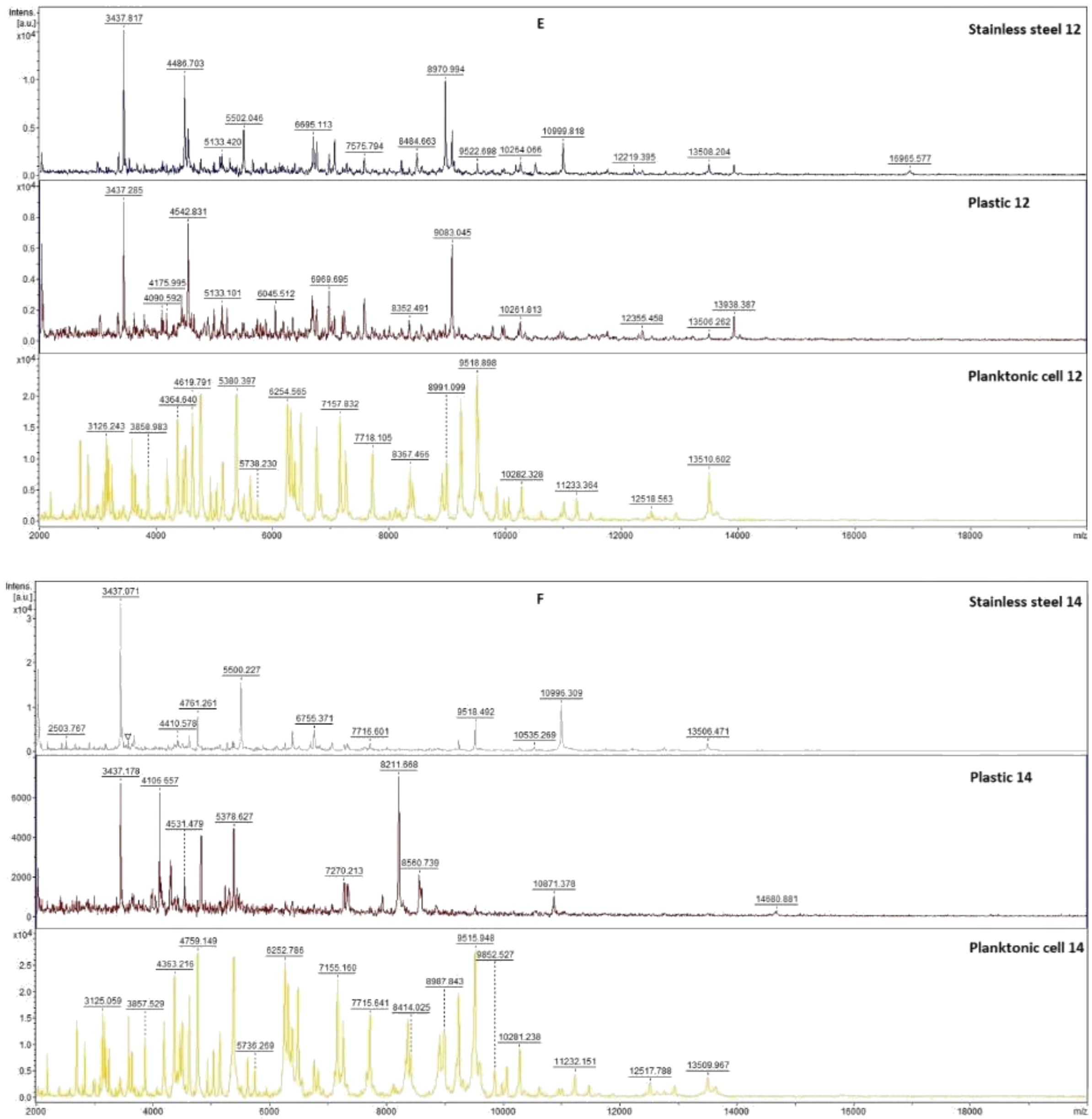


Figure 5 Representative MALDI-TOF mass spectra of *S. enterica*: A – 3rd day; B - 5th day; C - 7th day; D - 9th day; E - 12th day; F - 14th day

The dendrogram was designed as a visualization of mass spectra to determine some similarities in biofilm structure concerning MSP distance. The constructed dendrogram shows (Figure 2) that the planktonic stage (P) together with control groups and young biofilms had the shortest distance during the 3rd day. The similarity in the protein profile of the control groups was confirmed by short MSP distances. Young biofilms and control planktonic cells also had short MSP distances that corresponded to mass spectra. The distance between the experimental groups of SMEs has gradually increased over time. The mass spectra analyzed on days 12 and 14 of the experiment had the longest MSP distances, indicating changes in the molecular profile of *S. enterica*.

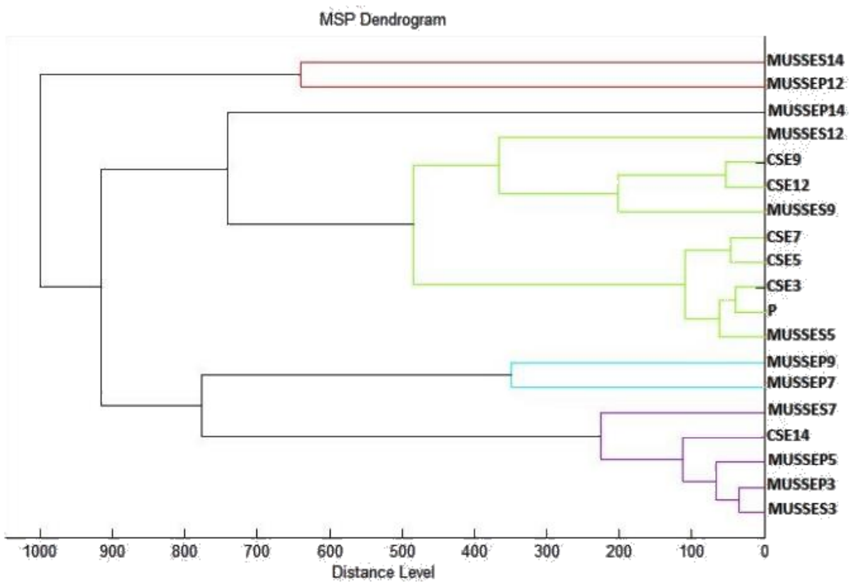


Figure 6 Dendrogram of *S. enterica* generated using the MSPs for planktonic cells and control. Symbols in the abbreviations are as follows: **MUS**- *Salvia sclarea;* **SE** – *S. enterica*; **C** - control; **S**- stainless steel; **P**-plastic; **only P**-planktonic cells

Aguiar et al. 2021 report that MALDI-TOF MS was able to detect specific biofilm proteins. Gaudreau et al. 2018 found that MALDI-TOF MS is suitable for the direct identification of biofilms without the use of organic solvents. The authors' findings confirm that MALDI-TOF MS Biotyper is suitable for the analysis of the protein structure of biofilms. Walencka et al. 2007 found that *S. sclarea* inhibited planktonic cells and the biofilm of *S. aureus* and *S. epidermidis*, while antibiotics did not show an inhibitory effect despite high concentrations. These findings are consistent with our findings on the potential use of SSEO as an alternative for biofilm control.

Conclusions

The results of our analysis show that *Salvia sclarea* essential oil has weak to moderate antimicrobial activity. Larger zones of inhibition against the biofilm-forming bacteria *S. enterica* and *P. fluorescens* are proof of the suitability of *Salvia sclarea* essential oil to combat bacterial biofilms. Analysis of biofilm mass spectra using the MALDI-TOF MS Biotyper and the constructed dendrogram shows that *Salvia sclarea* essential oil caused changes in the structure of the *S. enterica* biofilm. These structural changes are evidence of the inhibitory effect of *Salvia sclarea* against *S. enterica* biofilms on stainless steel and plastic surfaces. The effect of the essential oil on the structure of the biofilm may be caused by disrupting the polysaccharide matrix surrounding the biofilm bacteria, thereby reducing their resistance. MALDI-TOF MS Biotyper is a suitable tool for biofilm analysis, which is a prerequisite for its use in food and clinical practice.

Acknowledgment

This publication was made possible thanks to the support of the project APVV-20-0058 Potential of plant essential oils from aromatic plants for medical use and food preservation.

References

AGUIAR, A. P. et al. 2021. Rapid detection of biofilm-producing Candida species via MALDI-TOF mass spectrometry. Journal of Applied Microbiology. [online], vol. 131, no. 4, pp. 2049–2060 [2022-04-17]. Available on internet: DOI 10.1111/jam.15066.

DURLING, N. et al. 2007. Extraction of phenolics and essential oil from dried sage (Salvia officinalis) using ethanol–water mixtures. Food Chemistry. [online], vol. 101, no. 4, pp. 1417–1424 [2022-04-18]. Available on internet: DOI 10.1016/j.foodchem.2006.03.050.

FALLEH, H. et al. 2020. Essential oils: A promising eco-friendly food preservative. Food Chemistry. [online], vol. 330, pp. 127268 [2022-04-20]. Available on internet: DOI 10.1016/j.foodchem.2020.127268.

GALOVIČOVÁ, L. et al. 2021. Thymus vulgaris Essential Oil and Its Biological Activity. Plants. [online], vol. 10, no. 9, pp. 1959 [2022-04-20]. Available on internet: DOI 10.3390/plants10091959.

GAUDREAU, A.M. et al. 2018. Evaluation of MALDI-TOF mass spectrometry for the identification of bacteria growing as biofilms. Journal of Microbiological Methods. [online], vol. 145, pp. 79–81 [2022-04-20]. Available on internet: DOI 10.1016/j.mimet.2018.01.003.

HANIF, M. A. et al. 2019. Essential Oils. V: MALIK, Sonia (ed.), Essential Oil Research: Trends in Biosynthesis, Analytics, Industrial Applications and Biotechnological Production. online. Cham: Springer International Publishing. pp. 3–17. [Cit 21 apríl 2022]. ISBN 978-3-030-16546-8.

JANTSCH, J. et al. 2011. Cellular aspects of immunity to intracellular Salmonella enterica: Cellular microbiology of Salmonella. Immunological Reviews. [online], vol. 240, no. 1, pp. 185–195 [2022-04-22]. Available on internet: DOI 10.1111/j.1600-065X.2010.00981.x.

KAČÁNIOVÁ, M. et al. 2020. Biological Activity and Antibiofilm Molecular Profile of Citrus aurantium Essential Oil and Its Application in a Food Model. Molecules. [online], vol. 25, no. 17, pp. 3956 [2022-04-22]. Available on internet: DOI 10.3390/molecules25173956.

KONG, B. et al. 2010. Antioxidant activity of spice extracts in a liposome system and in cooked pork patties and the possible mode of action. Meat Science. [online], vol. 85, no. 4, pp. 772–778 [2022-04-22]. Available on internet: DOI 10.1016/j.meatsci.2010.04.003.

LOW, A. J. et al. 2019. ConFindr: rapid detection of intraspecies and cross-species contamination in bacterial whole-genome sequence data. PeerJ. [online], vol. 7, pp. e6995 [2022-04-22]. Available on internet: DOI 10.7717/peerj.6995.

NAHAR, S. et al. 2018. Advances and Future Prospects of Enzyme-Based Biofilm Prevention Approaches in the Food Industry: Enzyme-based biofilm prevention. Comprehensive Reviews in Food Science and Food Safety. [online], vol. 17, no. 6, pp. 1484–1502 [online], vol. 7, pp. e6995 [2022-04-22]. Available on internet: DOI 10.1111/1541-4337.12382.

ÖĞÜTÇÜ, H. et al. 2008. Bioactivities of the Various Extracts and Essential Oils of Salvia limbata C.A.Mey. and Salvia sclarea L. . 2008. pp. 12.

OVIDI, E. et al. 2021. Laurus nobilis, Salvia sclarea and Salvia officinalis Essential Oils and Hydrolates: Evaluation of Liquid and Vapor Phase Chemical Composition and Biological Activities. Plants. [online], vol. 10, no. 4, pp. 707 [2022-04-22]. Available on internet: DOI 10.3390/plants10040707.

PEREIRA, F. D.E.S. et al. 2015. Use of MALDI-TOF mass spectrometry to analyze the molecular profile of Pseudomonas aeruginosa biofilms grown on glass and plastic surfaces. Microbial Pathogenesis. [online], vol. 86, pp. 32–37 [2022-04-22]. Available on internet: DOI 10.1016/j.micpath.2015.07.005.

RAJABI, Z. et al. 2014. Compositions and yield variation of essential oils among and within nine Salvia species from various areas of Iran. Industrial Crops and Products. [online], vol. 61, pp. 233–239 [2022-04-22]. Available on internet: DOI 10.1016/j.indcrop.2014.06.038.

RUSSO, A. et al. 2013. Chemical composition and anticancer activity of essential oils of Mediterranean sage (Salvia officinalis L.) grown in different environmental conditions. Food and Chemical Toxicology. [online], vol. 55, pp. 42–47 [2022-04-22]. Available on internet: DOI 10.1016/j.fct.2012.12.036.

SAFAEIAN LAEIN, S. et al. 2021. Evaluation of Antibacterial and Antioxidant Activities of Essential Oil of Lime Citrus aurantifolia) Pomace Powder. Iranian Journal of Chemistry and Chemical Engineering (IJCCE). [online], vol. 40, no. 3 [2022-04-22]. Available on internet: DOI 10.30492/ijcce.2020.38253.

SHARMA, S. et al. 2021. Essential oils as additives in active food packaging. Food Chemistry. [online], vol. 343, pp. 128403 [2022-04-22]. Available on internet: DOI 10.1016/j.foodchem.2020.128403.

SREY, S. et al. 2013. Biofilm formation in food industries: A food safety concern. Food Control. [online], vol. 31, no. 2, pp. 572–585 [2022-04-22]. Available on internet: DOI 10.1016/j.foodcont.2012.12.001.

SU, L.-H. – CHIU, C.-H. 2007. Salmonella: Clinical Importance and Evolution of Nomenclature. 2007. Vol. 30, no. 3, pp. 10.

WALENCKA, E. et al. 2007. Salvipisone and Aethiopinone from Salvia sclarea Hairy Roots Modulate Staphylococcal Antibiotic Resistance and Express Anti-Biofilm Activity. Planta Medica. [online], vol. 73, no. 6, pp. 545–551 [2022-04-22]. Available on internet: DOI 10.1055/s-2007-967179.

Contact address: Ing. Lucia Galovičová, Slovak University of Agriculture in Nitra, Horticulture and Landscape Engineering Faculty, Institute of Horticulture, Tr. A. Hlinku 2, 94976 Nitra, Slovakia, +421 907 260 116, l.galovicova95@gmail.com.

ARTICLE HISTORY:
Received 05.05.2022
Received in revised form 16.05.2022
Accepted 20.05.2022

ANTIFUNGAL POTENTIAL OF EUCALYPTUS ESSENTIAL OIL AS A NATURAL PRESERVATIVE ALTERNATIVE

Veronika VALKOVÁ[1,2], Hana ĎÚRANOVÁ[1], Lucia GALOVIČOVÁ[2], Miroslava KAČÁNIOVÁ[2]

[1]AgroBioTech Research Centre, Slovak Agriculture University in Nitra, SLOVAKIA

[2]Institute of Horticulture, Slovak Agriculture University in Nitra, SLOVAKIA

Abstract

The growth inhibitory potential of eucalyptus essential oil (EEO) against three *Penicillium* (*P.*) spp. (*P. expansum*, *P. citrinum*, *P. crustosum*) was a focal priority area for our research. The antioxidant activity (AA) of the EEO was determined by DPPH radical assay, and *in vitro* the EO antifungal activity (62.5, 125, 250, and 500 µL/L) was evaluated using the disc diffusion method. To investigate the percentage inhibition of mycelial growth on a carrot, vapor contact method was employed. Despite a weak AA of the EO (91.0 ± 8.0 TEAC), *in vitro* antifungal analysis showed from moderate to strong ranging growth inhibition against all *Penicillium* strains with the highest inhibition zone (15.67 ± 1.15 mm) recorded for 500 µL/L of the EEO against the growth *of P. crustosum*. Further, the *in situ* antifungal efficacy of the EO against the analysed *Penicillium* spp. was found to be dose-dependent. In this line, these values gradually increased ($P < 0.05$) from 39.02 ± 2.31 % (62.5 µL/L in *P. crustosum*) to 98.49 ± 1.23 % (500 µL/L in *P. citrinum*). Our findings revealed the antifungal properties of the EEO, and suggest its potential practical application in suppressing the *Penicilliu*m spp. growth being a possible alternative to synthetic agents.

Keywords: *Eucalypti aetheroleum*, DPPH assay, disc diffusion method, carrot

Introduction

Due to the increasing population and the limited natural resources, many studies have been dealing with utilization of innovative packaging technologies (Krochta, 2002), allowing for releasing antimicrobial agents into foods to increase their shelf-life via minimizing or even eliminating the presence of food-borne microorganisms (de Dicastillo et al., 2016; Janjarasskul et al., 2016; Rizzolo et al., 2016). Regarding the possible multiple resistances and adverse reactions of synthetic antifungals, increasing attention has been directed toward application of natural alternatives (Namiki, 1990). Most importantly, consumers demand food products free of synthetic substances in the context of a healthy lifestyle (Serrano et al., 2005). As a natural antifungal alternative being incorporated into packaging, compounds derived from plants, such as essential oils (EOs), seems to be a favorable solution (Nazzaro et al., 2017).

In general, plant EOs are considered non-phytotoxic compounds and potentially effective against several microorganisms including many fungal pathogens (Chuang et al., 2007). They are defined as volatile hydrophobic substances extracted from different types of medicinal and aromatic plants, which often have a strong aroma (Bhavaniramya et al., 2019). In addition, these volatile compounds are a mixture of secondary metabolites that play an important role in plant defence mechanisms (Shaaban, 2020). Generally, it is known that these concentrated aromatics are extracted from various parts of plants including leaves, stems, seeds, flowers, fruits, roots, and bark (Hanif et al., 2019). Isolation of EOs is relatively simple and the chosen extraction technique directly reflects their chemical composition. Typically, they are obtained by hydrodistillation or solvent extraction (Bendahou et al., 2008) from 17 500 aromatic species of higher plants belonging mostly to a few families including the Myrtaceae, Apiaceae, Lamiaceae, Lauraceae, and Asteraceae. However, only a small proportion of them (approximately 300 species) are also used for commercial purposes (Regnault-Roger et al., 2012).

Eucalyptus spp. (Myrtaceae) belong to the most important and therapeutic valuable aromatic plants. This genus consists of more than 700 species growing all over the world (Batish et al., 2008), from which approximately 300 species contain volatile oils in their leaves. These oils are commercially used for the production of EOs by different industries (Marzoug et al. 2011). In this aspect, EOs obtained from leaves of these plants were approved as food additives, and they are on a large scale also applied in cosmetic formulations (Takashi et al., 2004). Recently, attention has been focused on their biological effects, such as antioxidant (Barra et al., 2010), anticancer (Vuong et al., 2015), insecticidal (Filomeno et al., 2017), antibacterial (Ghalem et al., 2008), antiviral (Schnitzler et al., 2001) and antifungal properties (Gakuubi et al., 2017). In fact, the high functional

 https://doi.org/10.15414/2022.9788055225029

value of Eucalyptus EO (EEO) is to a great extent responsible for the presence of its main constituent 1,8-cineole (Baukhatem et al., 2014; Sebei et al., 2015). Generally, it is known that chemical profiles (e.g., α-pinene, 1,8-cineole, citronellal, citronellol, and isopulegol), as well as the yield of EEO are largely influenced by the environmental conditions (Barra et al., 2010; Jemâa et al., 2012).

Therefore, the aim of the present study was aimed to investigate the antifungal activities (in *in vitro* and *in situ* conditions) of the commercially available EEO against three strains of *Penicillium* spp. (*P. expansum*, *P. crustosum*, *P. citrinum*), and to determine the antioxidant capacity of the EO, as well.

Material and methods

<u>Essential oil</u>

For our all analyses, a commercial eucalyptus essential oil (EEO; *Eucalypti aetheroleum*) obtained by the steam distillation of fresh stalks was used. The main volatile components of the EEO were 1,8-cineole (min. 80%), α-pinene, camphene, and borneol as declared by the manufacturer (Hanus Ltd., Nitra, Slovakia).

<u>Fungal strains</u>

Three strains of microscopic filamentous fungi of the genus *Penicillium* (*P. expansum*, *P. citrinum*, *P. crustosum*) were applied to carry out the experiment. The *Penicillium* spp. were isolated from berry samples of *Vitis vinifera*, and consequently classified using a reference-based MALDI-TOF MS Biotyper and 16S rRNA sequences analysis, as well.

<u>Determination of antioxidant activity</u>

To measure the antioxidant activity (AA) of the EEO, the 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical scavenging assay was used, as previously described by Valková et al. (2022). The AA was expressed as the percentage of DPPH inhibition, which was calculated using the following formula: $(A0 - A1)/A0 \times 100$; where A0 was the absorbance of DPPH and A1 was the absorbance of the sample. The power of AA was recognized as follows: weak (0 – 29 %) < medium–strong (30 – 59 %)

< strong (60 and more %). Moreover, the value for total AA was expressed according to the calibration curve as 1 µg of the standard reference Trolox to 1 mL of the LGEO sample (TEAC).

Disc diffusion method

The evaluation of the antifungal activity of the EEO was performed using the agar disc diffusion method. For this purpose, there was an aliquot of 0.1 mL of fungal suspension in distilled water inoculated to Sabouraud Dextrose Agar (SDA; Merck, Germany; 60 mm). Subsequently, the discs of filter paper (6 mm) were impregnated with 10 µL of the analysed EO samples (at four concentrations: 62.5, 125, 250, and 500 µL/L; diluted in 0.1 % dimethyl sulfoxide (DMSO)), then applied on the SDA surface, and incubated at 25 °C for 5 days. The diameters of the inhibition zones were measured in mm after incubation. The power of the antifungal activity was expressed as follows: weak antifungal activity (0 – 5 mm) < moderate antimicrobial activity (5 – 10 mm) < strong antifungal activity (10 – 15 mm) < very strong antimicrobial activity (zone > 15 mm). Each test was repeated three times (one repeat reflecting one separate plate).

Exposure of the food model to the EEO vapor phase

All three fungal strains (*P. expansum*, *P. citrinum*, *P. crustosum*) were used to estimate the antifungal activity of the EEO *in situ*. Here, carrot pieces were used as the substrate for the growth of the selected fungi species. The experiment itself was carried out according to Valková et al. (2022). Before inoculation, fungal strains were cultured on SDA at 25 °C for 5 days. Firstly, carrot pieces (5 mm) were transferred at the bottom of Petri dishes (PD; 60 mm), and the inoculum of the tested strains was applied by stabbing the carrot substrate with an injection pin one time. Then, a sterile filter paper disc (60 mm) was placed at the pin of PD, and 10 µL of the EEO in the concentrations of 62.5, 125, 250 and 500 µL/L (diluted in ethyl acetate) were applied to it. The control carrot was not treated with the EEO. Finally, the hermetically closed PDs were stored in an incubator for 14 days at 25 ± 1 °C.

After incubation, stereological methods were employed to determine the *in situ* fungal growths. Firstly, the volume densities (Vv) of fungal colonies were estimated using ImageJ software, counting the points of the stereological grid falling into the colonies (P) and those (p) hitting the reference space (i.e., the growth substrate used: carrot). Consequently, each Vv of the strain colony was calculated. Finally, the antimicrobial activity of the EEO was expressed as the percentage of the mycelial growth inhibition (MGI), according to the formula: Vv (%) = MGI = [(C −

T)/C] × 100; where C and T represent the growths of microorganism strains (expressed as Vv) in the control and treatment groups, respectively (Valková et al., 2022).

Statistical analysis

A completely randomized design consisting of a minimum of three observations was conducted in the study. One-way analysis of variance (ANOVA) followed by Tukey's test at $p < 0.05$ were performed using Prism 8.0.1 (GraphPad Software, San Diego, CA, USA).

Results and discussion

Antioxidant capacity of the EEO

Commonly, EOs are well-known for their antioxidant capacity whose determination has been the goal of many research papers (Anthony et al., 2012; Andrade et al., 2013). The DPPH assay (also applied in our research) is considered a sensitive and simple method being appropriate to the most plant extracts including EOs (Noipa et al., 2011). Using this method, our EEO exhibited weak antioxidant potential (Table 1) corresponding to the values of 91.0 ± 8.0 TEAC (i.e., 1.1 ± 1.7 %).

Table 1 Antioxidant activity of the EEO

Parameters	EEO
AA (%)	1.1 ± 1.7
AA (TEAC)	91.0 ± 8.0

Source: Mean ± standard deviation. EEO - eucalyptus essential oil; AA - antioxidant activity.

In line with our results, Kriendrebeogo et al. (2011) also recorded weak AA values (3.68 ± 0.25 %) of the EO obtained from *Eucalyptus camaldulensis* Dehnhardt. Their findings from chemical analysis indicated that their EO was a 1,8-cineole chemotype, which is in accordance with our EEO as it was declared by the manufacturer. In general, the AA of diverse EOs is largely influenced by the presence of volatile compounds in their composition (Diniz do Nascimento et al., 2020). Moreover, the antioxidant efficacy of the EOs is not attributed to just one or only some of their substances (Wang et al., 2008) but it is a result of the synergistic effect of all their compounds (Guimarães de Lima et al., 2011). Since 1,8-cineole, as well as other terpene compounds (such as sesquiterpene hydrocarbons and monoterpene) present also in the conception of our EEO have low solubility in the tested medium, and concurrently do not have the ability to donate hydrogen atoms (Mata et al., 2007), the weak AA of our EEO could be associated just with these aspects.

In vitro antifungal activity of the EEO

The disc diffusion method was applied to determine the sensitivity of three *Penicillium* spp. strains to four concentrations (62.5, 125, 250, and 500 µL/L) of the EEO (Table 2). Our findings showed that the growth inhibition of *Penicillium* strains depends on the concentration of the EEO used. The lowest concentration of EEO (62.5 µL/L) tested had weak (*P. expansum*) or moderate inhibitory efficacies (*P. citrinum*, and *P. crustosum*) against the growth of the strains. On the other hand, the highest growth inhibition ($P < 0.05$) was recorded in all three analyzed strains in the highest EEO concentration (500 µL/L) applied, proving a very strong antifungal activity against *P. crustosum*.

Table 2 Inhibitory effect of the EEO on the fungal growth in *in vitro* conditions

	Inhibition zones (mm) EEO (µL/L)			
Strains	62.5	125	250	500
P. expansum	3.67 ± 1.15 ^{aA}	8.00 ± 1.00 ^{aB}	11.33 ± 1.15 ^{aC}	13.67 ± 0.58 ^{aD}
P. citrinum	6.67 ± 1.15 ^{bA}	7.67 ± 0.58 ^{aA}	11.00 ± 1.00 ^{aB}	14.33 ± 1.15 ^{aC}
P. crustosum	6.33 ± 0.58 ^{bA}	9.00 ± 1.73 ^{aB}	9.33 ± 1.15 ^{aB}	15.67 ± 1.15 ^{aC}

Source: Means ± standard deviation. Values in the same column with different small letters, and those in the same row with different upper-case letters are different ($P < 0.05$). EEO - eucalyptus essential oil.

The antifungal properties of the EEO have been documented in many studies (Ramezani et al., 2002; Tolba et al., 2015). Confirming our findings, Gakuubi et al. (2017) revealed inhibitory activity of *Eucalyptus camaldulensis* EO on growth of *Fusarium* (*F.*) spp. (*F. solani*, *F. oxysporum*, *F. verticillioides*, *F. proliferatum*, and *F. subglutinans*) in a dose-dependent manner. In effect, the antifungal activity against the tested fungi increased with increasing concentrations of the EEO. Concretely, the authors reported the highest zone of inhibition (24.67 ± 1.20 mm) in *F. oxysporum* induced by 100 % EO concentration. On the other hand, the smallest zones of inhibition (6.00 ± 0.00 mm) were detected in all fungal strains exposed to the lowest (1.56%) EEO concentration, in all strains (except for *F. oxysporum*) treated with 3.13 % concentration, and in *F. solani* and *F. verticillioides* exposed to EEO in the concentration of 6.25 %. Antifungal efficacy of *Eucalyptus citriodora* EO against selected filamentous fungi species, *Microsporum* (*M.*) *canis*, *M. gypseum*, *Trichophyton* (*T.*) *mentagrophytes*, and *T. rubrum* has been investigated by Tolba et al. (2015). Similarly, the zones of inhibition also increased with the increasing EEO concentrations (10, 20, 30 µL). The highest inhibition zone was observed against *M. canis* (64 mm), *T. mentagrophytes* (64 mm), and *T. rubrum* (39 mm) induced by using 10 µL of the EO. On the other hand, *M. gypseum* was the most resistant to action of the EO displaying inhibition zones of 12 mm (10-20 µL), and 29.5 mm (30 µL). We hypothesize that the antifungal activity of our EEO can be attributed mainly to 1,8-cineole being the major compounds detected in its composition. This assumption is supported by the study of Shukla et al. (2012) showing the antifungal effects of 1,8-cineole against *Aspergillus flavus*.

In situ antifungal activity of EEO

Generally, antifungal substances are applied in the food industry to control the growth of microorganisms and natural spoilage processes (Shaaban, 2020). As spoilage of vegetables is mainly caused by microscopic filamentous fungi including *Penicillium* spp. (Yu et al., 2020), the antifungal action of the EEO in the vapor phase on the fungi growth inoculated on a carrot substrate as a food model (Table 3 and Figure 1) were evaluated in the present research. From the results it is clearly evident that the EEO in all concentrations tested (62.5, 125, 250, and 500 µL/L) exhibited antifungal efficacy against all evaluated *Penicillium* spp. strains. In this context, the strongest inhibitory effectiveness (97.09 ± 5.58 %, 98.49 ± 1.23 %, 96.97 ± 4.72 %, respectively) was detected in the highest concentration of the EO (500 µL/L) against *P. expansum*, *P. citrinum*, and *P. crustosum*. Further, it was found that with increasing EEO concentration, the inhibitory potential of the EO significantly increased ($P < 0.05$).

 https://doi.org/10.15414/2022.9788055225029

Table 3 Inhibitory effect of the EEO on fungal growth in *in situ* conditions (carrot)

	MGI (%) EEO (µL/L)			
Strains	62.5	125	250	500
P. expansum	51.09 ± 1.41 ^{aA}	93.95 ± 5.61 ^{aB}	96.76 ± 3.25 ^{aB}	97.09 ± 5.58 ^{aB}
P. citrinum	51.39 ± 2.93 ^{aA}	83.10 ± 1.81 ^{bB}	95.65 ± 5.49 ^{aC}	98.49 ± 1.23 ^{aC}
P. crustosum	39.02 ± 2.31 ^{bA}	57.94 ± 3.84 ^{cB}	96.90 ± 7.26 ^{aC}	96.97 ± 4.72 ^{aC}

Source: Means ± standard deviation. Values in the same column with different small letters, and those in the same row with different upper-case letters are different (P< 0.05). MGI - mycelial growth inhibition. EEO - eucalyptus essential oil.

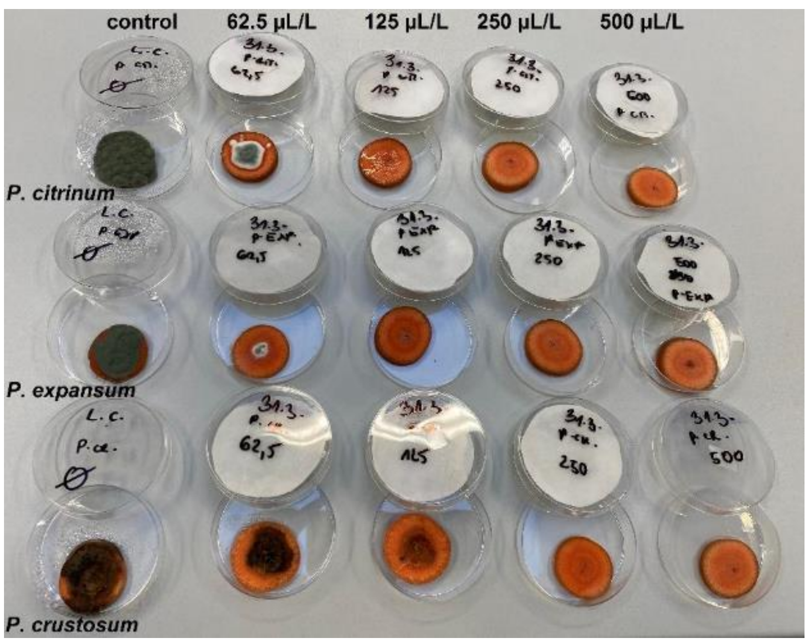


Figure 1 *In situ* analysis of antifungal activities of the EEO against selected *Penicillium* spp. strains

The results obtained from the study are in agreement with our previous experiments in which the antifungal effects of other important commercially available EOs, such as *Mentha piperita*, *Rosmarinus officinalis* and *Lavandula angustifolia* (Valková et al., 2021a), *Citrus recitulata* (Valková et al., 2021b), *Cymbopogon citratus* (Valková et al., 2022), *Cedar atlantica* (Kačániová et al., 2022), Pogostemon cablin (Galovičová et al., 2022) against the various *Penicillium* species were confirmed. To gain an expanding knowledge considering the EEO antifungal efficiency, we plan to carry out determinations of its inhibitory effects on the growth of other fungal species. Moreover, we also plan to implement a sensory analysis of treated carrot samples to investigate if such carrot has acceptable sensory properties and to find a concentration of the EO still optimal for consumers.

Conclusions

In the present research, the antioxidant and antifungal (*in vitro*, *in situ*) activities of commercial EEO obtained from the Slovak company (Hanus Ltd., Nitra, Slovakia) were investigated. Our findings revealed the weak AA (91.0 ± 8.0 TEAC) of the EO analysed. The *in vitro* antifungal determination showed that the EEO was effective in inhibiting the growth of fungal strains, and its effectiveness depended mainly on its concentration. A similar increasing trend was also observed in *in situ* analyzes where the EEO inhibitory action ranged from 39.02 ± 2.31% (62.5 µL/L for *P. crustosum*) to 98.49 ± 1.23% (500 µL/L for *P. citrinum*). Our obtained results suggest that the incorporation of the EEO as a natural antifungal agent into the active packaging of vegetables (including carrot) has a perspective to prolong their shelf-life in food practice.

Acknowledgment

This research was funded by the grant APVV-20-0058 “The potential of the essential oils from aromatic plants for medical use and food preservation”.

References

ANDRADE, M. A. et al. 2013. Chemical composition and antioxidant activity of essential oils from *Cinnamodendron dinisii* Schwacke and *Siparuna guianensis* Aublet. In Antioxidants, vol. 2, no. 4, pp. 384-397. DOI:10.3390/antiox2040384.

ANTHONY, K. P. et al. 2012. Comprehensive assessment of antioxidant activity of essential oils. In Journal of Food Science, vol. 77, no. 8, pp. C839-C843. DOI:10.1111/j.1750-3841.2012.02795.x.

BARRA, A. et al. 2010. Chemical variability, antifungal and antioxidant activity of *Eucalyptus camaldulensis* essential oil from Sardinia. In Natural Product Communications, 2010, vol. 5, no.2, pp. 1934578X1000500232. DOI:10.1177/1934578X1000500232.

BATISH, D. R. et al. 2008. Eucalyptus essential oil as a natural pesticide. In Forest ecology and management, vol. 256, no. 12, pp. 2166-2174. DOI:10.1016/j.foreco.2008.08.008.

BENDAHOU, M. et al. 2008. Antimicrobial activity and chemical composition of *Origanum glandulosum* Desf. essential oil and extract obtained by microwave extraction: Comparison with hydrodistillation. In Food Chemistry, vol. 106, no. 1, pp. 132-139. DOI:10.1016/j.foodchem.2007.05.050.

BHAVANIRAMYA, S. et al. 2019. Role of essential oils in food safety: Antimicrobial and antioxidant applications. In Grain & oil science and technology, vol. 2, no. 2, pp. 49-55. DOI:10.1016/j.gaost.2019.03.001.

BOUKHATEM, M. N. et al. 2014. Quality assessment of the essential oil from *Eucalyptus globulus* Labill of Blida (Algeria) origin. In International Letters of Chemistry, Physics and Astronomy, vol. 17, no. 3, pp. 303-315.

CHUANG, P.-H. et al. 2007. Anti-fungal activity of crude extracts and essential oil of *Moringa oleifera* Lam. In Bioresource technology, vol. 98, no. 1, pp. 232-236. DOI:10.1016/j.biortech.2005.11.003.

DE DICASTILLO, C. L. et al. 2016. Cross-linked methyl cellulose films with murta fruit extract for antioxidant and antimicrobial active food packaging. In Food Hydrocolloids, vol. 60, pp. 335-344. DOI:10.1016/j.foodhyd.2016.03.020.

DINIZ DO NASCIMENTO, L. et al. 2020. Bioactive natural compounds and antioxidant activity of essential oils from spice plants: New findings and potential applications. In Biomolecules, vol. 10, pp. 988. DOI:10.3390/biom10070988.

FILOMENO, C. A. et al. 2017. *Corymbia* spp. and *Eucalyptus* spp. essential oils have insecticidal activity against *Plutella xylostella*. In Industrial crops and products, vol. 109, pp. 374-383. DOI:10.1016/j.indcrop.2017.08.033.

GAKUUBI, M. M. et al. 2017. Antifungal activity of essential oil of *Eucalyptus camaldulensis* dehnh. against selected *Fusarium* spp. In International journal of microbiology, vol. 2017, pp. 1-7. DOI:10.1155/2017/8761610.

GALOVIČOVÁ, L. et al. 2022. Biological Activity of *Pogostemon cablin* Essential Oil and Its Potential Use for Food Preservation. In Agronomy, vol. 12, no. 2, pp. 387. DOI:10.3390/agronomy12020387.

GHALEM, B. R. et al. 2008. Antibacterial activity of leaf essential oils of *Eucalyptus globulus* and *Eucalyptus camaldulensis*. In African journal of Pharmacy and pharmacology, vol. 2, no. 10, pp. 211-215. DOI:10.5897/AJPP.9000039.

GUIMARÃES DE LIMA, L. G. et al. 2011. Antioxidant and fungitoxic activities of the lemongrass essential oil and citral. In Revista Ciência Agronômica, vol. 42, no. 2, pp. 464-472.

HANIF, M. A. et al. 2019. Essential oils. In: Essential oil research. Springer, Cham, 2019. pp. 3-17.

JANJARASSKUL, T. et al. 2016. Shelf life extension of sponge cake by active packaging as an alternative to direct addition of chemical preservatives. In LWT-Food Science and Technology, vol. 72, pp. 166-174. DOI:10.1016/j.lwt.2016.04.049.

JEMÂA, J. M. B. et al. 2012. Seasonal variations in chemical composition and fumigant activity of five Eucalyptus essential oils against three moth pests of stored dates in Tunisia. In Journal of Stored Products Research, vol. 48, pp. 61-67. DOI:10.1016/j.jspr.2011.10.001.

KAČÁNIOVÁ, M. et al. 2022. Chemical Composition, Antioxidant, *In Vitro* and *In Situ* Antimicrobial, Antibiofilm, and Anti-Insect Activity of Cedar atlantica Essential Oil. In Plants, vol. 11, no .3, pp. 358. DOI:10.3390/plants11030358.

KIENDREBEOGO, M. et al. Antiacetylcholinesterase and antioxidant activity of essential oils from six medicinal plants from Burkina Faso. Revista Brasileira de Farmacognosia, 2011, 21.1: 63-69. DOI:10.1590/S0102-695X2011005000008.

KROCHTA, J. M. 2002. Proteins as raw materials for films and coatings: definitions, current status, and opportunities. In Protein-based films and coatings, vol. 1, p. 1-40.

MARZOUG, H. N. B. et al. 2011. *Eucalyptus oleosa* essential oils: chemical composition and antimicrobial and antioxidant activities of the oils from different plant parts (stems, leaves, flowers and fruits). In Molecules, vol. 16, no.2, pp. 1695-1709. DOI:10.3390/molecules16021695.

MATA, A. T. et al. 2007. Antioxidant and antiacetylcholinesterase activities of five plants used as Portuguese food spices. In Food chemistry, vol. 103, no. 3, pp. 778-786. DOI:10.1016/j.foodchem.2006.09.017.

NAMIKI, M. 1990. Antioxidants/antimutagens in food. In Critical Reviews in Food Science & Nutrition, vol. 29, no.4, pp. 273-300. DOI:10.1080/10408399009527528.

NAZZARO, F. et al. 2017. Essential oils and antifungal activity. In Pharmaceuticals, vol. 10, no. 4, pp. 86. DOI:10.3390/ph10040086.

NOIPA, T. et al. 2011. New approach for evaluation of the antioxidant capacity based on scavenging DPPH free radical in micelle systems. In Food research international, vol. 44, no. 3, pp. 798-806. DOI:10.1016/j.foodres.2011.01.034.

RAMEZANI, H. et al. 2002. Antifungal activity of the volatile oil of *Eucalyptus citriodora*. In Fitoterapia, vol. 73, no. 3, pp. 261-262. DOI:10.1016/S0367-326X(02)00065-5.

REGNAULT-ROGER, C. et al. 2012. Essential oils in insect control: low-risk products in a high-stakes world. In Annual review of entomology, vol. 57, pp. 405-424. DOI:10.1146/annurev-ento-120710-100554.

RIZZOLO, A. et al. 2016. Volatile compound composition and antioxidant activity of cooked ham slices packed in propolis-based active packaging. In Food Packaging and Shelf Life, vol. 8, pp. 41-49. DOI:10.1016/j.fpsl.2016.03.002.

SCHNITZLER, P. et al. 2001. Antiviral activity of Australian tea tree oil and eucalyptus oil against herpes simplex virus in cell culture. In Die Pharmazie, vol. 56, no. 4, pp. 343-347.

SEBEI, K. et al. 2015. Chemical composition and antibacterial activities of seven *Eucalyptus* species essential oils leaves. In Biological research, vol. 48, no. 1, pp. 1-5.

SERRANO, M. et al. 2005. The use of natural antifungal compounds improves the beneficial effect of MAP in sweet cherry storage. In Innovative food science & emerging technologies, vol. 6, no. 1, pp. 115-123. DOI:10.1016/j.ifset.2004.09.001.

SHAABAN, H. A. 2020. Essential Oil as Antimicrobial Agents: Efficacy, Stability, and Safety Issues for Food Application. In Essential Oils-Bioactive Compounds, New Perspectives and Applications, vol. 2020, pp. 1-33.

SHUKLA, R. et al. 2012. Antifungal, aflatoxin inhibition and antioxidant activity of *Callistemon lanceolatus* (Sm.) Sweet essential oil and its major component 1, 8-cineole against fungal isolates from chickpea seeds. In Food Control, vol. 25., no. 1, pp. 27-33. DOI:10.1016/j.foodcont.2011.10.010.

TAKAHASHI, T. et al. 2004. Antimicrobial activities of eucalyptus leaf extracts and flavonoids from *Eucalyptus maculata*. In Letters in applied microbiology, no. 39, no.1, pp. 60-64. DOI:10.1111/j.1472-765X.2004.01538.x.

TOLBA, H. et al. 2015. Essential oil of Algerian Eucalyptus citriodora: Chemical composition, antifungal activity. In Journal de mycologie medicale, vol.25, no. 4, pp. e128-e133. DOI:10.1016/j.mycmed.2015.10.009.

VALKOVÁ, V. et al. 2022. *Cymbopogon citratus* Essential Oil: Its Application as an Antimicrobial Agent in Food Preservation. In Agronomy, vol. 12, no. 1, pp. 155. DOI: 10.3390/agronomy12010155.

VALKOVÁ, V. et al. 2021 b. The *Citrus Reticulata* essential oil: evaluation of antifungal activity against *Penicillium* species related to bakery products spoilage. In *Potravinarstvo*, vol. 2021, pp. 15. DOI:10.5219/1695.

VALKOVÁ, V. et al. 2021a. *In Vitro* antimicrobial activity of lavender, mint, and rosemary essential oils and the effect of their vapours on growth of *Penicillium* spp. in a bread model system. In Molecules, vol. 26, no. 13, pp. 3859. DOI:10.3390/molecules26133859.

VUONG, Q. V. et al. 2015. Physicochemical, antioxidant and anti-cancer activity of a *Eucalyptus robusta* (Sm.) leaf aqueous extract. In Industrial Crops and Products, vol. 64, pp. 167-174. DOI:10.1016/j.indcrop.2014.10.061.

WANG, W. et al. 2008. Antioxidative activity of *Rosmarinus officinalis* L. essential oil compared to its main components. In Food chemistry, vol. 108, no. 3, pp. 1019-1022. DOI:10.1016/j.foodchem.2007.11.046.

YU, L. et al. 2020. Postharvest control of *Penicillium expansum* in fruits: A review. In Food Bioscience, vol. 36, pp. 100633. DOI:10.1016/j.fbio.2020.100633.

Contact address:

Mgr. Veronika Valková, Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 94976 Nitra, Slovakia; Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Fruit Sciences, Viticulture and Enology, Tr. A. Hlinku 2, 94976 Nitra, Slovakia, +421 37 641 4928, veronika.valkova@uniag.sk.

RNDr. Hana Ďúranová, PhD., Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 94976 Nitra, Slovakia, +421 37 641 4975, hana.duranova@uniag.sk.

Ing. Lucia Galovičová, Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Fruit Sciences, Viticulture and Enology, Tr. A. Hlinku 2, 94976 Nitra, Slovakia, +421 907 260 116, l.galovicova95@gmail.com.

prof. Ing. Miroslava Kačániová, PhD., Slovak University of Agriculture in Nitra, Faculty of Horticulture and Landscape Engineering, Department of Fruit Sciences, Viticulture and Enology, Tr. A. Hlinku 2, 94976 Nitra, Slovakia, +421 37 641 4715, miroslava.kacaniova@uniag.sk.

 https://doi.org/10.15414/2022.9788055225029

ARTICLE HISTORY:
Received 19.05.2022
Received in revised form 01.06.2022
Accepted 01.06.2022

BIOSTIMULANT USE IN MODERN AGRICULTURE – THE REVIEW

Samuel Adamec[1]

[1]AgroBioTech Research Centre, Slovak University of Agriculture in Nitra, SLOVAKIA

Abstract

Agriculture, but also the whole world, is facing many significant and rapid changes. We are watching the arrival of new technologies, climate change, the growth of the human population, but also the loss of biodiversity and the urgency of many other environmental problems. Although an intensive and conventional approach still dominates in both agriculture and horticulture, a change of mindset is essential to ensure food security. Both scientists and farmers are looking for more environmentally friendly and, above all, sustainable practices that will sufficiently replace the current cultivation methods and at the same time alleviate the problems that farmers face. Plant biostimulants are a broad group of biological substances and microorganisms, including humic substances, amino acids, algae and plant extracts, and beneficial fungi or bacteria that live naturally in the soil. More and more scientists as well as growers of agricultural and horticultural products are paying close attention to them and have found answers to many problems in biostimulants use. In this review, our aim is to present the current position of biostimulants in modern agricultural development, considering the growing stressors that afflict cultivated plants, improving the fertility and quality of grown food with sustaining and ecologically acceptable crop production.

Key words: biostimulants, sustainability, microorganisms, ecological problems

Introduction

The world's population continues to grow. From an estimated 7.7 billion people worldwide in 2019, the medium-variant projection indicates that the global population could grow to around

8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion in 2100 what presents many challenges for sustainable development (United Nations, 2019). In this scenario, agriculture has a fundamental role in humanity's survival, with increasing consumption of natural resources in agricultural production (Laurett, Mainardes, 2021). Improving the utilization efficiency of agricultural resources is an important way to achieve sustainable agricultural development and it is also the inevitable path to achieving the “dual carbon” strategy, as well as a technical guarantee for the precise implementation of the government’s “emission reduction” policy (Fu, et al. 2022). Agricultural and food system can unequivocally be described as major agent of global change since it has been responsible for more environmental externalities than any other technology in a variety of ways. This system has also had a significant impact on humanity, notably through the process of development with which it is intimately associated (Behnassi, et al. 2014), while the availability, access, utilization, and stability of food supply over time are the four pillars of food security which support nutrition outcomes (Ozgul, et al. 2019).

In most developing countries agriculture products has increased per farmers which exhibits the efficiency of novel technology application thus basic practicing of research and development in the field of agriculture is important (Hajirostamlo, et al. 2015). Since the Green Revolution, worldwide agriculture has been characterized by a typical top–down approach. The degree of autonomy, creativity, and responsibility of farmers has been limited by the continuous external inputs of chemicals, machinery, advice, subsidies, and knowledge (Pagliarino, et al. 2020). For various countries is priority automation in agriculture while traditional strategies employed by farmers are not efficient enough to fulfil the rising demand (Hassan, et al. 2021). It relates to the movement from soil to soilless culture systems, what can improve water use efficiency and management (Gruda, 2019). Pesticides are also contributing in current agriculture to fulfil the need of raising population. But they can be toxic to nature and pose acute risks on the human health and the environment (Rani, et al. 2021). Problem is that improper use of nutrients, water, fertilizers and pesticides disturbs the agricultural growth, and the land remains barren with no fertility (Hassan, et al. 2021).

Despite the intense agricultural production, global agriculture is confronted by several substantial challenges, with some of them being existential, such as emerging infectious plant diseases and adverse impacts of climate change (Lau, et al. 2022; Blakeney, 2022). The natural environment for plants is composed of a complex set of abiotic stresses and biotic stresses. Plant responses to these stresses are equally complex (Cramer, et al. 2011). Climate change bring to plants many stress factors: heat, drought, salinity, tropospheric ozone, and excess UV radiation are one of them (Wang, Frei, 2011). This abiotic stress is defined as environmental conditions that reduce growth and yield below optimum levels, whereas plants require energy (light), water, carbon, and mineral nutrients for growth (Cramer, et al. 2011). Exposure to environmental stress induces numerous physiological stress reactions in plants that can alter the chemical composition of crops and thus the quality of the harvested products (Wang, Frei, 2011). A significant change in climate on a global scale will impact agriculture and remain a challenge to the natural environment and agriculture (De la Pena, Hughes, 2007; Pereira, 2016). Moreover, the decreasing arable land, rising urbanization and increasing scarcity of water acutely demands proper water and soil management practices to ensure crop sustainability (Gruda, 2019; Petropoulos, et al. 2020.). As generally adaptable organisms, insect pests respond differently to different causes of climate change. It is expected that global climate warming could trigger an expansion of their geographic range, increased overwintering survival, increased number of generations, increased risk of invasive insect species and insect-transmitted plant diseases, as well as changes in their interaction with host plants and natural enemies. As climate change exacerbates the pest problem, there is a great need for future pest management strategies (Skendžić, et al. 2021). The search for innovative and alternative methods for chemical control to manage pests is an increasingly growing reality (Pereira, et al. 2021).

Significant sustainable agricultural innovation is required to deal with these challenges (Blakeney, 2022). The issue of sustainability has brought complexity and uncertainty to this mainly linear process of innovation, steering agriculture toward alternative models (Pagliarino, et al. 2020) where input provides stable output with a minimum of unfavourable side effects to the environment. Many current plant production systems are characterized by fast growing, highly extractive plant varieties creating imbalanced ecological interrelationships (Feldmann, et al. 2022).

The use of plant biostimulants has gained substantial and significant heed worldwide as an environment-friendly alternative for sustainable and resilient agricultural production (Hamid, et al. 2021). Biostimulants: According to Regulation (EU) 2019/1009, Article 47, a “plant biostimulant means a product stimulating plant nutrition processes independently of the product’s nutrient content with the sole aim of improving one or more of the following characteristics of the plant or the plant rhizosphere: (a) nutrient use efficiency; (b) tolerance to abiotic stress; (c) quality traits; (d) availability of confined nutrients in soil or rhizosphere.” (EU, 2019). The advancement/understanding in plant-biostimulant interaction relies on the current scientific research to elucidate the extent of benefits conferred by these biostimulants under adverse conditions (Lau, et al. 2022). As products reduces the need for fertilizers and increase plant growth, resistance to water and abiotic stresses. In small concentrations, these substances are efficient, favoring the good performance of the plant’s vital processes, and allowing high yields and good quality products. In addition, biostimulants applied to plants enhance nutrition efficiency, abiotic stress tolerance and/or plant quality traits, regardless of its nutrient contents (De Vasconcelos, Chaves, 2019). Biostimulants boosted physiological and metabolic responses, including gas exchange, leaf water potential, relative water content, and proline accumulation of stressed plants (Elansary, et al. 2020). The characterization of the molecular mechanism of action of biostimulants can be obtained using the omics approach, which includes the determination of transcriptomic, proteomic, and metabolomic changes in treated plants (Franzoni, et al. 2022).

The main active substances used in such preparations are humic and fulvic acids, protein hydrolysates, compounds containing nitrogen, seaweed extracts, beneficial fungi, and bacteria. Biostimulant formulations may be single- or multi-component, but the synergic action of several different components has been observed. Many groups of biostimulants have been distinguished through their method of application (soil, foliar), the material from which they were produced (plant, animal), or the process by which they were created (hydrolysis, fermentation, extraction). Natural soil stimulants can induce the development of beneficial soil organisms that provide substrates for plant growth. The use of natural preparations that are not harmful to the environment is particularly important in connection with the progressive processes of soil degradation and atmospheric pollution (Drobek, et al. 2019). Presently, there is especially an increasing curiosity of industry and researchers in microbial biostimulants especially, bacterial plant biostimulants to improve crop growth and productivity (Hamid, et al. 2021) and with major importance for positive, mutualistic effects, but as well for detrimental effects leading to plant damage and yield loss (Feldmann, et al. 2022). Soil microbial communities also perform critical functions in ecosystem processes (Habig, Swanepoel, 2015).

Material and methods

Several current publications and studies have been prepared as part of the present review. Based on the obtained results and information, we processed three broad areas of importance of biostimulants for the current direction of agriculture and horticulture.

 https://doi.org/10.15414/2022.9788055225029

Results

a) Biostimulants as a tool of mitigating the effects of abiotic and biotic stresses on plants

Agriculture is one of the anthropogenic activities that will be more affected in the future (Buono, 2021). In the current scenario of rapidly evolving climate change, crop plants are more frequently subjected to stresses of both abiotic and biotic origin, including exposure to unpredictable and extreme climatic events, changes in plant physiology, growing season and phytosanitary hazard, and increased losses up to 30% and 50% in global agricultural productions (Sangiorgio, et al. 2020; Parađiković, et al. 2019). Apparently, this is manifested by more occurrences of tropical cyclones, uneven rainfall distribution, leading to transient drought conditions and higher temperatures (Gopalakrishnan, Ghosh, 2022). These stressors are connected through the physiological events at the molecular and cellular level, whereas the metabolites play the crucial role in plant adaptation and survival (Teklić, et al. 2021). This complex and worrying scenario requires the urgent implementation of sustainable measures which are capable of improving crop yield and quality, fostering the robustness and resilience of cropping systems (Buono, 2021). In consequence, resilience against such stresses is one of the keys aims of farmers and is attained by adopting both suitable genotypes and management practices (Mariani, Ferrante, 2017). Some of the strategies to enhance the agricultural productivity would be to genetically engineer drought tolerant plants, but that has regulatory hurdles across the globe. Other way is to devise treatments that bring about tolerance to abiotic stress by regulating the genes responsible for drought tolerance in plants and bolster the antioxidant system in plants (Sangiorgio, et al. 2020; Parađiković, et al. 2019). However, increase of crop stress tolerance through genetic improvements requires long breeding programmes and different cultivation environments for crop performance validation (Bulgari, et al. 2019).

Biostimulants have been proposed as agronomic tools to counteract abiotic stress. These products containing bioactive molecules have a beneficial effect on plants and improve their capability to face adverse environmental conditions, acting on primary or secondary metabolism (Bulgari, et al. 2019). This tolerance in crops could act both by increasing the water absorption capacity of plants and by stimulating the accumulation of substances with protective roles for cell membranes (Franzoni, et al. 2022). Biostimulants have a vital effect on metabolic and physiological processes in plants such as the protection of photosynthetic machinery against photo-damage, generation of reactive oxygen species, elevated level of antioxidants, and increased synthesis of ion transporters. The biostimaultory effects regulate several metabolic and cellular processes which consequently benefits socio-economic and environmental aspects. Biostimulants have a direct effect on antioxidative defense mechanism especially on phenolic compounds, lycopene, and ascorbic acid (Malik, et al. 2021). The mechanisms involved in the protective effects of biostimulants are varied depending on the compound and/or crop and mostly related with improved physiological processes and plant morphology aspects such as the enhanced root formation and elongation, increased nutrient uptake, improvement in seed germination rates and better crop establishment, increased cation exchange, decreased leaching, detoxification of heavy metals, mechanisms involved in stomatal conductance and plant transpiration or the stimulation of plant immune systems against stressors (Shahrajabian, et al. 2021) while living plant roots have long been known to increase soil shear strength and enhance aggregate stability (Mamo, Bubenzer, 2001). But these mechanisms are difficult to identify and are still under study. Considering the physiological effects induced by biostimulants, it is realistic that the bioactive molecules contained in these compounds can affect plant metabolism acting on specific pathways (Franzoni, et al. 2022). Various biostimulants used in plant production nowadays, contain a plethora of functional compounds which can influence on metabolic pathways in treated plants, and chemical composition of plant tissues and organs (Teklić, et al. 2021). Several research have been developed in order to evaluate the biostimulants in improving plant development subjected to stresses, saline environment, and development of seedlings, among others (De Vasconcelos, Chaves, 2019) and many companies are investing in new biostimulant products development and in the identification of the most effective bioactive molecules contained in different kinds of extracts, able to elicit specific plant responses against abiotic stresses. Most of these compounds are unknown and their characterization in term of composition is almost impossible; therefore, they could be classified based on their role in plants (Bulgari, et al. 2019). It is also crucial to design an adequate experimental plan and statistical data analysis, in order to find robust correlations between biostimulant treatments and crop performance (Franzoni, et al. 2022).

Plant growth promoting rhizobacteria (PGPR)-based biostimulants have shown effectiveness in nutrition use, mitigation of abiotic/biotic stress, and/or crop quality characteristics when applied to agricultural and horticultural crop plants (fruits, vegetables, ornamental plants, and medicinal plants). PGPR fight various abiotic and biotic stresses through a multitude of mechanisms or a combination of an array of mechanisms such as phytohormone regulation, signaling pathways, gene regulation and expression, secondary metabolites, VOCs, bioactive compound enhancement, ROS enzyme activities, etc. Furthermore, PGPR make soil elements such as iron, phosphorus, potassium, and zinc more available to plants through the phytohormone regulation, production, and release of siderophores, organic acids, and enzymes (Hamid, et al. 2021). Plant interaction with environment, including either beneficial or pathogenic microorganisms, can result in a significant accumulation of secondary metabolites, as part of a strategy to alleviate abiotic and

 https://doi.org/10.15414/2022.9788055225029

biotic stress that meets the recent trends for low-input agricultural practices (Ganugi, et al. 2021). Under specific conditions, for example within salt stress, the use of the microbial biostimulants modified seedling growth and its response to salt stress. They had a growth-promoting effect on the unstressed seedlings increasing fresh and dry biomass accumulation, leaf number, and leaf area and were successful in increasing salinity tolerance of seedlings (Miceli, et al. 2021). Similarly, arbuscular mycorrhizal fungi (AMF) alone or in combination with plant growth-promoting bacteria (PGPB) had positive effects on the tolerance to a water deficit condition in pots, through the evaluation of biochemical stress markers and hormonal profiles (ABA and IAA). They state that many factors can affect the success of inoculation and persistence of inoculated microorganisms in soil, including compatibility with the target environment, the degree of spatial competition with other soil organisms in the target niche and the timing of inoculation. For this reason, further efforts should be done, mainly for bacteria species, to implement methods for monitoring and characterizing the degree of root/rhizosphere colonization of the microbial inoculants (Mannino, et al. 2020). For example, Petropoulos, et al. (2020) recorded the AM fungi alleviation of negative effects of drought stress on green bean plants and yield. Wild-type plants grown with humic acids are more heat-tolerant compared to those grown in the absence of humic acids. Among other functions, humic acids accelerate the transcriptional expression of heat shock protein with function as molecular chaperones to protect against thermal denaturation of substrates and facilitate refolding of denatured substrates (Cha, et al. 2020).

Modern agriculture increasingly demands an alternative to synthetic chemicals (fertilizers and pesticides) in order to respond to the changes in international law and regulations, but also consumers' needs for food without potentially toxic residues (Rouphael, Colla, 2020). Pesticide soil sorption is a primary factor that influences the fate of pesticides in the environment, affecting regulation of microbiological and chemical degradation, volatilization, and leaching. The organic fraction of the soil was the main soil factor related to the sorption of all study pesticides. Particularly, humic acid content regulated the sorption between pesticide and soil, especially through the carboxylic groups (Alister, et al. 2020).

HS effects of plants are complex and involve non-linear, cross-interrelated and dynamic processes that need be treated with an interdisciplinary view. Being the humic associations recalcitrant to microbiological attack, their use as vehicle to introduce beneficial selected microorganisms to crops has been proposed. This represents a perspective for a sort of new biofertilizer designed for a sustainable agriculture, whereby plants treated with HS become more susceptible to interact with bioinoculants, while HS may concomitantly modify the structure/activity of the microbial community in the rhizosphere compartment (Canellas, Olivares, 2014). Also seaweed based biostimulants have shown enormous potential of mitigating climate change effects by imparting drought tolerance in crops (Gopalakrishnan, Ghosh, 2022) and in Parađiković, et al. (2013) positive influence of biostimulant treatment on yield parameters was observed along with significant decrease in incidence of blossom-end rot (BER) in two pepper cultivars. Promising results were recorded regarding the alleviation of negative effects of drought stress after application of arbuscular mycorrhizal fungi (AMF; G treatment), which increased the total yield of green pods up to 20,8%. Moreover, the nutritional value and chemical composition of pods and seeds was positively affected by biostimulants application (Barsanti, et al. 2019).

Biostimulants are among the natural preparations that improve the general health, vitality, and growth of plants and protect them against infections. They can be successfully used in both agri- and horticultural crops (Drobek, et al. 2019). This feature is even more current because more than one-tenth of all pests have reached more than half the countries that grow their hosts. If current trends continue, many important crop-producing countries will be fully saturated with pests by the middle of the century. While dispersal increases with host range overall, fungi have the narrowest host range but are the most widely dispersed group (Bebber, et al. 2014). Many biostimulants prove their beneficial effect as a protective tool against plant pests and diseases, for example: Soppelsa, et al. (2018) tested several biostimulants (10 in total), including humic acids, macro and micro seaweed extracts, alfalfa protein hydrolysate, amino acids alone or in combination with zinc, B-group vitamins, chitosan and a commercial product containing silicon on apples. The research shown their positive effect on storage disorders. The use of AM as biopesticides has not only an impact on plant health, but also indirectly on the protection of the environment and our health as it reduces the need for harmful chemical pesticides (Adamec, Andrejiová, 2018). In the research of D'Addabbo, et al. (2019) source materials of most biostimulants derived from plant or seaweed raw materials were documented for a reliable suppression of root-knot nematode species on tomato. The suppressiveness of microbial biostimulants was found largely variable, as related to the crop and to environmental factors. Chitosan-based biostimulants were also stated for a variable phytonematode suppression, though clearly demonstrated only by a few numbers of studies.

b) <u>Biostimulants and their beneficial effect on yields and quality of agricultural products</u>

Modifications in growing techniques can affect the yield and nutritional quality of various cultivated plant species (Parađiković, et al. 2011, Grabowska, et al. 2012). Biostimulants are preparations that favorably impact the growth, development, and yield of plants (Kocira, et al.

2020), while the advantage of using these substances is just due to their effectiveness in improving crop productivity and quality (Buono, 2021). In wide array of studies, the evaluated biostimulants mostly enhanced seed and transplant vigor, stimulated vegetative growth, improved nutrient acquisition and distribution within the plant, increased antioxidative capacity of plant tissues, contributing to higher stress tolerance, and improved plant yield and fruit/flower quality (Sangiorgio, et al. 2020, Parađiković, et al. 2019). Biostimulants have been gaining interest as they also stimulate crop physiology and biochemistry such as the ratio of leaf photosynthetic pigments (carotenoids and chlorophyll), enhanced antioxidant potential, tremendous root growth, improved nutrient use efficiency (NUE), and reduced fertilizers consumption (Malik, et al. 2021).

Each group of biostimulants can exhibit a specific set of features which can be shown by example of plant growth promoting bacteria (PGPB). The plant biostimulants that are based on PGPR (plant growth-promoting rhizobacteria) play plausible roles to promote/stimulate the crop plant growth through several mechanisms that include, i) nutrient acquisition by nitrogen (N2) fixation and solubilization of insoluble minerals (P, K, Zn), organic acids and siderophores, ii) antimicrobial metabolites and various lytic enzymes, iii) action of growth regulators and stress-responsive/induced phytohormones, iv) ameliorating abiotic stress like drought, high soil salinity, extreme temperatures, oxidative stress, and heavy metals by using different modes of action, and v) plant defence induction modes (Hamid, et al. 2021). The elicitation of these plant secondary metabolism can promote the accumulation of functional compounds in the edible portions. Considering that plant defence processes and the related redox imbalance play a pivotal role in plant response to microorganisms, the use of microbial biostimulants leads to accumulation of antioxidant compounds (Ganugi, et al. 2021). They can also mitigate abiotic/biotic stress, and/or crop quality characteristics when applied to agricultural and horticultural crop plants (fruits, vegetables, ornamental plants, and medicinal plants). PGPR make soil elements such as iron, phosphorus, potassium, and zinc more available to plants through the phytohormone regulation, production, and release of siderophores, organic acids, and enzymes (Hamid, et al. 2021).

From many studies it can be mentioned: A positive effect of PGPB biostimulant on the quality of carrots from organic and nonorganic farms: applied in couple they promoted the accumulation of monosaccharides, ascorbic acid, carotenoids, phenols, and increased antioxidant activity (Gavelienė, et al. 2021). Other bacterial biostimulant had a positive effect on the flower and fruit set numbers, as well as on the pollination efficiency in all genotypes of cultivated eggplants (Pohl, et al. 2019). Under open field conditions, the lettuce shoot and root dry weight increased by 61% and 57%, respectively, with biostimulant microorganism application in field conditions. For zucchini, early and total yields were significantly increased by 59% and 15%, respectively, when plants were inoculated with both microorganisms (Colla, et al. 2015). Under non-fertilized regimens, foliar PBs application boost growth and yield of baby lettuce in comparison to non-treated plants: significant increases in marketable fresh yield (averaging 14%, 6% and 7% at 10, 20 and 30 kg N·ha^{-1}, respectively) compared to untreated plants (Di Mola, et al. 2019).

However, there are a number of results demonstrating the effects of other types of biostimulants: The use of alfalfa hydrolysate, vitamins, chitosan, and silicon was able to promote biomass accumulation in roots (four to seven folds) and fruits (+20%) of treated strawberry plants. Final berry yield was found around 20% higher in chitosan- and silicon-treated plants. Chitosan treatment significantly increased pulp firmness (by 20 %), while a high nutritional value (e.g., phenolic compounds concentration) was observed in alfalfa- and seaweed-treated fruits (+18 % – 20 % as compared to control). Aminoplant significantly influenced not only carrot productivity, but mainly chemical composition of the roots of carrot (Grabowska, et al. 2012). Rodrigues, et al. (2020) describes positive effect on fruit, plant growth and quality of tomato, pepper, grapevine, apple, berry and apricot are also displayed by algae extracts and protein hydrolysates. Amino acid biostimulant showed positive and negative effects on plants and harvest and exhibited high resistance, stable growth, and fruits with few rots of tomatoes (Balas, et al. 2021). Sweet corn plant height, total nitrogen, total protein and organic matter content were significantly affected by the foliar application treatments, while leaves number, root length, root/shoot length ratio, ear length, leaf relative water content, water potential, phosphorus and potassium were not significantly affected by the foliar application treatments (Nolla, et al. 2019), however in study Adamec, et al. (2020) amino acids they did not have a statistically significant effect on the yield and quality of sweetcorn. The tomato fruits of paramylon-treated plants (from microalgae) reached the first ripening stage two weeks before untreated plants grown under the optimal water regime. Moreover, antioxidant compounds (carotenoids, phenolic acid, and vitamins) of fruits from treated plants underwent a two-fold increase with respect to untreated plants, as well as soluble carbohydrates (glucose, fructose, and sucrose) (Barsanti, et al. 2019). The macroseaweed extract was effective in stimulate apple tree growth potential in both years, as shown by a significantly larger leaf area (+20% as compared to control) and by a higher chlorophyll content and leaf photosynthetic rate. As for the yield performances and apples quality traits at harvest (Soppelsa, et al. 2018). In different research humic substances increased carotenoids and total soluble solids content in carrot roots (Fabianová, et al. 2021).

As we described, there are many examples that the application of plant biostimulants can improve not only the yield but also the nutritional quality of fruits (Rodrigues, et al. 2020). Biostimulants improved the antioxidant activity, vitamin C and phenolic contents in fruits as well as the pigment

 https://doi.org/10.15414/2022.9788055225029

content in leaves of treated compared with non-treated pepper plants (Di Mola, et al. 2019). Plant fresh and dry weights were significantly influenced by all the tested biostimulants. Significant increases in protein, carbohydrate and chlorophyll content in amaranthus hybridus (Ngoroyemoto, et al. 2019). The applicated biostimulants significantly increased the yield, and slightly increased carotenoids, anthocyanins and total phenols in leaf lettuce (Amanda, et al. 2009). The biostimulants enhanced plant growth and the productivity of perennial wall rocket. The winter–spring cycle led to higher leaf yield than the winter one. The two plant biostimulants enhanced leaf dry matter, oxalic and citric acids, Ca and P concentrations, phenols, and ascorbic acid content as well as antioxidant activity, but did not increase nitrate content (Caruso, et al. 2019). The biostimulant application increased a wealth of traits, including P, Mg, Fe, Mn, and Zn by 20.8 % – 97.4% and various phenolic acids compared to the non-inoculated control. This effect occurred irrespective of the water availability. In addition, the microbial-based biostimulant increased plant yield, Ca and Cu, and isochlorogenic acid concentrations (Saia, et al. 2019). Similarly, in Parađiković, et al. (2013) Biostimulants increased yield, macro- and microelement content in fruits of treated pepper cultivars. A biostimulants applied in couple promoted the accumulation of monosaccharides, ascorbic acid, carotenoids, phenols, and increased antioxidant activity (Hamid, et al. 2021) and increased cucumber yield due to improving chemical and physical features related to immunity, productivity, and stress defense (Hassan, et al. 2021). A single and combined use of high-purity fulvic acid and PGPR had positive effects on the growth of cherry tomato in fertile soil and under stressed conditions (Turan, et al. 2021).

c) Biostimulants and their place in future challenges in agriculture and horticulture

The international agricultural research agenda has evolved over the past 50 years as development needs and goals related to food and agriculture is changing dramatically. An early focus on increasing yields for staple crops now encompasses work on dynamic food systems, multiple burdens of malnutrition, and climate and ecosystem challenges (Pardey, et al. 2014; McDermott, J. 2019). The primary objective of modern agriculture includes the environmental sustainability, low production costs, improved plants' resilience to various biotic and abiotic stresses, and high sowing seed value (Amanda, et al. 2009). Over the past half century or so, hundreds of studies have been published reporting measures of agricultural productivity, the effects of agricultural research and development on agricultural innovation and productivity patterns, and the resulting social payoffs to investments in agricultural research and development (Malik, et al. 2021). The traditional agricultural production systems are evolving more and more towards organic, sustainable, or environmentally friendly systems. On the other hand, it is important to keep the

 https://doi.org/10.15414/2022.9788055225029

yield and the quality of crops (Vernieri, et al. 2005). Organic farming has generated significant interest among consumers and scientists owing to their healthier and safer characteristics to human health. However, nutrient (N and P) availability has been identified to be a major yield-limiting factor in many organic farming systems (De Pascale, et al. 2017).

An increasing need for a more sustainable agriculturally productive system is required to preserve soil fertility and reduce soil biodiversity loss (Castiglione, et al. 2021), what is further augmented with the exclusion of synthetic fertilizers and pesticides (Lau, et al. 2022). The challenges before us in plant biology and crop improvement are to integrate the systems level information on abiotic stress response pathways, identify stress protective networks, and engineer environmentally stable crops that yield more, with less water and dwindling natural resources, to feed the growing world population (Pereira, 2016). Biological inputs can stimulate the substitution of chemical inputs without questioning the current fundaments or can be adopted as a turning point to intensify the harsh processes of transition to more environmentally friendly agriculture (Olivares, et al. 2017). It is necessary to increase our knowledge on the bio-molecular action mechanisms. Unravelling the molecular effects of these diverse metabolites or metabolite mixtures is a complex task that justifies a multi-disciplinary approach embracing genomics, transcriptomics, proteomics, and metabolomics, as well as plant physiology (Carillo, et al. 2020).

High-throughput phenotyping technologies successfully employed in plant breeding and precision agriculture, could prove extremely useful in unravelling biostimulant-mediated modulation of key quantitative traits, and would also facilitate the screening process for development of effective biostimulant products in controlled environments and field conditions (Rouphael, et al. 2018). Furthermore, a special consideration has been given to the application of biostimulants in intensive agricultural systems that minimize the fertilizers' usage without affecting quality and yield along with the limits imposed by European Union (EU) regulations (Malik, et al. 2021). That is why designing and developing new biostimulants is a crucial process which requires an accurate testing of the product effects on the morpho-physiological traits of plants and a deep understanding of the mechanism of action of selected products. Product screening approaches using omics technologies have been found to be more efficient and cost effective in finding new biostimulant substances (Paul, et al. 2019). In fact, the effectiveness of biostimulants mainly depends on their composition, which unfortunately remains the most critical point, given the difficulty in characterizing it. To obtain more stable biostimulants, efforts have been made to reduce the heterogeneity of the starting materials and to standardize the different extraction technologies used. (Franzoni, et al. 2022). The main scientific challenge in this field is the complexity of the physiological effects of biostimulants. In general terms, the primary effects of biostimulants are to

 https://doi.org/10.15414/2022.9788055225029

induce physiological responses in the plant. Many of these responses bear on primary metabolism, growth and development. These processes are subject to tight homeostatic regulations which originate from millions of years of biological evolution and explain why plants occupy specific ecological niches and display characteristic phenotypic responses to fluctuating environments. Acting on such biological processes is challenging and attention should be paid to the many cross talks between processes and pathways in plant organisms in their response to their environment. Furthermore, the use of biostimulants can only be successful if the tripartite interactions between the biostimulant, the plant and the environment can be properly addressed. As an example, phosphorus mobilization by the help of phosphatase-releasing PGPRs may contribute to plant growth and crop yield if soil inorganic phosphate is indeed limiting and if the plant contributes to the maintenance and activity of the PGPR inoculant in the rhizosphere, e.g. via its exudates (Du Jardin, 2015).

Plants coevolved with microbial symbionts, which are involved in major functions both at the ecosystem and plant level. The use of microbial biostimulants, by exploiting this symbiotic interaction, represents a sustainable strategy to increase plant performances and productivity, even under stresses due to climate changes (Sangiorgio, et al. 2020; Parađiković, et al. 2019). Microbial biostimulants are innovative technologies able to ensure agricultural yield with high nutritional values, overcoming the negative effects derived from environmental changes. The increased use of these products requires the achievement of an accurate selection of beneficial microorganisms and consortia, and the ability to prepare for future agriculture challenges (Castiglione, et al. 2021). Fertilizer levels seemed to play a minor role in determining microbial diversity and activity, whereas the cropping systems played a more important role in determining the activity of soil microbial communities (Habig, Swanepoel, 2015). Similarly maximum benefits from activity of arbuscular mycorrhizal fungi will be achieved by adopting beneficial farming practices (e.g. reduction of chemical fertilisers and biocides), by inoculating efficient arbuscular mycorrhizal fungi strains and also by the appropriate selection of plant host/fungus combinations (Rouphael, et al. 2015). This is an area where modern farming systems such as the precision agriculture plays an important role, whereas precision fertilization is the core of this field (Chen, et al. 2014) and specifically targeted products, based on the characterization of plant-microbe and microbial community interactions (Sangiorgio, et al. 2020, Parađiković, et al. 2019).

The diversity of biostimulants also reflects their variability in terms of their effect after application. For example, chitosan as biostimulant can be used in plant defense systems against biological and environmental stress conditions and as a plant growth promoter—it can increase stomatal conductance and reduce transpiration or be applied as a coating material in seeds. Moreover, it can be effective in promoting chitinolytic microorganisms and prolonging storage life through post-harvest treatments, or benefit nutrient delivery to plants since it may prevent leaching and improve slow release of nutrients in fertilizers. Finally, it can remediate polluted soils through the removal of cationic and anionic heavy metals and the improvement of soil properties (Shahrajabian, et al. 2021). New exciting biological advances are expected from the application of molecular genetics to investigate the unexplored plant responses to algal extracts. The need to reduce the non-renewable chemical input in agriculture has recently prompted an increase in the use of algal extracts as a plant biostimulant, also because of their ability to promote plant growth in suboptimal conditions such as saline environments is beneficial (Carillo, et al. 2020). Simirarly, botanical extracts of higher and lower group of plants and specifically already commercialized seaweed extracts have shown enormous potential as 'biostimulants' in agricultural system. Systematic application of plant-based products has up-scaled nutrition uptake; exhibited growth promoting activity; improved different modes of environmental stress tolerance; emphasized defense dynamics and significantly enhanced crop productivity. However, selection, characterization, dosage optimization, technical constrains and real-time evaluation are the five major complex bottlenecks in front of wide range acceptance botanical extracts and seaweed extracts (Tudu, et al. 2022).

Humic substances are viewed as an inherent component of soil organic matter, which plays multiple life-sustaining functions in the environment. The complexity of the molecular ensemble of humic substances is reflected in singular physicochemical features and results in uniquely broad and diverse interactions with both abiotic components and living organisms directed towards adaptation of life to its abiotic environment (Perminova, et al. 2019). Humic acid-based products have been used in crop production in recent years to ensure the sustainability of agriculture production. Reviewed literature shows that humic acids can positively affect soil physical, chemical, and biological characteristics, including texture, structure, water holding capacity, cation exchange capacity, pH, soil carbon, enzymes, nitrogen cycling, and nutrient availability (Kwame, et al. 2022). An enhanced knowledge of the effects on plants physiology and biochemistry and interaction with rhizosphere and endophytic microbes should lead to achieve increased crop productivity through a better use of humic substances inputs in Agriculture (Canellas, Olivares, 2014).

If the natural basis is diverse and stable, the modification of agricultural cultivation methods can be the key for starting a change to more ecologically equilibrated production systems. Introducing microorganisms to production systems can boost the system only for a short time, e.g. one season, if the microbes cannot establish sustainably. Sustainable establishment of microorganisms is only

 https://doi.org/10.15414/2022.9788055225029

possible if the growth conditions for them are appropriately modified in the production system parallel to inoculation. Modifications of the abiotic environment can be effectively initiated by non-microbial biostimulants and soil improvers, which nevertheless might have positive or negative effects on other soil factors (Feldmann, et al. 2022). However, also growing technique which combines soilless culture and biostimulants may reduce nutrient and water use with beneficial impact on the environment (Parađiković, et al. 2013). Overall, agronomic factors such as cultivar selection and biostimulant management i.e., how much biostimulant to use, when to use it, where to use it (greenhouse or open field), and in which modality it is administered (foliar, drench, seed treatment, nutrient solution), sometimes are the make-or-break decisions that may or may not express the crops' and products' full potential, and still have to be carefully considered (Cristofano, et al. 2021).

Conclusion

Within this study we reviewed the role of biostimulants in the process of current changes and problems facing agriculture. We have divided our study into three larger chapters, each of which addresses one of the basic areas in which biostimulants have found their importance in today's agriculture.

In the first chapter, we focused mainly on their impact on plants exposed to stressful conditions, such as climate change and fluctuations, poor soil quality, lack of water or increasing pressure from diseases and pests.

In the second chapter we deal with the effect of biostimulants on the quality and yield of cultivated crops, vegetables and fruits. We consider the great variability of biostimulation products and the diversity of their functional mechanisms by which they stimulate plants. We describe their action mainly on the example of a group of beneficial microorganisms.

In the third chapter, we conducted scientific studies on why biostimulants are proving to be a nature-friendly solution to new farming practices, and what are the basic options for a better understanding of biostimulants and their interactions between plants, soil and soil life.

Based on many studies and scientific publications proving and describing the observed beneficial effects of biostimulants on plants, we can conclude that biostimulants are indeed a very potential means of achieving sustainable agriculture in the future. However, it is necessary to know many factors related to their use, such as the farmer's agricultural technology and method of application of biostimulants, soil type and quality, crop species and variety or climatic characteristics of the area.

Therefore, there is still plenty of room for future studies that can provide a wealth of valuable information and bring closer the truly effective use of these promising biological products and microorganisms.

Acknowledge

This publication was supported by the Operational Program Integrated Infrastructure within the project: Demand-driven Research for the Sustainable and Innovative Food, Drive4SIFood 313011V336, cofinanced by the European Regional Development Fund.

References

ADAMEC, S. – ANDREJIOVÁ, A. 2018. Mycorrhiza and Stress Tolerance of Vegetables: A Review. Acta Horticulturae et Regiotecturae, vol.21, no.2, pp.30-35. https://doi.org/10.2478/ahr-2018-0008.

ADAMEC, S. et al. 2020. Evaluation of the foliar nutrition influence on selected quantitative and qualitative paprameters of sugar mayze (Zea mays SK saccharata). Potravinarstvo Slovak Journal of Food Sciences, 14, 208–215. https://doi.org/10.5219/1194.

ALISTER, C. et al. 2020. Humic Substances and their Relation to Pesticide Sorption in Eight Volcanic Soils. Article; Planta daninha 38, https://doi.org/10.1590/S0100-83582020380100021.

AMANDA, A. et al. 2009. EFFECT OF BIOSTIMULANTS ON QUALITY OF BABY LEAF LETTUCE GROWN UNDER PLASTIC TUNNEL. Acta Hortic. 807, 407-412 https://doi.org/10.17660/ActaHortic.2009.807.58.

BALAS, J. et al. 2021. Biostimulants affect the quality and yield of tomato fruits from open-field production. Acta Hortic. 1326, 93-102 https://doi.org/10.17660/ActaHortic.2021.1326.12.

BARSANTI, L. et al. 2019. Paramylon Treatment Improves Quality Profile and Drought Resistance in Solanum lycopersicum L. cv. Micro-Tom. Agronomy. 9(7):394. https://doi.org/10.3390/agronomy9070394.

BEBBER, D. P. et al. 2014. The global spread of crop pests and pathogens. Global Ecology and Biogeography. 23 (12), pp. 1398-1407. https://doi.org/10.1111/geb.12214.

BEHNASSI, M. et al. 2014. Agricultural and Food System—Global Change Nexus: Dynamics and Policy Implications. in: Science, Policy and Politics of Modern Agricultural System. 2014. Original Paper, Chapter 1. Available at: https://www.springerprofessional.de/en/agricultural-and-food-system-global-change-nexus-dynamics-and-po/4830718.

BLAKENEY, M. 2022. Agricultural Innovation and Sustainable Development. Sustainability. 14(5):2698. https://doi.org/10.3390/su14052698.

BULGARI, R. et al. 2019. Biostimulants Application in Horticultural Crops under Abiotic Stress Conditions. Agronomy. 2019; 9(6):306. https://doi.org/10.3390/agronomy9060306.

BUONO, D.D. 2021. Can biostimulants be used to mitigate the effect of anthropogenic climate change on agriculture? It is time to respond, In Science of The Total Environment, Volume 751, 141763, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2020.141763.

CANELLAS, L.P. – OLIVARES, F.L. 2014. Physiological responses to humic substances as plant growth promoter. Chem. Biol. Technol. Agric. 1, 3. https://doi.org/10.1186/2196-5641-1-3.

CARILLO, P. et al. 2020. Enhancing Sustainability by Improving Plant Salt Tolerance through Macro- and Micro-Algal Biostimulants. In Biology. 9(9):253. https://doi.org/10.3390/biology9090253.

CARUSO, G. et al. 2019. Protein Hydrolysate or Plant Extract-based Biostimulants Enhanced Yield and Quality Performances of Greenhouse Perennial Wall Rocket Grown in Different Seasons. Plants. 8(7):208. https://doi.org/10.3390/plants8070208

CASTIGLIONE, A.M. et al. 2021. Microbial Biostimulants as Response to Modern Agriculture Needs: Composition, Role and Application of These Innovative Products. Plants. 10(8):1533. https://doi.org/10.3390/plants10081533.

CHA, J. Y. et al. 2020. Humic acid enhances heat stress tolerance via transcriptional activation of Heat-Shock Proteins in Arabidopsis. Scientific reports, 10(1), 15042. https://doi.org/10.1038/s41598-020-71701-8.

CHEN, C. et al. 2014. A review of precision fertilization research. Environ Earth Sci 71, 4073–4080. https://doi.org/10.1007/s12665-013-2792-2

COLLA, G. et al. 2015. Co-inoculation of Glomus intraradices and Trichoderma atroviride acts as a biostimulant to promote growth, yield and nutrient uptake of vegetable crops. J. Sci. Food Agric., 95: 1706-1715. https://doi.org/10.1002/jsfa.6875.

CRAMER, G.R. et al. 2011. Effects of abiotic stress on plants: a systems biology perspective. BMC Plant Biol 11, 163. https://doi.org/10.1186/1471-2229-11-163.

CRISTOFANO, F. et al. 2021. Biostimulant Substances for Sustainable Agriculture: Origin, Operating Mechanisms and Effects on Cucurbits, Leafy Greens, and Nightshade Vegetables Species. Biomolecules, 11(8), 1103. https://doi.org/10.3390/biom11081103.

D'ADDABBO, T. et al. 2019. Biostimulants for Plant Growth Promotion and Sustainable Management of Phytoparasitic Nematodes in Vegetable Crops. Agronomy, 9, 616. https://doi.org/10.3390/agronomy9100616.

DE LA PENA, R. – Hughes, J. 2007. Improving vegetable productivity in a variable and changing climate. International Crops Research Institute for the Semi-Arid Tropics, 4, 1-22. Available at: https://www.researchgate.net/publication/26520774.

DE PASCALE, S. et al. 2017. Plant biostimulants: innovative tool for enhancing plant nutrition in organic farming. in Eur.J.Hortic.Sci. 82(6), 277-285. DOI: 10.17660/eJHS.2017/82.6.2, https://doi.org/10.17660/eJHS.2017/82.6.2.

DE VASCONCELOS, A. C. F. – Chaves, L. H. G. 2019. Biostimulants and Their Role in Improving Plant Growth under Abiotic Stresses. In S. M. Mirmajlessi, & R. Radhakrishnan (Eds.), Biostimulants in Plant Science. IntechOpen. https://doi.org/10.5772/intechopen.88829.

DI MOLA, I. et al. 2019. Effect of Vegetal- and Seaweed Extract-Based Biostimulants on Agronomical and Leaf Quality Traits of Plastic Tunnel-Grown Baby Lettuce under Four Regimes of Nitrogen Fertilization. Agronomy. 9(10):571. https://doi.org/10.3390/agronomy9100571.

DROBEK, M. et al. 2019. Plant Biostimulants: Importance of the Quality and Yield of Horticultural Crops and the Improvement of Plant Tolerance to Abiotic Stress—A Review. Agronomy. 2019; 9(6):335. https://doi.org/10.3390/agronomy9060335.

DU JARDIN, P. 2015. Plant Biostimulants: Definition, Concept, Main Categories and Regulation. Scientia horticulturae, v. 196 ,. pp. 3-14. doi: 10.1016/j.scienta.2015.09.021.

ELANSARY, O.H. et al. 2020 Effects of Water Stress and Modern Biostimulants on Growth and Quality Characteristics of Mint. Agronomy. 10(1):6. https://doi.org/10.3390/agronomy10010006.

EU (2019) Regulation (EU) 2019/1009 of the European Parliament and of the Council of 5 June 2019 laying down rules on the making available on the market of EU fertilising products and amending Regulations (EC) No 1069/2009 and (EC) No 1107/2009 and repealing Regulation (EC) No 2003/2003

FABIANOVÁ, J. et al. 2021. The effect of soil biostimulant Agriful on the selected quantitative and qualitative parameters of carrot (Daucus carota subsp. sativus (Hoffm.) Arcang.). Potravinarstvo Slovak Journal of Food Sciences, 15, 1120–1127. https://doi.org/10.5219/1696.

FELDMANN, F. et al. 2022. Biostimulants, soil improvers, bioprotectants: promoters of bio-intensification in plant production. J Plant Dis Prot. https://doi.org/10.1007/s41348-022-00567-x

FRANZONI, G. et al. 2022. Biostimulants on Crops: Their Impact under Abiotic Stress Conditions. Horticulturae. 8(3):189. https://doi.org/10.3390/horticulturae8030189.

FU, L. et al. 2022 Evaluation of Agricultural Sustainable Development Based on Resource Use Efficiency: Empirical Evidence From Zhejiang Province, China. Front. Environ. Sci. 10:860481. https://doi.org/10.3389/fenvs.2022.860481.

GANUGI, P. et al. 2021. Microbial biostimulants as a sustainable approach to improve the functional quality in plant-based foods: a review, Current Opinion in Food Science, Volume 41, Pages 217-223, ISSN 2214-7993, https://doi.org/10.1016/j.cofs.2021.05.001.

GAVELIENĖ, V. et al. 2021. Plant Microbial Biostimulants as a Promising Tool to Enhance the Productivity and Quality of Carrot Root Crops. Microorganisms. 9(9):1850. https://doi.org/10.3390/microorganisms9091850.

GOPALAKRISHNAN, V.A.K. – GHOSH, A. 2022. Seaweed Biostimulants for Climate Change Adaptations in Dryland Agriculture in Semi-arid Areas. In: Poshiwa, X., Ravindra Chary, G. (eds) Climate Change Adaptations in Dryland Agriculture in Semi-Arid Areas. Springer, Singapore. https://doi.org/10.1007/978-981-16-7861-5_25.

GRABOWSKA, A. et al. 2012. The Effect of Cultivar and Biostimulant Treatment on the Carrot Yield and its Quality. Journal of Fruit and Ornamental Plant Research, 77, 37 - 48.

GRUDA, N.S. 2019. Increasing Sustainability of Growing Media Constituents and Stand-Alone Substrates in Soilless Culture Systems, Agronomy 9, no. 6, 298. https://doi.org/10.3390/agronomy9060298.

HABIG, J. – SWANEPOEL, C. 2015. Effects of Conservation Agriculture and Fertilization on Soil Microbial Diversity and Activity. Environments. 2(3):358-384. https://doi.org/10.3390/environments2030358.

HAJIROSTAMLO, B. et al. 2015. The Role of Research and Development in Agriculture and Its Dependent Concepts in Agriculture. In Asian Journal of Applied Science and Engineering, Vol. 4. pp. 78-80.

HAMID, B. et al. 2021. Bacterial Plant Biostimulants: A Sustainable Way towards Improving Growth, Productivity, and Health of Crops. Sustainability. 13(5):2856. https://doi.org/10.3390/su13052856.

HASSAN, S. I. et al. 2021. A Systematic Review on Monitoring and Advanced Control Strategies in Smart Agriculture, in IEEE Access, vol. 9, pp. 32517-32548, doi: 10.1109/ACCESS.2021.3057865.

HASSAN, S.M. et al. 2021. Impact of Seaweed Liquid Extract Biostimulant on Growth, Yield, and Chemical Composition of Cucumber (Cucumis sativus). Agriculture. 11(4):320. https://doi.org/10.3390/agriculture11040320.

KOCIRA, A. et al. 2020. Changes in Biochemistry and Yield in Response to Biostimulants Applied in Bean (Phaseolus vulgaris L.). Agronomy. 10(2):189. https://doi.org/10.3390/agronomy10020189.

KWAME, A. et al. 2022. Understanding the Role of Humic Acids on Crop Performance and Soil Health. Frontiers in Agronomy, 2022. vol. 4. doi: 10.3389/fagro.2022.848621.

LAU, S.E. et al. 2022. Microbiome engineering and plant biostimulants for sustainable crop improvement and mitigation of biotic and abiotic stresses. Discov Food 2, 9 (2022). https://doi.org/10.1007/s44187-022-00009-5.

LAURETT, R. P. A. – MAINARDES, E. W. 2021. Sustainable Development in Agriculture and its Antecedents, Barriers and Consequences – An Exploratory Study, In Sustainable Production and Consumption, Volume 27, Pages 298-311, ISSN 2352-5509, https://doi.org/10.1016/j.spc.2020.10.032.

MALIK, A. et al. 2021. Biostimulant-Treated Seedlings under Sustainable Agriculture: A Global Perspective Facing Climate Change. Agronomy. 11(1):14. https://doi.org/10.3390/agronomy11010014.

MAMO, M. – BUBENZER, G.D. 2001. Detachment Rate, Soil Erodibility, And Soil Strength As Influenced By Living Plant Roots Part I: Laboratory STUDY. Transactions of the ASABE, 44, 1167-1174.

MANNINO, G. et al. 2020. Effects of Different Microbial Inocula on Tomato Tolerance to Water Deficit. Agronomy. 10(2):170. https://doi.org/10.3390/agronomy10020170.

MARIANI, L. – FERRANTE, A. 2017. Agronomic Management for Enhancing Plant Tolerance to Abiotic Stresses—Drought, Salinity, Hypoxia, and Lodging. Horticulturae. 3(4):52. https://doi.org/10.3390/horticulturae3040052.

MCDERMOTT, J. 2019. Leveraging Agri-Food Systems for Food Security and Nutrition – The Role of International Research for Development, Editor(s): Pasquale Ferranti, Elliot M. Berry, Jock R. Anderson, Encyclopedia of Food Security and Sustainability, Elsevier, Pages 411-417, ISBN 9780128126882, https://doi.org/10.1016/B978-0-08-100596-5.21566-7.

MICELI, A. et al. 2021. Use of Microbial Biostimulants to Increase the Salinity Tolerance of Vegetable Transplants. Agronomy, 11, 1143. https://doi.org/10.3390/agronomy11061143.

NGOROYEMOTO, N. et al. 2019. Effect of organic biostimulants on the growth and biochemical composition of Amaranthus hybridus L., in South African Journal of Botany, Volume 124, Pages 87-93,https://doi.org/10.1016/j.sajb.2019.03.040.

NOLLA, A. et al. 2019. Soil coverage, phytomass production and nutrient accumulation at intercropping maize and legumes system. 2019, 13(03), doi: 10.21475/ajcs.19.13.03.

OLIVARES, F.L. et al. 2017. Plant growth promoting bacteria and humic substances: crop promotion and mechanisms of action. Chem. Biol. Technol. Agric. 4, 30. https://doi.org/10.1186/s40538-017-0112-x.

OZGUL, A. et al. 2019. The Future Challenges of Food and Agriculture: An Integrated Analysis of Trends and Solutions, Sustainability 11, no. 1: 222. https://doi.org/10.3390/su11010222.

PAGLIARINO, E. et al. 2020. Participatory research for sustainable agriculture: the case of the Italian agroecological rice network. Eur J Futures Res 8, 7. https://doi.org/10.1186/s40309-020-00166-9.

PARAĐIKOVIĆ, N. et al. 2011, Effect of natural biostimulants on yield and nutritional quality: an example of sweet yellow pepper (Capsicum annuum L.) plants. J. Sci. Food Agric., 91: 2146-2152. https://doi.org/10.1002/jsfa.4431.

PARAĐIKOVIĆ, N. et al. 2013. Natural biostimulants reduce the incidence of BER in sweet yellow pepper plants (Capsicum annuum L.). Agricultural and Food Science, 22(2), 307–317. https://doi.org/10.23986/afsci.7354.

PARAĐIKOVIĆ, N. et al. 2019. Biostimulants research in some horticultural plant species—A review. Food Energy Secur. 8:e00162. https://doi.org/10.1002/fes3.162.

PARDEY, P.G. et al. 2014. Investments in and the Economic Returns to Agricultural and Food R&D Worldwide, Editor(s): Neal K. Van Alfen, in Encyclopedia of Agriculture and Food Systems, Academic Press, Pages 78-97, ISBN 9780080931395, https://doi.org/10.1016/B978-0-444-52512-3.00045-0.

PAUL, K. et al. 2019. Understanding the Biostimulant Action of Vegetal-Derived Protein Hydrolysates by High-Throughput Plant Phenotyping and Metabolomics: A Case Study on Tomato. Front Plant Sci. 8;10:47. doi: 10.3389/fpls.2019.00047.

PEREIRA, A. 2016. Plant Abiotic Stress Challenges from the Changing Environment. Front. Plant Sci. 7:1123. https://doi.org/10.3389/fpls.2016.01123

PEREIRA, R.V. et al. 2021. The Effects of Biostimulants on Induced Plant Defense. Front. Agron. 3:630596. https://doi.org/10.3389/fagro.2021.630596.

PERMINOVA, I.V. et al. 2019. Humic substances and nature-like technologies. J Soils Sediments 19, 2663–2664. https://doi.org/10.1007/s11368-019-02330-6.

PETROPOULOS, S.A. et al. 2020. Biostimulants Application Alleviates Water Stress Effects on Yield and Chemical Composition of Greenhouse Green Bean (Phaseolus vulgaris L.). Agronomy. 10(2):181. https://doi.org/10.3390/agronomy10020181.

POHL, A. et al. 2019. Biostimulant Application Enhances Fruit Setting in Eggplant—An Insight into the Biology of Flowering. Agronomy. 9(9):482. https://doi.org/10.3390/agronomy9090482.

RANI, L. et al. 2021. An extensive review on the consequences of chemical pesticides on human health and environment. In Journal of Cleaner Production. Volume 283, 124657, ISSN 0959-6526, https://doi.org/10.1016/j.jclepro.2020.124657.

RODRIGUES, M. et al. 2020. Organic Plant Biostimulants and Fruit Quality—A Review. Agronomy. 10(7):988. https://doi.org/10.3390/agronomy10070988.

ROUPHAEL, Y. – COLLA, G. 2020. Toward a Sustainable Agriculture Through Plant Biostimulants: From Experimental Data to Practical Applications. Agronomy. 10(10):1461. https://doi.org/10.3390/agronomy10101461.

ROUPHAEL, Y. et al. 2015. Arbuscular mycorrhizal fungi act as biostimulants in horticultural crops, in Scientia Horticulturae, Volume 196, Pages 91-108, ISSN 0304-4238, https://doi.org/10.1016/j.scienta.2015.09.002.

ROUPHAEL, Y. et al. 2018. High-Throughput Plant Phenotyping for Developing Novel Biostimulants: From Lab to Field or From Field to Lab?; in Frontiers in Plant Science; Vol. 9. ISSN=1664-462X, https://doi.org/10.3389/fpls.2018.01197.

SAIA, S. et al. 2019. An endophytic fungi-based biostimulant modulated lettuce yield, physiological and functional quality responses to both moderate and severe water limitation, in Scientia Horticulturae, Volume 256, 108595, ISSN 0304-4238, https://doi.org/10.1016/j.scienta.2019.108595.

SANGIORGIO, D. et al. 2020. Facing Climate Change: Application of Microbial Biostimulants to Mitigate Stress in Horticultural Crops. Agronomy. 10(6):794. https://doi.org/10.3390/agronomy10060794.

SHAHRAJABIAN, M.H. et al. 2021. Sustainable Agriculture Systems in Vegetable Production Using Chitin and Chitosan as Plant Biostimulants. Biomolecules. 11(6):819. https://doi.org/10.3390/biom11060819.

SHAHRAJABIAN, M.H. et al. 2021. Biostimulants Application: A Low Input Cropping Management Tool for Sustainable Farming of Vegetables. Biomolecules. 11(5):698. https://doi.org/10.3390/biom11050698.

SKENDŽIĆ, S. et al. 2021. The Impact of Climate Change on Agricultural Insect Pests. Insects, 12, 440. https://doi.org/10.3390/ insects12050440.

SOPPELSA, S. et al. 2018. Use of Biostimulants for Organic Apple Production: Effects on Tree Growth, Yield, and Fruit Quality at Harvest and During Storage. in Frontiers in Plant Science; vol. 9; ISSN1664-462X; https://doi.org/10.3389/fpls.2018.01342.

TEKLIĆ, T. et al. 2021. Linking abiotic stress, plant metabolites, biostimulants and functional food. Ann Appl Biol. 2021; 178: 169– 191. https://doi.org/10.1111/aab.12651.

TUDU, CH. K. et al. 2022. Chapter 8 - Role of plant derived extracts as biostimulants in sustainable agriculture: A detailed study on research advances, bottlenecks and future prospects, Editor(s): Harikesh Bahadur Singh, Anukool Vaishnav, New and Future Developments in Microbial Biotechnology and Bioengineering, Elsevier, 2022, Pages 159-179, ISBN 9780323855792, https://doi.org/10.1016/B978-0-323-85579-2.00017-4.

TURAN, M. et al. 2021. Effect of Biostimulants on Yield and Quality of Cherry Tomatoes Grown in Fertile and Stressed Soils, HortScience horts, 56(4), 414-423. Retrieved May 18, 2022, from https://journals.ashs.org/hortsci/view/journals/hortsci/56/4/article-p414.xml

UNITED NATIONS, Department of Economic and Social Affairs, Population Division. 2019. World Population Prospects 2019: Highlights (ST/ESA/SER.A/423). Available at: https://population.un.org/wpp/publications/files/wpp2019_highlights.pdf.

VERNIERI, P. et al. 2005. Application of biostimulants in floating system for improving rocket quality; Journal of Food, Agriculture & Environment Vol.3 (3&4) : 86-8., Available at: https://www.researchgate.net/publication/233852232.

WANG, Y. – FREI, M. 2011. Stressed food – The impact of abiotic environmental stresses on crop quality. In Agriculture, Ecosystems & Environment. Volume 141, Issues 3–4. Pages 271-286, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2011.03.017.

https://doi.org/10.15414/2022.9788055225029

Contact address:

MSc. Samuel Adamec, PhD. Slovak University of Agriculture in Nitra, AgroBioTech Research Centre, Tr. A. Hlinku 2, 94976 Nitra, Slovakia, +421 37 641 4947, samuel.adamec@uniag.sk.

https://doi.org/10.15414/2022.9788055225029

POSTER SECTION

https://doi.org/10.15414/2022.9788055225029

INFLUENCE OF SLOPE ON FOREST SOIL PROPERTIES IN A FORESTED MICRO-WATERSHED

Gabriela Tomášová*, Nikola Žižlavská, Pavel Samec*, Aleš Bajer ***

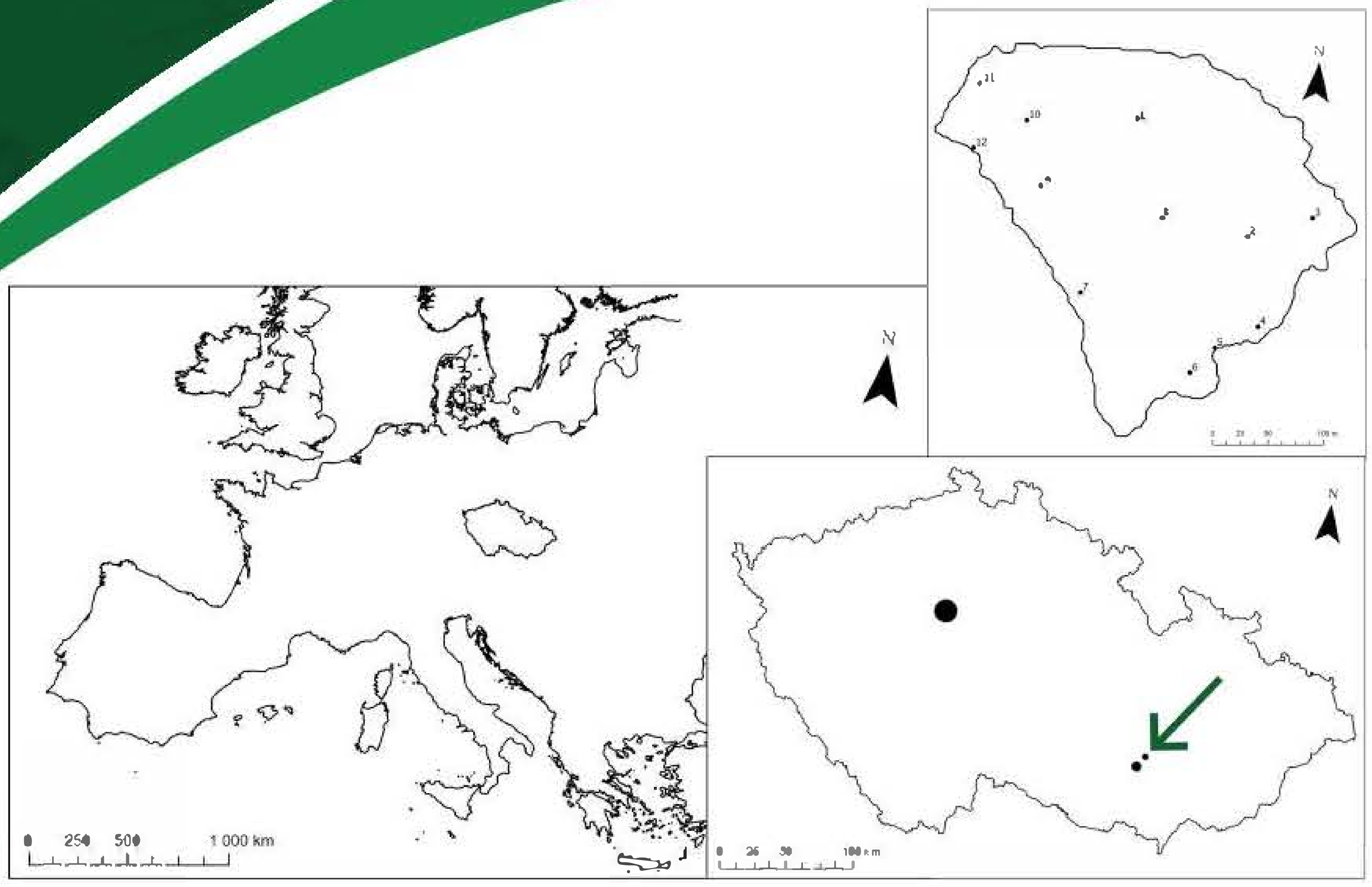
* Department of Geology and Pedology, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic, gabriela.tomasova@mendelu.cz

** Department of Forest Management and Applied Geoinformatics, Faculty of Forestry and Wood Technology, Mendel University in Brno, Zemědělská 3, 613 00 Brno, Czech Republic, xzizlav1@mendelu.cz

INTRODUCTION

The monitoring of carbon sequestration in forest ecosystems is an essential requirement for mitigation projects against global warming. Forest soils are important reservoirs of organic carbon in the form of humidified organic matter, which in turn is associated with vegetation cover (Stendahl et al., 2010; Rodríguez et al., 2017), environmental factors, topography, soil depth (Avilés-Hernández et al., 2009), quantity and type of plant coverage, and processes associated with litter mineralisation (Coûteaux et al., 1995).

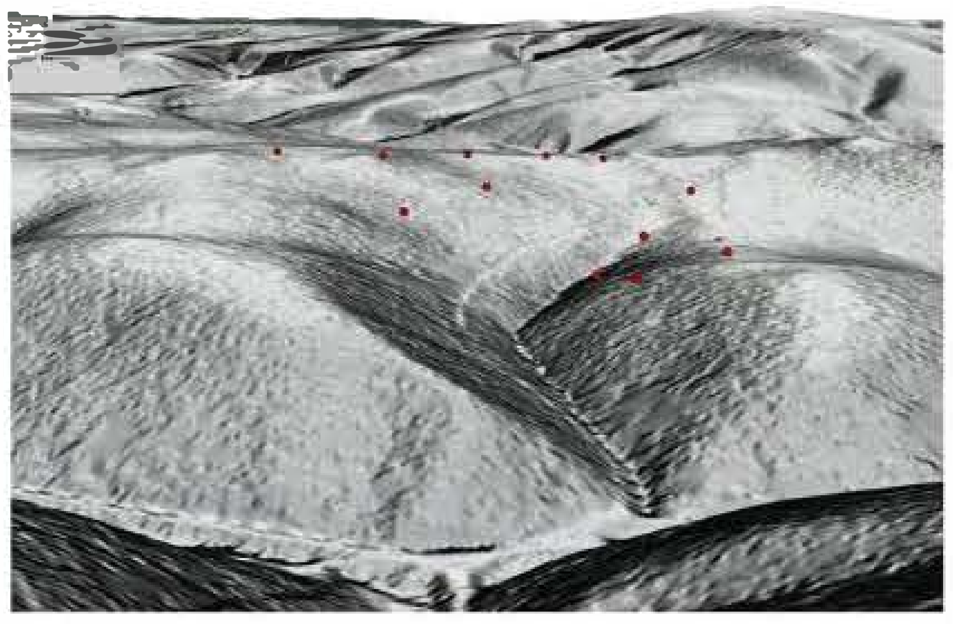
This study presents recent insights into changes in soil properties in relation to terrain slope in the Podhoské microbasin spring source region (South Moravia, Czech Republic). The results form part of a larger project addressing interrelationships between surface and subsurface water regimes over small areas. The soil survey was carried out using standard pedological surveying techniques and geoinformation technologies such as GIS. A total of 97 soil samples, each representing a fixed depth and organo-mineral horizon, were obtained from 24 soil probes. In the laboratory, each sample was assessed for oxidizable carbon/nitrogen (Cox N), soil granularity, pH and redox potential.



MATERIALS AND METHODS

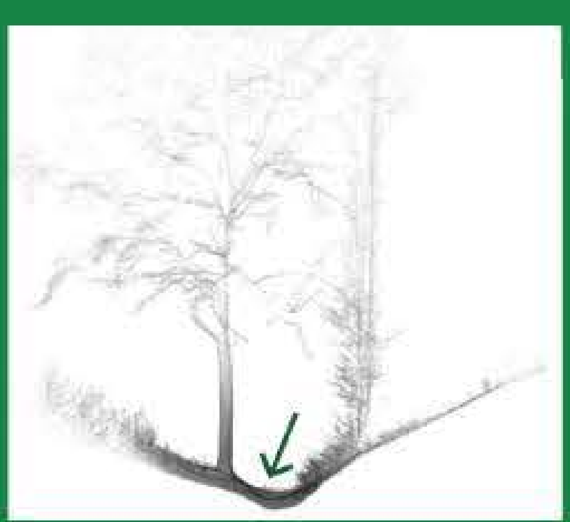
The Kanice microbasin is situated in the Žiluvský river basin, approximately 15 km north of Brno in the cadastral area of Babice nad Svitavou. The area has a high diversity of soil types, including modal cambium, brown soil and luvizum, that lie on the granodiorite subsoil of the Brno Massif.

Using GIS, documents were prepared for the selection of 12 representative sites, each centred around a tree (RHP1–RHP12). Two soil probes were then installed at each representative site, the first located close to the tree (near tree, RHP–NT) and the second mid-way between this and the next tree (between trees, RHP–BT). Soil samples were then obtained from 10, 30, 60 and 100 cm depth from both organo-mineral (Ah) and mineral horizons. The soil units were then mapped (Němeček et al. 2001) and soil hydrophysical properties, carbon, nitrogen and soil differentiation (granularity; FAO Soil Taxonomy units) determined. The study area was divided into four categories according to slope classification, i.e. flat (0–5°), moderate (6–10°), medium (11–20°) and steep (21–30°) (Vokoun et al. 2002). The surroundings of each soil probe were then scanned with a GeoSLAM ZEB Horizon laser scanner, which generated a point cloud for individual sections at each locality that could be visualised using GIS. In each case, significant differences ($p < 0.05$) in the data were assessed using two-factor ANOVA.



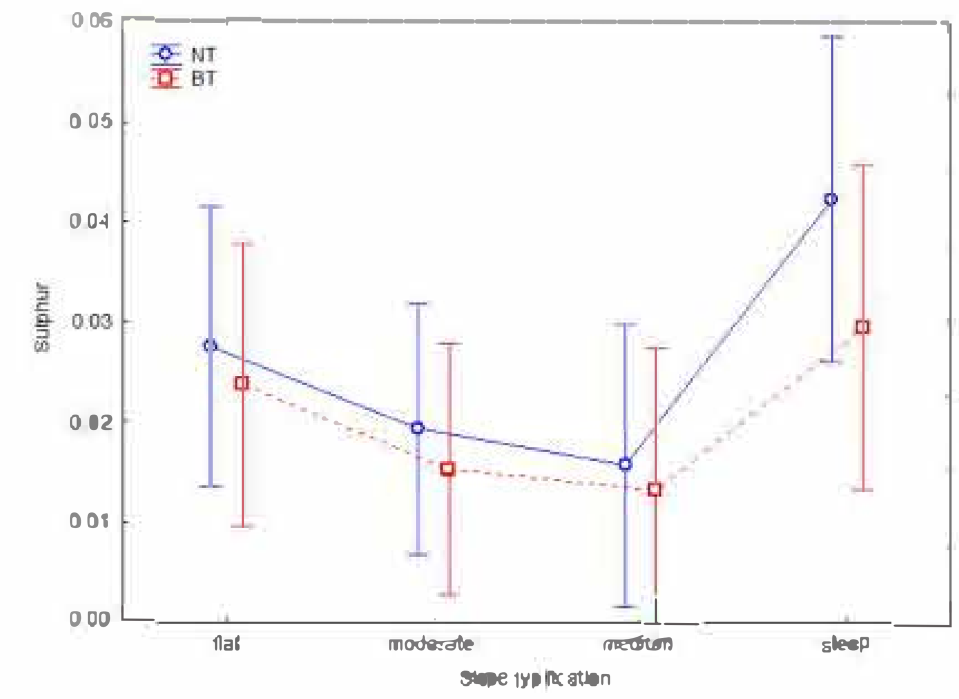
3D visualization of the study area with the deployment individual soil probes

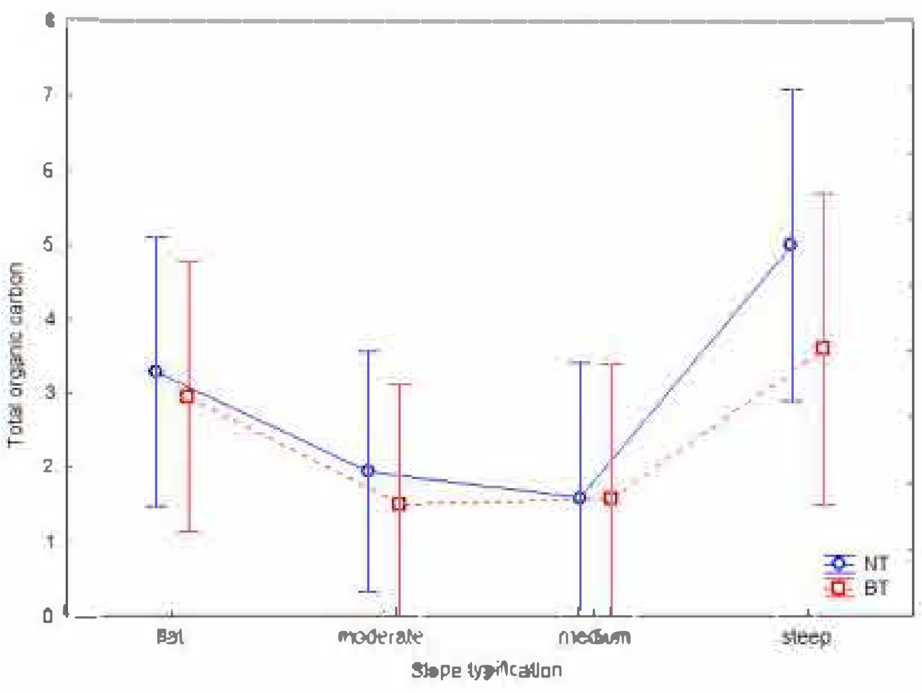
Laser scanner GeoSLAM ZEB Horizon

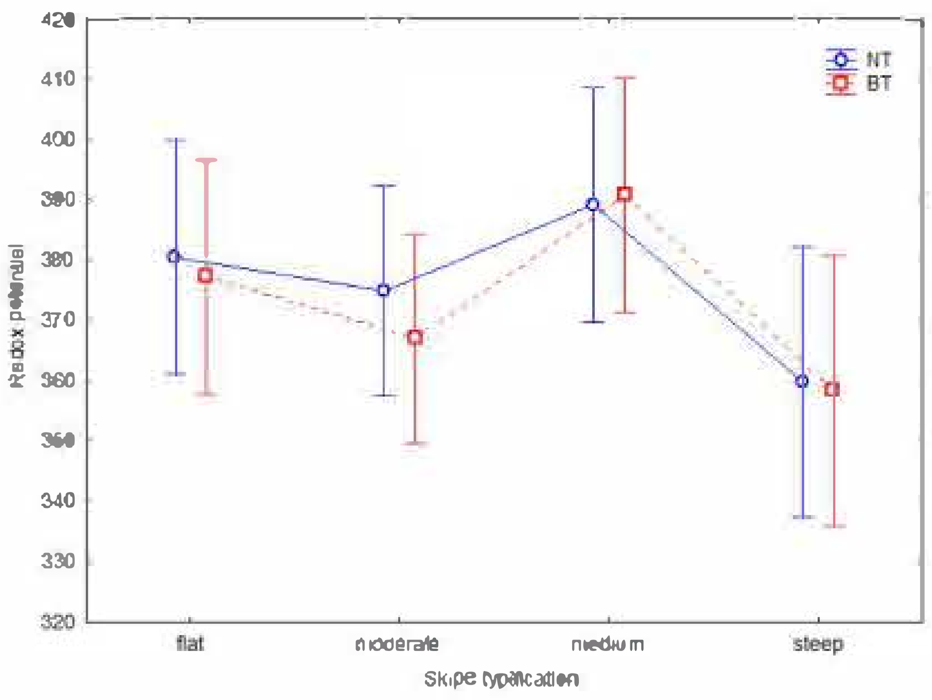


Visualization of a point cloud showing cross section of relief and vegetation

RESULTS







Our results showed that slope type (i.e. flat, moderate, medium, steep) had a significant impact on soil properties ($p < 0.05$), while distance of the soil probe from a tree or its placement among trees did not ($p > 0.05$). Significant differences were also observed within each slope category, particularly as regards the proportion of carbon and nitrogen in different mineral horizons. Overall, values for carbon and nitrogen were significantly higher on steep slopes ($p < 0.05$), while redox potential was lowest on steep slopes.

SUMMARY

This study set out to determine the impact of terrain slope and tree distance on forest soil properties in the foothills of the Podhoské spring source region (Czech Republic). We found significant ($p < 0.05$) differences in soil hydrophysical properties, carbon, nitrogen and soil differentiation (granularity; FAO Soil Taxonomy) with slope steepness, confirming our hypothesis that terrain slope (i.e. increasing steepness) contributes greatly to the increased representation of carbon and nitrogen in soil horizons. Distance of soil probes from a tree or its placement among trees had no significant impact on observed soil properties.

Mendelova univerzita v Brně

This work was supported by the Internal Grant Agency of Mendel University in Brno, Registration no.: CZ.02.2.69/0.0/0.0/19_073/0016670, under the framework of the European Social Fund (ESF).

Stendahl, J., Johansson, M. B., Eriksson, E., Nilsson, Å., & Langvall, O. (2010). Soil organic carbon in Swedish spruce and pine forests – differences in stock levels and regional patterns. Silva Fennica, 44(1), pp 5–21/ /Rodríguez, R. M., Yunta, M. F., Guirado, T. M., Ortega, M. A., Cuevas, R. J., & Gumuzzio, F. J. (2017). Carbono orgánico en suelos forestales del Principado de Asturias: importancia de los horizontes subsuperficiales e influencia de la fisionomía de la cubierta vegetal (Organic carbon in forest soils of the Principality of Asturias: importance of subsurface horizons and influence of the physiognomy of the vegetation cover). 7° Congreso Forestal Español. Sociedad Española de Ciencias Forestales (Ed.), Plasencia, Cáceres, España. (in Spanish)/ /Avilés-Hernández, V., Velázquez-Martínez, A., Angeles-Pérez, Etchevers-Barra, G. J., De los Santos-Posadas, H., & Llanderal, T. (2009). Variación en almacenes de carbono en suelos de una toposecuencia (Variation in carbon stores in soils of a toposequence). Agrociencia, 43(5), pp 457–464. (in Spanish)/ /Coûteaux, M.-M., Bottner, P., & Berg, B. (1995). Litter decomposition, climate and litter quality. Tree, 10(2), pp 63–66/ / Vokoun, J. et al. Příručka pro průzkum lesních půd. Brandýs nad Labem: Ústav pro hospodářskou úpravu lesů, 2002./ Němeček, J., Macků, J., Vokoun, J., Vavříček, D., Novák, P., 2001: Taxonomický klasifikační systém půd České republiky. Praha, 78 s.

https://doi.org/10.15414/2022.9788055225029

Effect of Biochar Application on CO_2 Emission from Agriculture soil under Temperate Climate Conditions

[1]TATIJANA KOTUŠ – [1]JÁN HORÁK – [1] KATARÍNA DRGOŇOVÁ
[1] Institute of Landscape Engineering, Faculty of Horticulture and Landscape Engineering, Slovak University of Agriculture, Hospodárska 7, 949 01 Nitra, Slovakia

INTRODUCTION

The issue of air pollution and greenhouse gas production has resonated strongly in recent years. For more than 25 years, scientists around the world have regularly demonstrated at climate summits that climate change affects the entire planet. Everything indication that the global production of CO_2 and other greenhouse gases is significantly changing the Earth's climate. Research into reducing the production of greenhouse gases has become a natural necessity for humanity's survival. Scientists from all over the world are continuously looking for new ways to reduce CO_2 emissions. Agriculture also contributes to increased concentrations of CO_2 emissions. One of the possible ways to decrease concentrations of CO_2 and mitigate climate change is biochar application to agricultural soil.

Keywords: CO_2 emission, biochar, chemical soil properties, N–fertilization

METHODOLOGY

Experimental site

The biochar field experiment was established at Malanta site (coordinates 48˚19'23" N; 18˚09'01" E). It is located in a temperate climate zone with an average annual air temperature of 9.8 °C and an average annual rainfall of 539 mm. The soil at the research site was classified as Haplic Luvisol, according to the Soil Taxonomy (IUSS, 2015).

Biochar and N–fertilizer

Biochar was applied in 2014 and reapplied in 2018 at dose of 0, 10 and 20 t.ha^{-1} (acronym "B0, B10, B20") in combination with three levels of N–fertilizer (acronym "N0, N1, N2"). The fertilization dose is dependent on the farmed crop at given year. In 2019 the N–fertilizer was applied at dose of 0, 108 and 162 kg.ha^{-1}. The experiment included 15 treatments in three replications, and it is arranged in 45 experimental plots in a randomized block design separated by 0.5 m wide buffer zone. The distribution of experimental plots is shown in Figure 1.

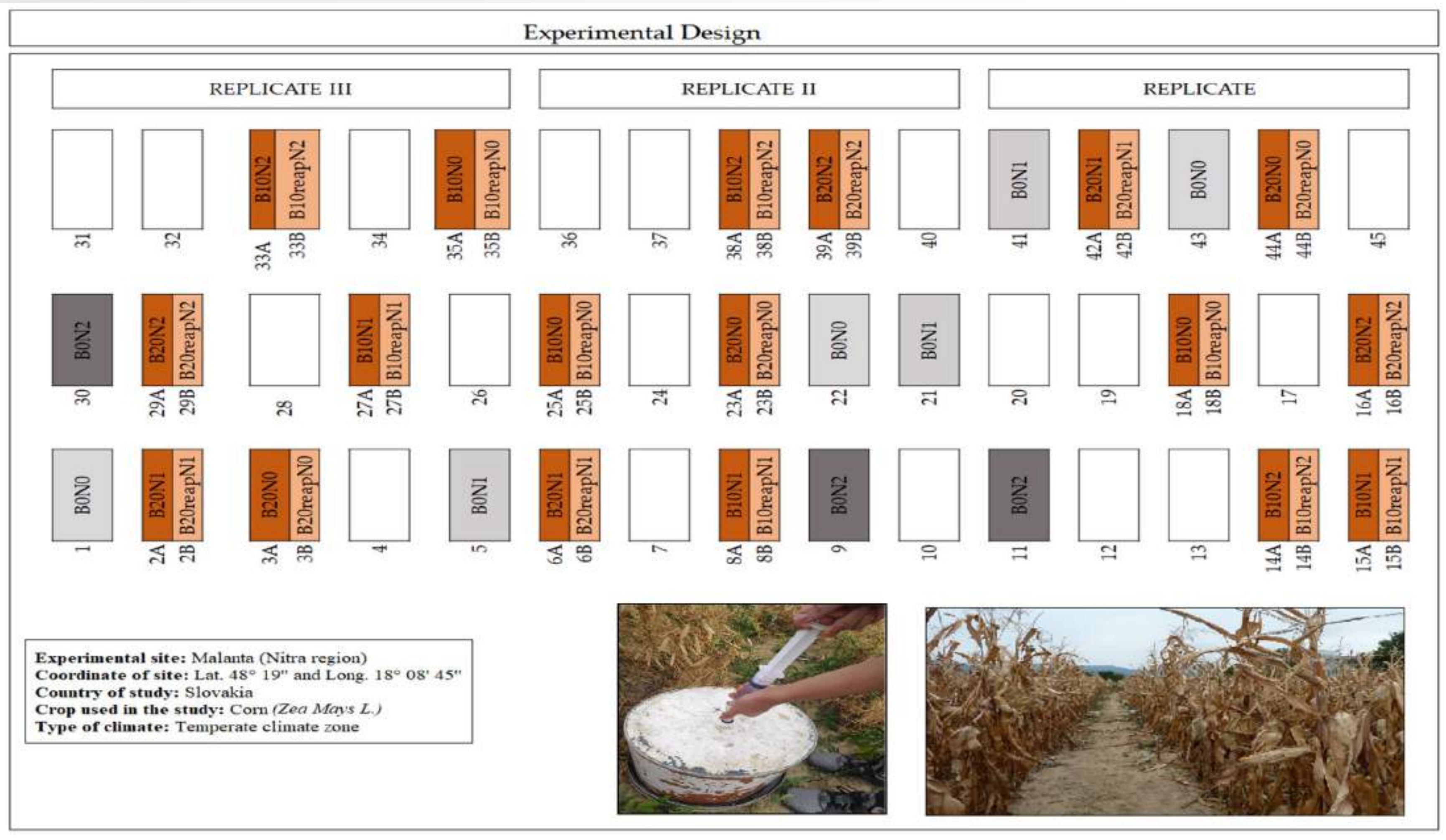


Figure 1 *Experimental site and the spatial distribution of the treatments*

CONCLUSION

In this research biochar application to the soil showed its potential to reduce CO_2 emissions from the soil. The highest CO_2 emission reduction during spring period was found for treatments where biochar was applied in combination with higher level of N–fertilizer (N2). However, further studies are required at different ecosystems before the final recommendation of biochar dose for farmers practice could be made.

ACKNOWLEDGEMENTS

This study was supported by the The Slovak Grant Agency (VEGA) project no. 1/0116/21. M.L. received support from the European Social Fund EVA 4.0 (OP RDE, CZ.02.1.01/0.0/0.0/16_019/0000803).

RESULTS

Table 1 shows the effect of biochar treatments on CO_2 emission from the soil over the spring period during in 2019. The average daily CO_2 emissions over the spring period from treatments combined with N–fertilizer were generally higher compared to treatments without N–fertilizer.

Almost all biochar treatment with or without N–fertilizer decreased average daily soil CO_2 emissions as compared to control treatments. Increasing were found in treatments B20N0, B20reapN0, B10N1, B20N1 and B10reapN1 as compared to their controls. Statistically significant increasing was observed in treatment B20N1. These results could confirm the cumulative CO_2 emissions showed in Table 1.

Table 1 *Average daily and cumulative CO_2 emission during spring season in 2019 (means ± standard error)*

Treatments	Average CO_2 emission	Cumulative CO_2 emission	Increase/decrease of cumulative CO_2 emission
Not fertilized group "N0" (0 kg. ha^{-1})			
B0N0	47.58 ± 3.4 a	2797.8	-
B10N0	36.34 ± 1.89 a	2437.8	-12.87 %
B20N0	55.46 ± 1.56 a	3395.8	+21.37 %
B10reapN0	32.19 ± 1.78 a	1914.1	-31.59 %
B20reapN0	49.43 ± 1.66 a	2958.2	+5.73 %
Fertilized group "N1" (108 kg. ha^{-1})			
B0N1	53.85 ± 1.93 a	2996.1	-
B10N1	76.39 ± 4.01 a	5145.7	+71.75 %
B20N1	**143.99 ± 10.0 b**	8724.9	+191.21 %
B10reapN1	53.50 ± 5.44 a	3371.4	+12.53 %
B20reapN1	40.06 ± 1.83 a	2438.4	-18.61 %
Fertilized group "N2" (162 kg. ha^{-1})			
B0N2	76.65 ± 19.80 a	4625.3	-
B10N2	58.65 ± 2.01 a	3399.6	-26.50 %
B20N2	57.65 ± 11.09 a	3301.6	-28.62 %
B10reapN2	48.40 ± 15.55 a	2879.9	-37.74 %
B20reapN2	48.88 ± 5.29 a	2860.3	-38.16 %

Table 2 shows relations between soil CO_2 emissions and soil chemical properties (NO_3^-, NH_4^+ and pH). Generally, our study showed that soil NO_3^- and soil pH was the influencing factor of soil CO_2 emission. Significant correlation was observed between soil CO_2 emission and soil NO_3^- in treatments B10N0 and B10N1. Exploring the relationships between CO_2 emission and soil pH, we found significant effects in treatments B10N0, B0N2 and B20reapN2.

Table 2 *Relationship between CO_2 emissions and selected chemical properties of the soil for different treatments (*P <0.05;**P <0.01).*

Treatments	NO_3^- (mg. kg^{-1})	NH_4^+ (mg. kg^{-1})	$pH_{(KCl)}$ (-)
Not fertilized group "N0" (0 kg. ha^{-1})			
B0N0	0.41	0.91	0.63
B10N0	**0.99 ***	0.93	**0.99 ***
B20N0	0.74	0.11	0.98
B10reapN0	0.96	0.81	0.46
B20reapN0	0.62	0.20	0.70
Fertilized group "N1" (108 kg. ha^{-1})			
B0N1	0.52	0.26	0.93
B10N1	**0.99 ***	0.03	0.35
B20N1	0.20	0.93	0.97
B10reapN1	0.87	0.92	0.89
B20reapN1	0.45	0.61	0.60
Fertilized group "N2" (162 kg. ha^{-1})			
B0N2	0.98	0.99	**0.99 ****
B10N2	0.31	0.07	0.95
B20N2	0.41	0.93	0.96
B10reapN2	0.39	0.21	0.76
B20reapN2	0.34	0.94	**0.99 ***

FLOODS AND CLIMATE CHANGE

70 SUA 1952 - 2022 SLOVENSKÁ POĽNOHOSPODÁRSKA UNIVERZITA V NITRE SLOVAK UNIVERSITY OF AGRICULTURE IN NITRA

iesprit®

16TH ANNUAL INTERNATIONAL SCIENTIFIC CONFERENCE SCIENCE OF YOUTH 2022
01. - 03. 06. 2022 Banská Štiavnica, Slovakia

GIS IN THE ASSESSMENT OF THE MORPHOMETRIC PARAMETERS OF THE RIVER

Aybek Arifjanov (1), Tatiana Kaletova (2), Dinislam Atakulov (1)

https://doi.org/10.15414/2022.9788055225029

1. Department of Hydraulics and hydroinformatics, “Tashkent institute of irrigation and agricultural mechanization engineers” National Research University, Tashkent, Uzbekistan
2. Institute of Landscape Engineering, Slovak University of Agriculture in Nitra, Nitra, Slovakia

Introduction

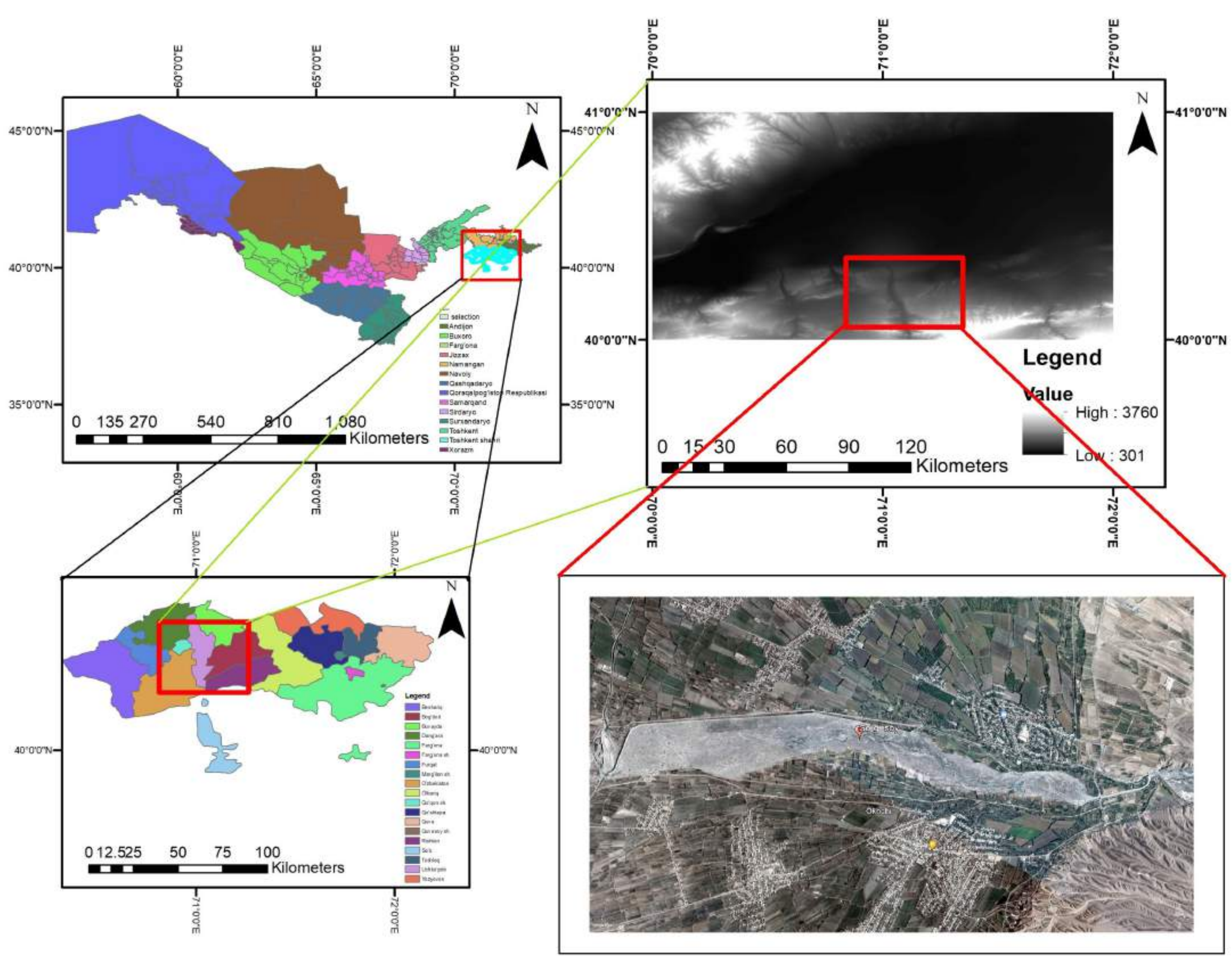
Today, there are cases of mudflow and in the riverbed, irrigation canals, hydraulic structures, which have a significant impact on the efficient use of water resources. Improving the methods of forecasting and preventing these changes, as well as maintaining their water permeability, and setting new measures remain an urgent problem.

Aim of study

Determination of the morphometric parameters of the channel based on the change in the average depth of the stream, the width of the stream and the assessment of erosion or accumulation processes with using GIS.

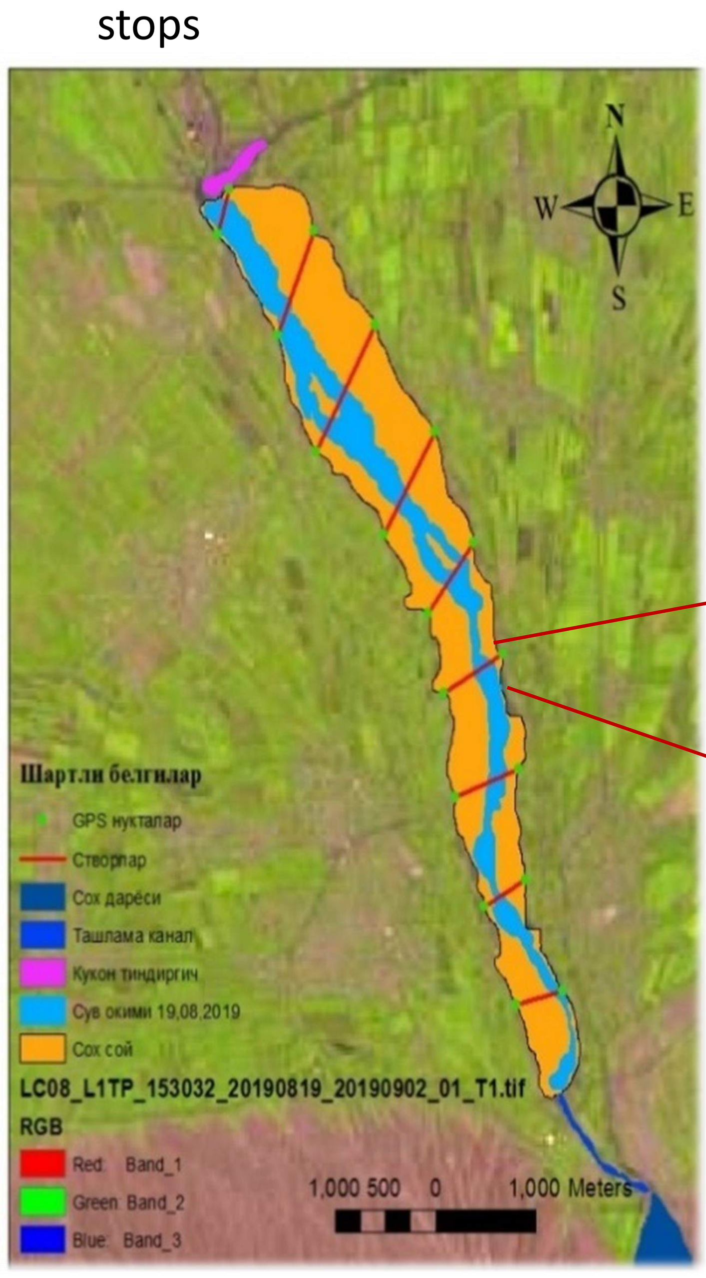
Research area

The Sokh River valley, located in the Sokh river basin. Fergana region, Uzbekistan.



Parameters of the Sokh riverbed

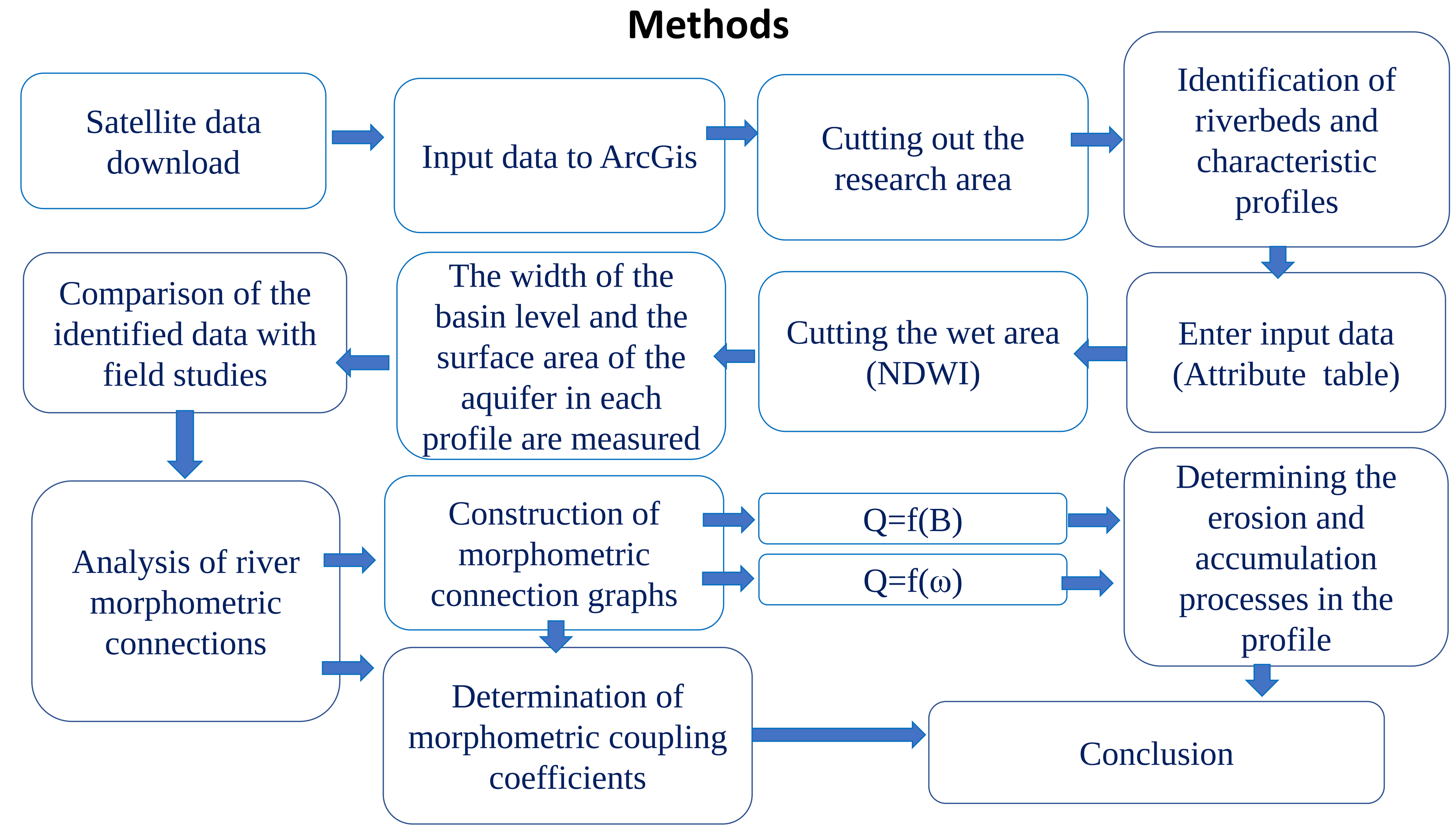
- the total length of the river is 9.4 km
- the average width is 550 m
- the depth is 1.1 m
- the bottom slope is 0.01
- maximum water discharge is up to 180 m^3/s and varies over the years
- a distinctive feature of the Sokh River is that the water flows in a certain part of the year
- In the spring, in late May, the river begins to receive water, and in some cases, the water in the river flows in early June, and in mid-September, the flow to the river stops



- natural field research in 2018-2020
- used devices: Garmin GPS and geodesic Auto level

- satellite data: Sentinel 2 and Landsat 8
- downloaded from: earthexplorer.usgs.gov

Methods



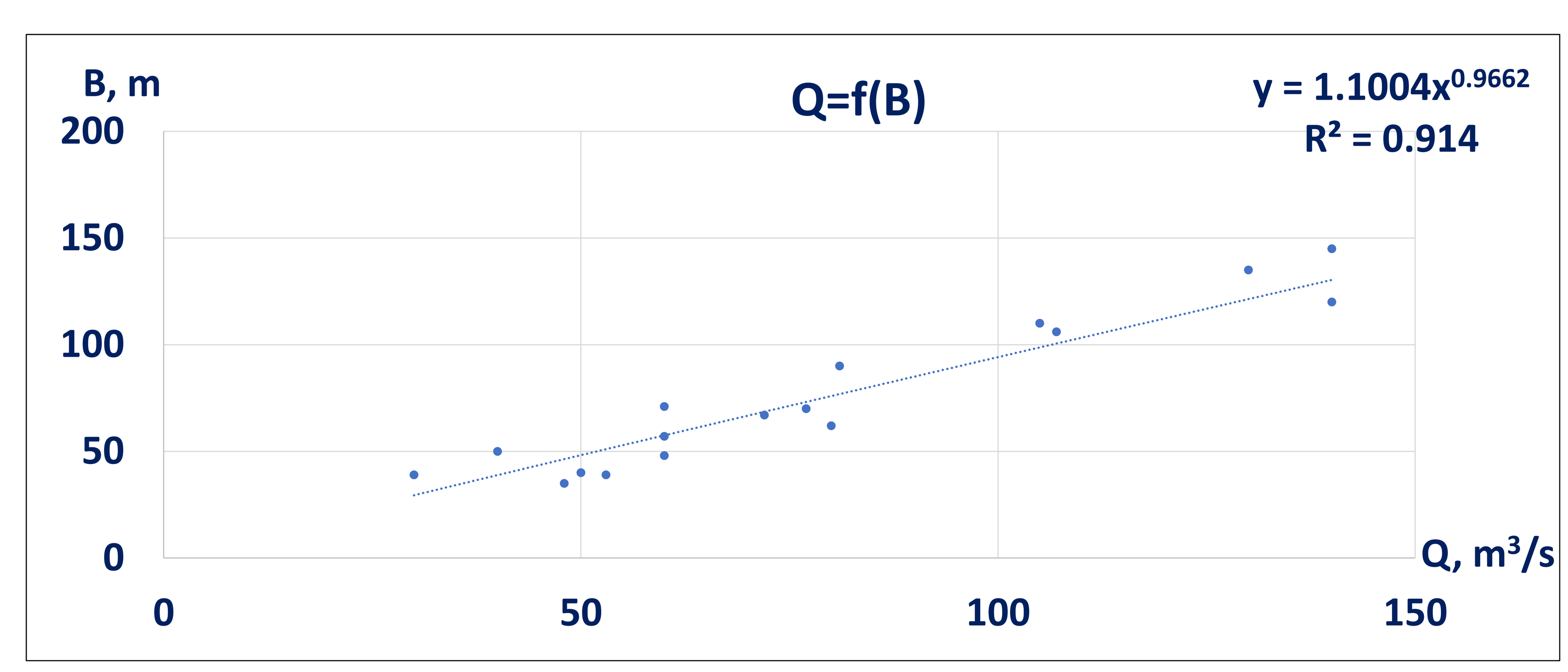
Formulas used

$$\mathrm{NDWI} = \frac{\mathrm{NIR}-\mathrm{SWIR}}{\mathrm{NIR}+\mathrm{SWIR}} \qquad \frac{Bi}{ad} = A_B\left[\frac{Qi^{\frac{5}{2}}}{(ad)^2\sqrt{agdi}}\right]^{y_1} \qquad \frac{Hi}{ad} = A_H\left[\frac{Qi^{\frac{5}{2}}}{(ad)^2\sqrt{agdi}}\right]^{y_2}$$

where: A_B, A_H, y_1, y_2 connection indicators. Scientists have found different values, which does not work today. We calculate them by GIS and compare with field measurements.

Results

A graph was generated based on the function Q = f (B) by linking the change in the width of the flow level B to the current discharge. We have included all the water consumption, average sediment diameter, average density, etc. determined in the B field experiments determined in GIS into one equation. We found that the correlation coefficient was 0.85, which is enough to conclude that the law exists and works.



The correlation formulas of river morphometric parameters proposed by different scientists and determined by GIS were compared. Based on the analysis of the obtained results (Q / B = (0.9-1.1)), the coefficients and levels of the expression proposed by M. Velikanov can be proposed in the following intervals:

№	B, m	A_H	y_1	y_2
1	30-40	0.31	0.13	0.53
2	40-50	0.32	0.14	0.51
3	50-60	0.34	0.15	0.50
4	60-80	0.35	0.16	0.47
5	80-100	0.36	0.16	0.45
6	100-130	0.37	0.16	0.42
7	130-160	0.39	0.17	0.41

Conclusion

The advices of proposed methods are rapid assessment of river morphometric changes and continuous monitoring. It can be used for prevention of erosion and accumulation and forecasting for the future. Using the equations of the determined connection indicators and morphometric connections of the river, it is possible to accurately and reliably assess and monitor the accumulation process in which part of the river erosion and in which part along the length of the river.

This study is a result of KX-Atex-2018-69 - research project on "Development of technology for the assessment of erosion and accumulation processes in the rivers using geographic information systems (GIS)„ and was supported by VEGA 1/0747/20.

Estimation of Evapotranspiration Rate from Eddy Covariance over Vineyard Ecosystem

Aysan Badraghi[*a,b], Beáta Novotná[a] Lucia Tátošová[a]

[a] The Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic

[b] Faculty of Science, Charles University in Prague, Benátská 2, 128 43 Praha 2, Czech Republic

*Corresponding author: qbadraghi@uniag.sk

Introduction

Evapotranspiration (ET) is the largest component of water balance, which plays a critical role in the water cycle. In this context, nowadays, with increasing extreme weather events concerning global warming, which is resulted in reduced water availability in much of the world; monitoring ET can help to evaluate regional water use and improve water resources management in the agroecosystem. The Eddy Covariance (EC), Penman-Monteith, and Bowen ratio energy balance are very largely used techniques for accessing ET. Among those techniques, EC is the most accurate approach for monitoring greenhouse gas (GHG) fluxes such as H_2O, CO_2, and CH_4.

Methodology

The study site was a vineyard field in Dvorníky (Trnava region) which is located in the west part of the Slovak Republic (48°18' N and 17°46' W; 300 m a.s.l.; Fig 1b). An eddy covariance tower was mounted at 3.0 m height above the soil surface, to quantify water exchange at 30-minute intervals (Fig 1a). The EC consisted of a closed-path infrared gas analyzer (IRGA analyzer Li-7200 from LI-COR Biosciences, Lincoln, Nebraska USA) to monitor GHG fluxes continuously and a 3-dimensional sonic anemometer (CSAT3, Campbell Scientific Inc., Logan, UT) to collect wind velocities and sonic temperature at 10 Hz, and datalogger to stored raw data (CR3000, Campbell Scientific Inc.,Logan, UT). EC binary and raw data processing were undertaken using LoggerNet (Campbell Scientific Inc.,Logan, UT) and EddyPro software (LI-COR, NE, USA). After thorough data quality checking, daily values of ET were calculated from 30-minute.

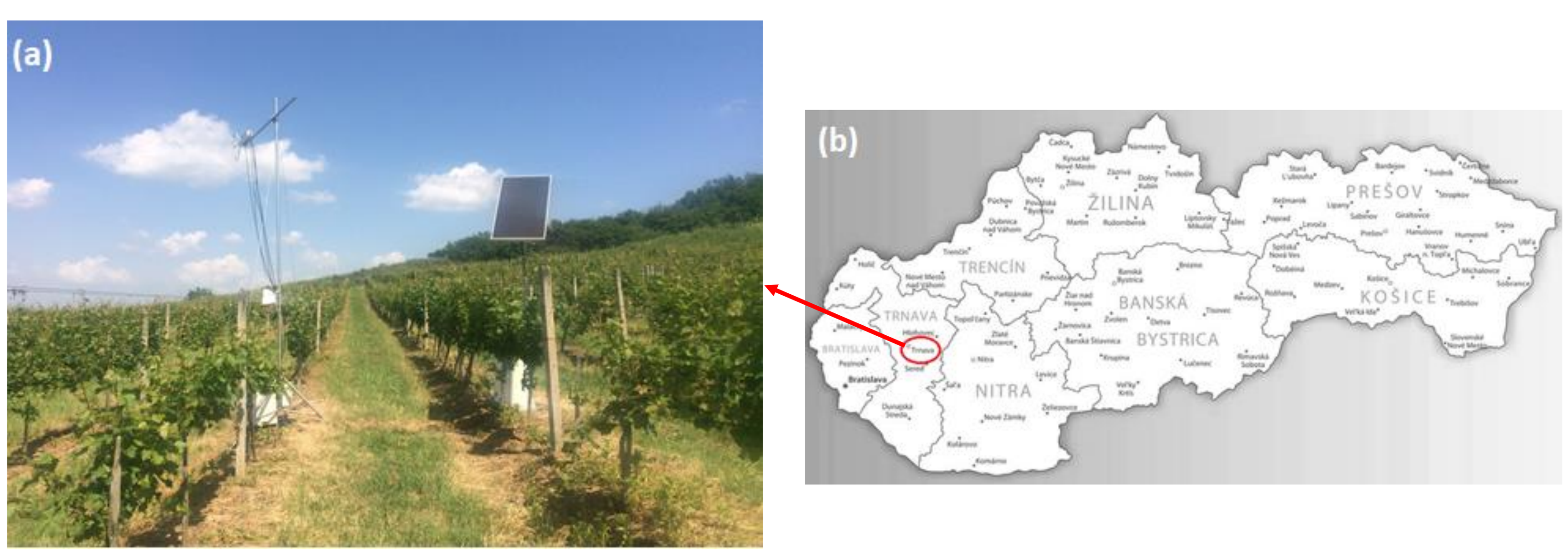


Fig 1. Photograph of eddy covariance tower (EC; a) and location of case study in Slovakia (b).

Result

Climatic variables for the period of 2010–2019

To assess change in the climatic variables, annual and monthly (June-September) sums of precipitation (mm, Automatic Precipitation Gauge 386C, MetOne Instrument, USA) and annual and monthly air temperature means (ºC, Sensor RHA1, Delta-T Devices, UK) were collected from the meteorological station which situated close to study site, for a 10-year (2010-2019; for the summer seasons; Fig. 2). During the 10-year time period, the years 2018 and 2019, with mean temperatures of 20.4 ± 3.3 and 20.5 ± 2.9 ºC, had the warmest summer; and, compart to the mean temperature of our ten-year period (19.5 ± 3.4 ºC), the average temperature increased about 1°C during the summers of 2018 and 2019. However, this increase was not significant (p-value=0.21). The year 2019 had the driest summer, with a mean monthly precipitation of 40.1 mm, which was significantly lower than in 2010 (p-value=0.05).

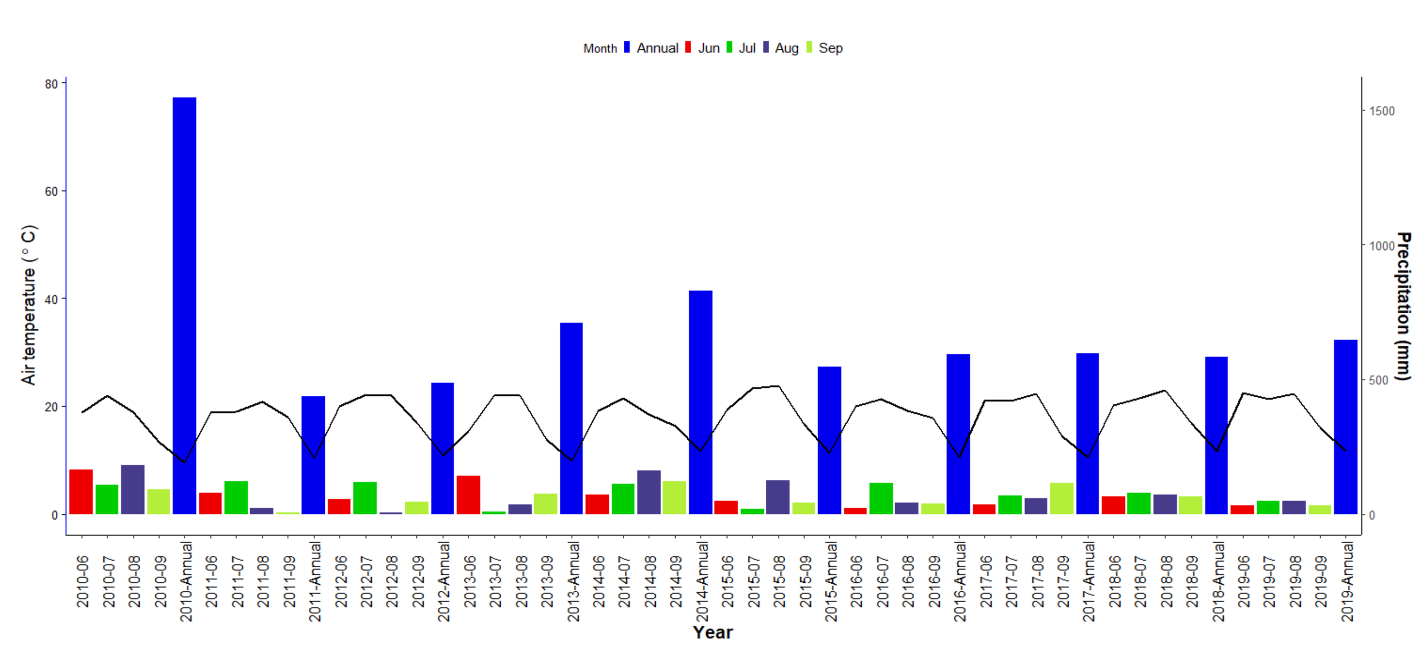


Fig. 2. A monthly (Jun-Sep) and annual sums of precipitation (mm) and monthly and annual air temperature means (°C) for a 10-year (2010–2019).

Evapotranspiration changes rate during summertime

The mean daily value of ET rates was quantified for June, July, August, and September from EC in the level vineyard. ET ranged between 7.3 ± 5.4 to 3.6 ± 1.2 mm.day^{-1}. As shown in Fig. 3, ET approached its highest value in July and the lowest value recorded for September, however, statistical analysis could not confirm a significant difference between measurement campaigns (p-value=0.09).

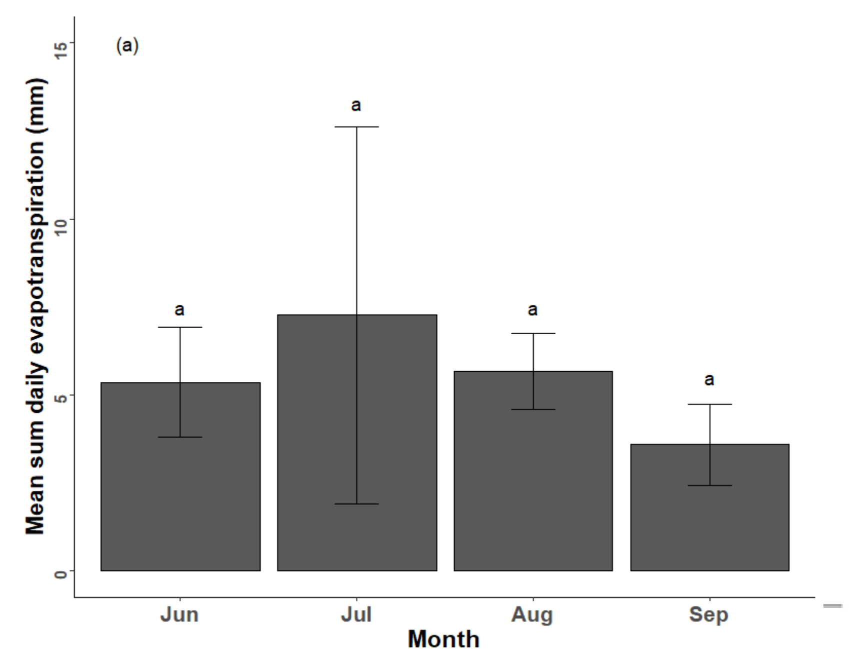


Fig 3. The mean daily value of evapotranspiration during the field measurement campaigns (June, July, August and September)

Evapotranspiration responses to climatic variables

The linearity between ET and the important affecting factors on ET (temperature, vapor pressure deficit (VPD), wind speed, and humidity relative (RH)) was tested by the linear regressions. Overall, the tendency of ET to temperature, VPD, and wind speed was positive and significant, i.e., the higher value of temperature, VPD, and the wind speed increased ET rate significantly, in contrast, a negative significant relationship was found between ET and RH (Fig. 4). Furthermore, our data confirmed that the ET was mainly controlled by VPD, and ca. 46% variance of ET was explained by VPD.

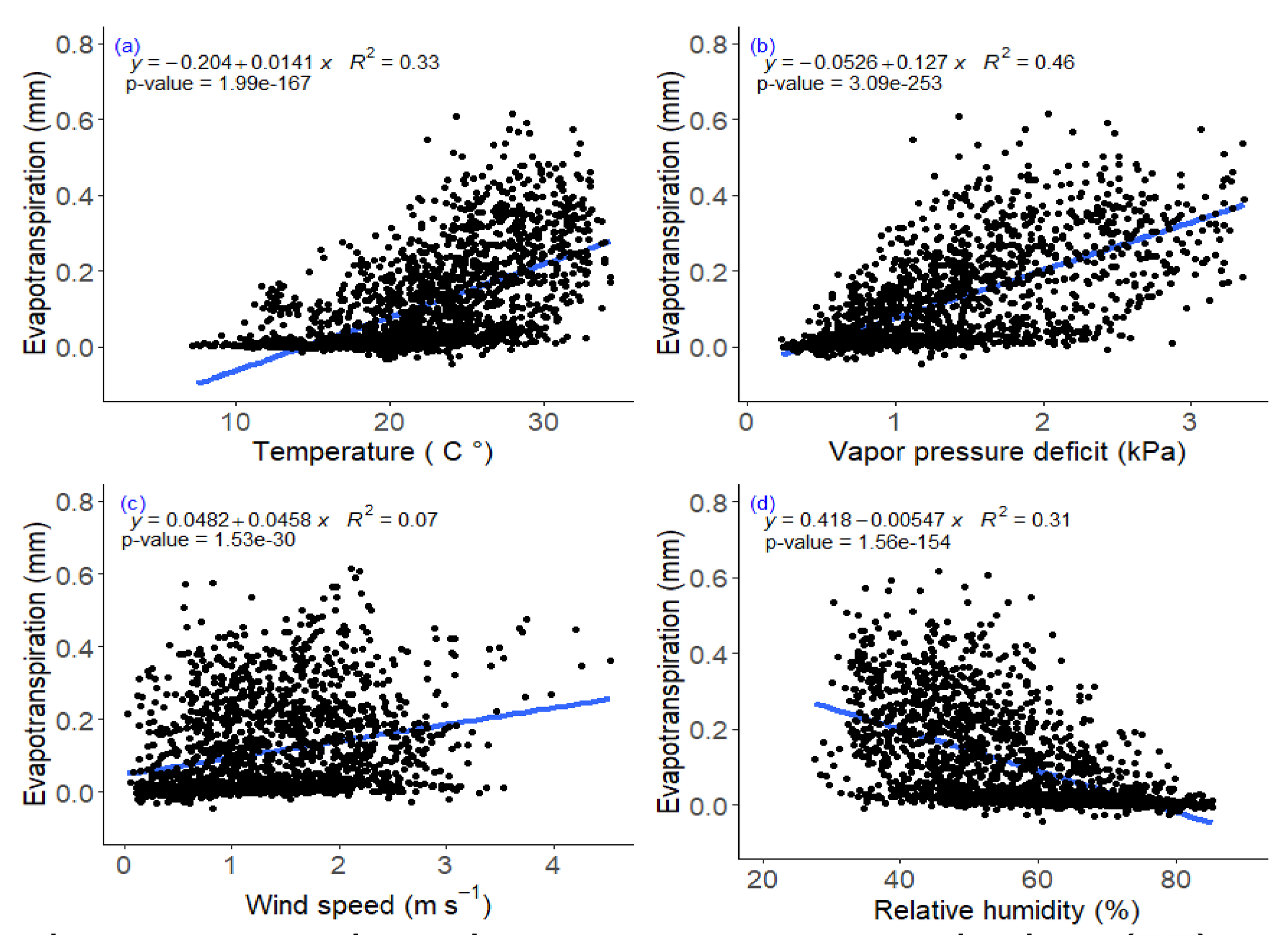


Fig 4. Linear regressions between evapotranspiration (ET) and important affecting factors on ET. Regression lines were built from 30-min eddy covariance measurement.

Conclusion

From the four-month data in the level vineyard, we found that the daily value of ET is high during summer, and on a small-scale, about 5.5 ± 2.3 (mm.day^{-1}) of water was lost from a vineyard field. Meanwhile, the mean sum value of monthly precipitation was 40.1 ± 10.7. This finding pointed out that the study site lost water 4-time larger than the amount of precipitation through the evapotranspiration process, during the summer.

Acknowledgment

This research was funded by the Cultural and Educational Grant Agency KEGA Project no. 29SPU-4/2020: Iinteractive learning as a tool for analysis and solutions design for the water modeling training in the landscape.

https://doi.org/10.15414/2022.9788055225029

https://doi.org/10.15414/2022.9788055225029

Norway grants

WETLAND CONDITION IMPROVEMENT

ON THE TERRITORY OF SKUEV0075

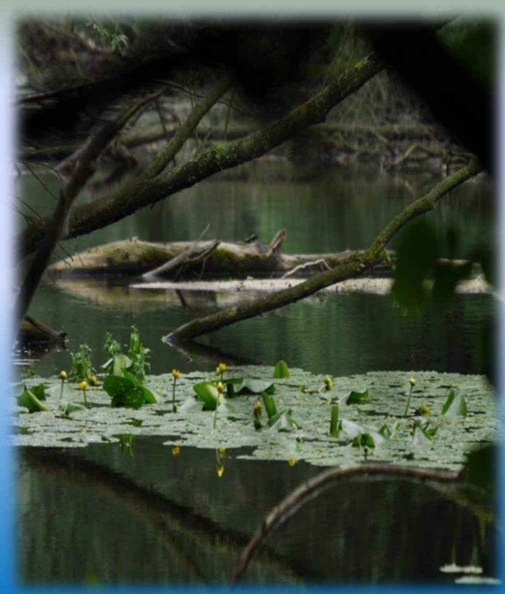
SCIENCE OF YOUTH 2022

2022

Richard HANZLÍK, Martina SLÁVIKOVÁ, Ľuboš JURÍK, Lucia TÁTOŠOVÁ

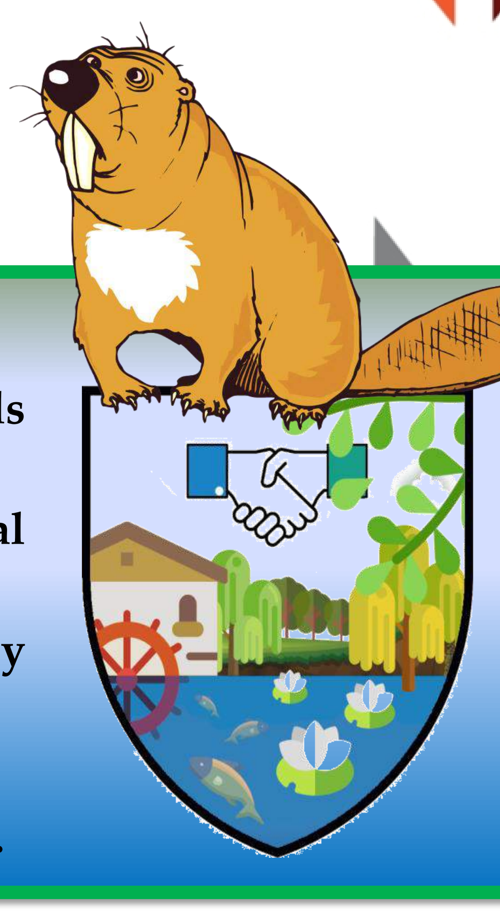
INTRODUCTION

- The wetland on the territory of SKUEV0075 is called Klátovské rameno and it does not have a spring or is not separated from any other stream, it rises from the groundwater, thanks to which it is characterised by a high degree of purity.
- In its upper section does not have a continuous water surface; it is formed only by small lakes with rich bank vegetation.
- The water depth varies from a few centimetres to 5 m.



OBJECTIVES

- Analysis of the current status of wetlands in the context of climate change.
- Water management and environmental study.
- Landscape-ecological study of potentially suitable measures.
- Implementation of selected measures.
- Communication and promotion package.



MATERIALS AND METHODS

- There are 3 monitoring sites for WFD monitoring.
- Monitoring, sediment sampling and quality analysis, particularly at areas where the field mapping will be carried out.
- Mathematical modelling of surface water flow in interaction with groundwater flow.
- In-situ habitat mapping of native and invasive species using modern technologies - drone, satellite data, lidar, spectral analysis.

- Collecting and removing litter in mapped locations throughout the Klatovy Arm together with local youth, students from local primary and secondary schools, as well as adult residents of the surrounding villages.
- Creation of a nature trail and a youth organisation to educate and guide children and young people to protect nature from childhood.

RESULTS

- The fieldwork provided us with a reality check in addition to the beautiful scenery. In the highest level of nature protection, it is unacceptable to influence the biota in any anthropogenic way without permission.

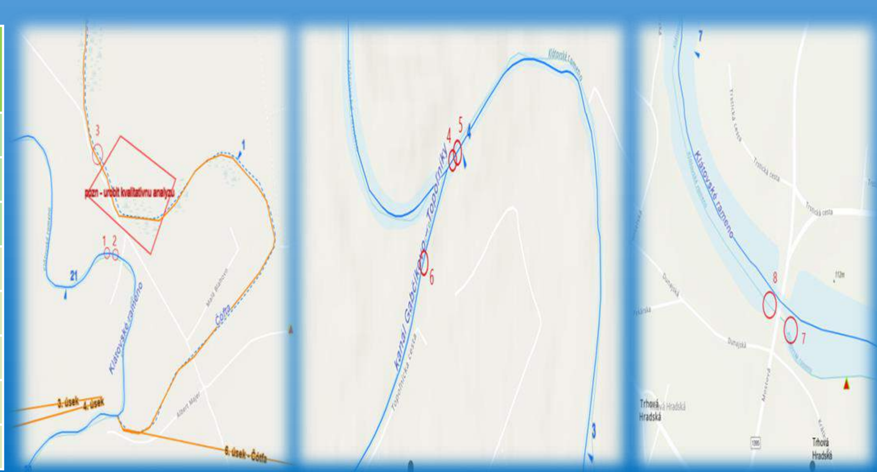
- Environmental pressures on the landscape, such as discharges of wastewater and threats to water and sediment quality, are another problem.

- There is constant erosion of the banks, which also causes trees to fall into the stream bed and create shoals.

- The amount of beavers (lat. Castor fiber) living in the area is excessive, as is the presence of woody debris and invasive plant species.

- Basic laboratory analyses of water quality already show elevated pH and conductivity values, excessive salinity and total dissolved solids (TDS) in some sections.

Date	Sampling point [no.]	pH	TDS [ppm]	Sal.	Cond. [µS]
02.12.21	1	7.33	549	0.39	775
	2	7.86	575	0.41	812
	3	7.41	861	0.60	**1213**
16.12.21	4	7.97	444	0.31	624
	5	7.39	465	0.33	654
	6	7.90	430	0.30	603
	7	7.63	570	0.40	804
	8	8.05	539	0.38	760



CONCLUSION

The project focuses on scientific and technical issues, but as in all environmental management activities, the importance of community perspectives and values should not be overlooked. The presence or absence of public support for a restoration project can be the difference between positive results and failure. Coordination with the people and organizations that are affected by the project can help build the support needed to get the project continuing and ensure long-term protection of the restored area. In addition, partnership with stakeholders can also add useful resources, ranging from money and technical expertise to volunteer help with implementation and monitoring.

ACKNOWLEDGEMENTS

This publication is the result of the project implementation: „Status improvement of wetland of Klátovské rameno NNR located in SKUEV0075" (ACC04/08) and „3D modelling and in situ technologies for research, teaching and application in remote sensing, photogrammetry and GIS laboratories in landscaping" (027SPU-4/2020) supported by the MINISTRY OF ENVIRONMENT OF THE SLOVAK REPUBLIC funded by the NORWAY GRANTS.

MINISTRY OF ENVIRONMENT OF THE SLOVAK REPUBLIC

SLOVAK WATER MANAGEMENT ENTERPRISE, state enterprise

STU SvF

MINISTRY OF EDUCATION, SCIENCE, RESEARCH AND SPORT OF THE SLOVAK REPUBLIC

*Contact: hanzlik.richard94@gmail.com

SCIENCE OF YOUTH 2022

https://doi.org/10.15414/2022.9788055225029

ULTRASTRUCTURAL FEATURES OF COLUMELLA STATOCYTES AS A VALUABLE INDICATOR OF ABIOTIC STRESS ACTIONS IN PLANTS

Hana Ďúranová[1*] - Veronika Valková[1] - Ľuba Ďurišová[2] - Lucia Olexíková[3] - Marek Kovár[4] - Miroslava Požgajová[1]

[1]AgroBioTech Research Centre, Slovak University of Agriculture, Tr. A. Hlinku 2, Nitra 949 76, Slovakia
[2]Institute of Plant and Environmental Sciences, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, Nitra 949 76, Slovakia
[3]NPPC, Research Institute for Animal Production Nitra, Institute of Farm Animal Genetics and Reproduction, Hlohovecká 2, Lužianky 951 41, Slovakia
[4]Department of Plant Physiology, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, Nitra 949 76, Slovakia
[*]Corresponding author: hana.duranova@uniag.sk

INTRODUCTION

Abiotic stresses including extreme temperatures, deficient or excessive water, high salinity, heavy metals, and ultraviolet radiation are hostile to plant growth and development, causing great crop yield penalty worldwide [1]. Indeed, all these factors affect plants at the level of molecular function, developmental processes, morphological traits, and physiology [2].

ROOT CAP OF PLANTS AS AN ATTRACTIVE MODEL SYSTEM FOR VARIOUS ULTRASTRUCTURAL STUDIES

Plant root, composed of multiple cell types with different functions [3], is a critical organ for productivity and adaptation of plants to diverse abiotic factors [4]. In this regard, a root tip has the ability to act as a finely tuned sensor for various stress circumstances [5]. The growing root tip is protected by a root cap, a multilayered dome of spindle-shaped parenchyma cells which physically protects the root apical meristem as it penetrates the soil. Besides, the root caps have many other important functions, most of which are closely related to their cellular structure [6], remaining stable throughout the root growth. This occurs due to constant root cap cell turnover, in which the last layer of the root cap is released, and new root cap cells are produced [7]. The root cap is strictly organized into two parts: the columella (in a central position), and the lateral root cap surrounding the columella [8]. Histologically, the columella itself is composed of two different cell types: the statocytes, mostly located in the internal layers of columella, and the secretory cells constituting the lateral root cap and the external columella layer [9]. Deviations of the statocytes with respect to the earthly gravity vector lead to a displacement of starch-filled amyloplasts (statoliths) relative to the cell due to their inertia, and thus to gravity perception [10].

ULTRASTRUCTURAL FEATURES OF STATOCYTES

Electron microscopic studies on central columella cells in roots (Figure 1) indicate that statocytes are highly polarized cells that contain a peripheral system of endoplasmic reticulum, a nucleus positioned in the middle or at the top, and many amyloplasts toward the lower end of the cell [11]. In effect, because starch is denser than cytoplasm, the amyloplasts (statoliths) tend to sediment. Additionally, statocytes are depleted of a central vacuole and lack prominent microfilament bundles or microtubule arrays [12].

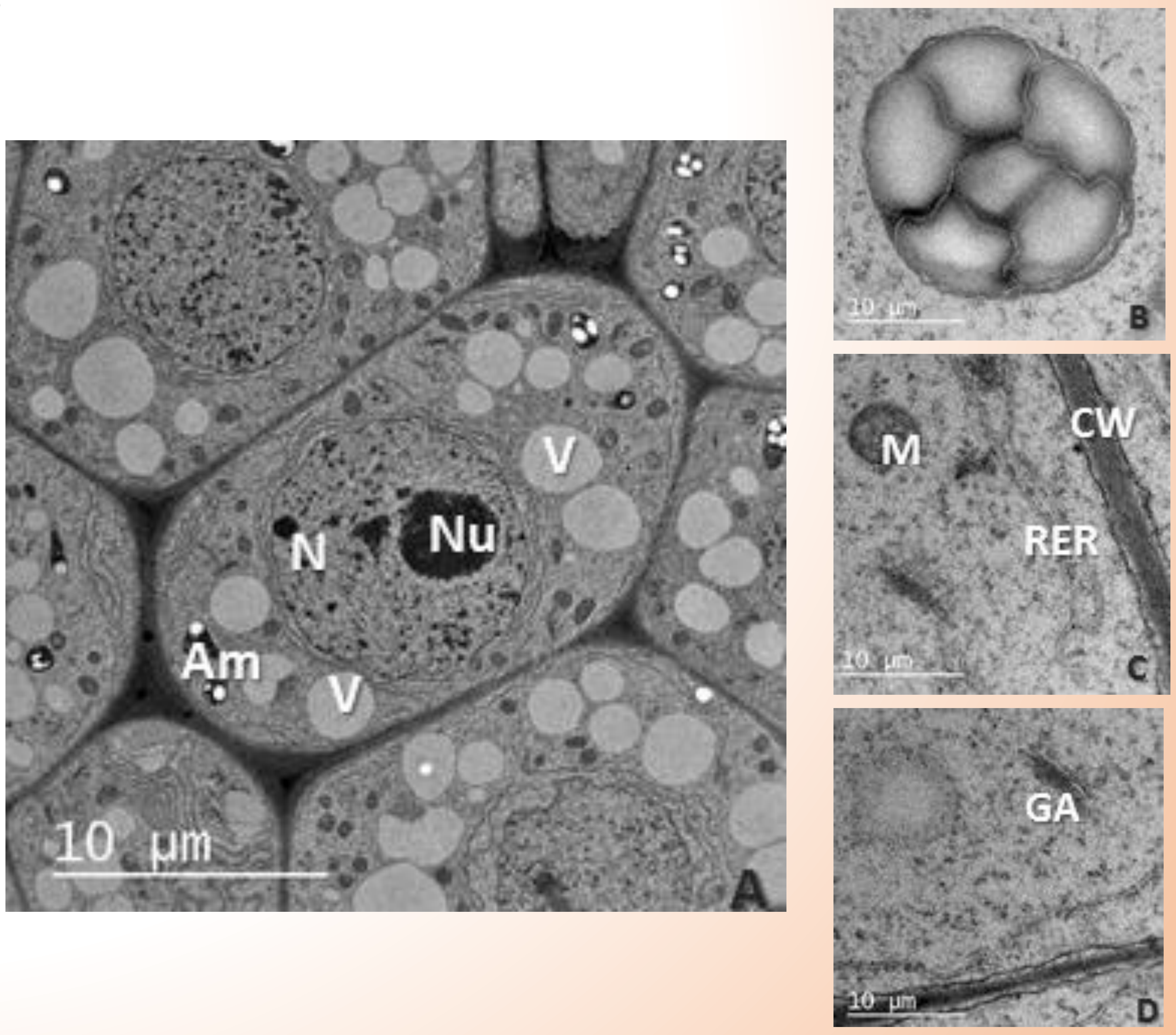


Figure 1 Central columella cells in the root tip of *Zea mays*. Transverse thin section of the statocytes (A), and a more detailed ultrastructural organization of amyloplast with starch granules (B), cell wall, tubular type of mitochondria, rough endoplasmic reticulum (C), and Golgi apparatus (D). Note: N - nucleus, Nu - nucleolus, V - vacuole, RER – rough endoplasmic reticulum, Am - amyloplasts, M - mitochondrion, GA - Golgi apparatus, CW - cell wall; scale bars: 10 µm [magnification x600 (A); x6,000 (B, C, D)]; JEOL JEM-2100 transmission electron microscope (JEOL, Tokyo, Japan) (operating at 200 kV)

CONCLUSION

To investigate the actions of defined abiotic stress factors on various plant models, the ultrastructure of statocytes will be evaluated in our studies from both qualitative and quantitative (unbiased stereological estimations) points of view. In a such manner, understanding the adaptive responses of the plant roots to changing conditions can be assessed from the morphological aspect.

References: 1. He, M., He, C. Q., Ding, N. Z. 2018. *Front. Plant Sci.*, *9*, 1771.; 2. Gray, S. B., Brady, S. M. 2016. *Dev. Biol.*, *41*, 64-77.; 3. Qiao, Z., Libault, M. 2013. *Front. Plant Sci.*, *4*, 484.; 4. Khan, M. A., Gemenet, D. C., Villordon, A. 2016. *Front. Plant Sci.*, *7*, 1584.; 5. Koyro, H. W. 2002. Ultrastructural effects of salinity in higher plants. In *Salinity: Environment-Plants-Molecules* (pp. 139-157). Springer, Dordrecht.; 6. Iijima, M., Morita, S., Barlow, P. W. 2008. *Plant Prod. Sci.*, *11*, 17-27.; 7. Kumar, N., Iyer-Pascuzzi, A. S. 2020. *Plants*, *9*, 308.; 8. Arnaud, C., Bonnot, C., Desnos, T., Nussaume, L. 2010. The root cap at the forefront. *C. R. Biol.*, *333*, 335-343.; 9. Purnobasuki, H. 2013. *Am. J. Plant Sci.*, 4, 30003.; 10. Schüler, O., Hemmersbach, R., Böhmer, M. 2015. *Front. Plant Sci.*, *6*, 1176.; 11. Srivastava, L. M. 2002. *Plant growth and development: hormones and environment*. Elsevier.; 12. Rosen, E., Chen, R., Masson, P. H. 1999. *Trends Plant Sci.*, *4*, 407-412.

Acknowledgement: „This publication is the result of the project implementation: „Scientific support of climate change adaptation in agriculture and mitigation of soil degradation" (ITMS2014+ 313011W580) supported by the Integrated Infrastructure Operational Programme funded by the ERDF."