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ASSESSMENT OF CLIMATIC PARAMETERS DURING THE VEGETATION PERIOD IN TERMS OF EFFICIENCY OF GROWING OF ENERGY PLANTS IN SLOVAKIA REGIONS

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Abstract

Reliable identification of realistic biomass at regional level is particularly important in creating a real energy strategy. It must stand for the region in particular in the long-term aspect of its sustainable development. The aim of the paper is to identify and quantify environmental impacts, especially microclimatic impacts, on the possibility of establishing and growing economically and energy-efficient plantations of fast-growing energy plants in Slovakia regions. The NUTS III methodology was used to locate the climatic conditions of the Slovakia regions. Climatic factors in Slovakia regions were expressed as average monthly air temperatures and average monthly precipitation for the vegetation period from April to October. The climatic parameters of the model plantation in the Nitra region were defined on the basis of measurements of the Physicus Meteostation, located in the field conditions of Kolíňany village. Regions in the southern and south-eastern regions of Slovakia (Bratislava, Trnava, Nitra, Košice) are the most climatic friendly for the growing Mustanthus and Populus. The Northern regions (Žilina and Prešov) are less suitable for climatic reasons - the shorter length of vegetation period required for the economically efficient production of above-ground biomass. In the Nitra region, productivity in real climatic conditions is 33.66 t.ha^{-1} (Miscanthus) and 135.14 t.ha^{-1} (Populus).

Key words: *climatic parameters, region, Slovakia, production, energy plants*

INTRODUCTION

Global problems caused by climate change and energy security have significantly increased interest in renewable energy, including energy crops in different regions. In addition, economic assessments have confirmed that the cultivation of energy crops has the potential to offer farmers a cost-effective alternative to often decreasing yields from conventional land use. Environmental protection also forms part of the EU's support measures under the CAP [15,16] farmers should be rewarded for services they provide within the countryside (landscape development, biodiversity, climate stability) that are beneficial to the climate and the environment.

Energy based on renewable energy sources focuses on long-term aspects and global solutions. The long-term goal for research and development of energy use of biomass is primarily to ensure its competitiveness with fossil fuels [20].

Solution of the climate change requires global coordination and a long-term strategy. The Paris agreement of 2015 provides a framework to limit global warming to below 2 ° C above pre-industrialization levels. The EU has set binding climate and energy targets for 2020 and 2030. Member States have set up an energy union to provide affordable, safe and sustainable energy [6]. Such an energy union is prospective for the climate [7].

Renewable Energy Directive (RED) (2009/28 /EC) sets binding targets for 2020 for the share of renewable energy in gross final energy consumption, the Energy Efficiency Directive puts forward targets expressed in primary energy. As the latter is part of the EU 20-20-20 climate and energy package, understanding the interactions between different RES technologies and their statistical impacts on primary energy is useful to policymakers [19].

Among all renewable energy sources, biomass could contribute to meeting the EU's renewable energy targets by 2020 [4,9]. In Italy, interest in biofuels has increased over the past 10 years. Cultivation of crops for biomass production was in fact included in the cultural plans of several farms, particularly in the northern regions of Italy.

Technologies of energy crops production are focused on the production of biomass for direct combustion, gasification, anaerobic digestion, the production of liquid biofuels, and other methods of energy and, eventually, industrial use. Energy crops are usually divided into herbaceous and woody plants. The potential in the subsequent use of the biomass thus obtained has regional or local character.

Potential problems that biomass, as a renewable energy source, can cause to the environment are compared to fossil-based energy more acceptable in terms of long-term corporate intentions.

Reliable identification of realistic biomass at regional level is particularly important in creating a real energy strategy. It must stand for the region especially in the long-term aspect of its sustainable development.

Phytoenergetics, as a new sector of the economy, includes a set of technologies enabling the use of biomass as an alternative source of energy and it can have a significant role in the energy development of the regions. It includes biomass technologies, biomass cultivation technology and biomass processing for energy use at local and regional level.

Targeted cultivation of energy plants has potential to be applied in economic and social practice and leads to an increase in the sustainable development of the regions. The partial goal of planting energy plants is to reduce the energy dependence of the state and its individual regions, to reduce greenhouse gas emissions, to increase the share of renewable resources in the state's energy mix. In recent years, the production of energy crops has also been affected by increasingly frequent weather extremes [14].

The aim of the paper is to identify and quantify environmental impacts, especially microclimatic impacts, on the possibility to establish and grow economically and energy-efficient plantations of fast-growing energy plants in the Slovakia regions.

MATERIALS AND METHODS

The NUTS III methodology (La Nomenclature des Unités Territoriales Statistiques) was used to locate and assess the climatic conditions of the Slovakia regions. NUTS III regions are divided into 8 regions in Slovakia (BA - Bratislava, TT - Trnava, TN - Trenčín, NR - Nitra, ZA - Žilina, BB – Banská Bystrica, PO - Prešov and KE - Košice region).

Climatic factors in the Slovakia regions are expressed as average monthly air temperatures and average monthly sums precipitation for the vegetation period from April to October. The data were processed according to the database of the Slovak Hydrometeorological Institute for the years 2010 to 2017.

The climatic parameters of the model plantation in the Nitra region were specified on the basis of Physicus Meteostation measurements, localized in the village of Kolíňany in specific field conditions. Average monthly air temperatures and average monthly precipitation sums for the vegetation period 2015-2017 were expressed.

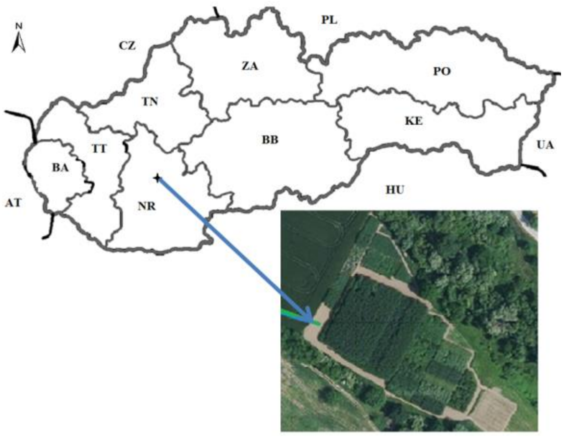


Fig. 1. Localization of model plantation of fast-growing energy plants in Kolíňany, Nitra Region
Source: pôdnemapy.sk, own processing, 2017

The model area of experimental research on growing fast-growing plants is located in the Nitra region in the cadastre village of Kolíňany. The GPS location of the model plantations is 48 ° 21'21 "N 18 ° 12'25" E (Figure 1) with an altitude of 80 m above the sea. A more detailed description of the abiotic conditions of the model area is given in the article [10].

The plantation of the energy woody plant green poplar and the energy grass *Miscanthus* were evaluated in the model area of the Nitra region. A more detailed description of the plant material is given in the works [3] and [12]. Biomass harvesting of energy grass is done annually. The plantation of energy woody plant *Populus* is set on a three-year harvest cycle.

RESULTS AND DISCUSSIONS

The significant biomass production and limiting element for localization of plantations of fast growing plants in the regions are climatic parameters. *Populus* and *Miscanthus* for their growth and biomass production need appropriate temperature and humidity conditions during the vegetation period and stable climatic conditions at the beginning of the vegetation period. Based on the databases of average monthly air temperatures and average monthly sums of precipitation were processed the regional differences of selected climatic parameters (Table 1) in Slovakia regions.

Table 1. Differentiation of selected abiotic conditions in Slovakia regions - climatic parameters

region / parameter	**Ø air temperature (°C) during the vegetation period**	**Ø total precipitation (mm) in the vegetation period**
BA	16.32	504.85
TT	16.28	419.76
TN	15.45	486.03
NR	16.98	423.39
ZA	13.32	622.53
BB	15.36	525.34
PO	14.22	549.61
KE	15.71	496.10

Source: own processing, 2018

For the cultivation of the energy grass *Miscanthus* and the energy woody plant *Populus*, the climatically most tolerant regions are situated in the southern and south-eastern regions of Slovakia. On the contrary, the northern regions (Žilina and Prešov) are less suitable for climatic factors - the shorter length of vegetation period required for economically efficient production of above-ground biomass. Even here, however, are local exceptions, in relation to the altitude of a particular habitat.

a) b)

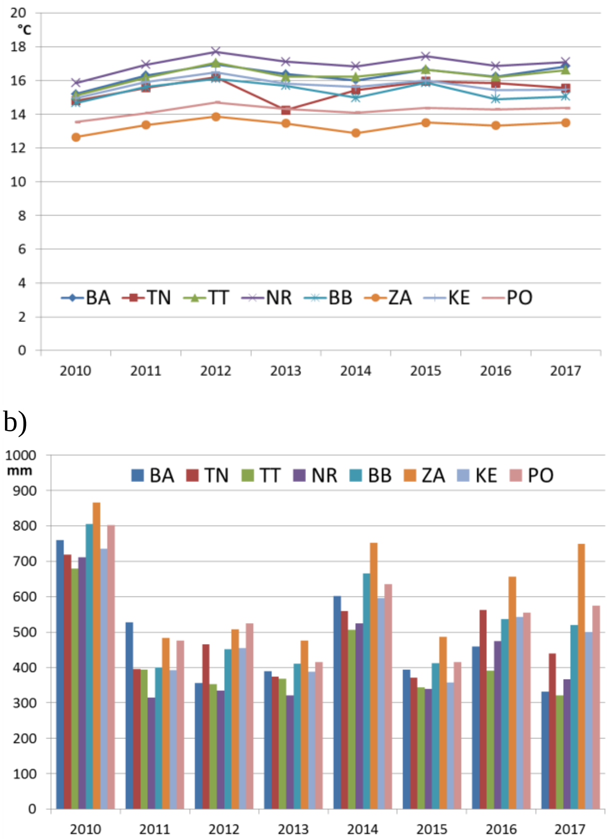


Fig. 2 Comparison of climatic parameters in the Slovakia regions during the vegetation period 2010 - 2017 (a) average temperature during the vegetation period b) average precipitation during the vegetation period)
Source: own processing, 2018

The trend of average temperatures and average precipitation during the vegetation period from 2010 to 2017 in Slovakia regions shows Figure 2. The differentiation of climatic parameters over the years under review shows the graphs a) and b). It is possible to identify warmer and drier years during the period under review (2012 and 2015). The graph shows the years when there was enough precipitation during the vegetation period with the appropriate temperature conditions (2010 and 2014). Relative fluctuations between years were recorded in the analysis of precipitation during the vegetation period of the years under review.

Already in 2009, the authors [17] presented the results of a study, where they were analysing spatial and economic conditions for establish of the energy plants plantations in Illinois regions (USA), which they differ in soil quality and climatic conditions.

In China, authors [21] solved a similar spatial differentiation of regions eligible for growing of *Miscanthus* on the basis of climatic parameters. They determined the length of the vegetation period defined as the time for biomass start of the start at an average daily temperature ≥ 10 ° C and a total precipitation during the vegetation time ≥ 400 mm as a limiting factor in the assessment of climatic conditions.

The authors [8] evaluated regional differences in relation to the climatic parameter. Specifically, they focused on the influence of low temperatures at the beginning of the vegetation period on the tolerance of energy grasses against spring frost. They confirmed the variation in the possibility of growing these plants due to differences in air temperature.

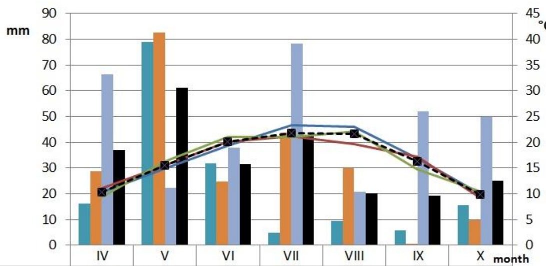
Based on the assessment of the average monthly air temperatures and the average monthly precipitation during the vegetation period for an eight-year period, the differentiation of the regions where it is appropriate to establish and cultivate such plantations was evaluated (Table 2). In the ZA and PO regions were detected a short vegetation period, the temperatures above 10 ° C occur between mid-May and mid-September. The early end of the vegetation period was indicated in the TN, PO and KE regions, the temperatures dropping below 10 ° C in late September and early October., In the BA and NR region were indicated favorable conditions in terms of average air temperature during vegetation time and were indicated early onset of daily temperatures above 10 ° C.

Table 2. Evaluation of regional differentiation of selected climatic parameters in Slovakia regions

region / parameters	temperature conditions	humidity conditions
BA	+	+
TT	+	+ / -
TN	+ / -	+ / -
NR	+	+ / -
ZA	-	+
BB	+ / -	+
PO	-	+
KE	+ / -	+ / -

Legend: + appropriate, + / - acceptable, - inappropriate
Source: own processing, 2018

In the TN, TT and NR regions, there is less sums precipitation at the beginning of the vegetation period, which limits the growth of new shoots in *Miscanthus* and the slowing of foliage formation for *Populus*. In the western and southern regions, there is also a lower average of the sums precipitation during the culmination of biomass growth of these plants at the end of June and early July. ZA, BB and PO are regions where the humidity conditions are suitable for growing throughout the vegetation period.



	IV	V	VI	VII	VIII	IX	X
mm 2015	16.00	78.80	31.38	4.80	9.40	5.60	15.60
mm 2016	28.60	82.60	24.80	43.80	30.00	0.60	9.60
mm 2017	66.20	22.20	37.80	78.40	20.80	51.80	49.80
mm average	36.93	61.20	31.47	42.33	20.07	19.33	25.00
°C 2015	10.28	14.19	19.28	23.24	22.94	16.84	9.98
°C 2016	11.07	15.48	20.01	21.21	19.69	17.22	9.14
°C 2017	9.36	16.24	20.94	21.08	22.14	14.69	10.39
°C average	10.24	15.54	20.08	21.84	21.59	16.25	9.84

Fig. 3. The average values of climate parameters for the years 2015 – 2017 at the model plantation of fast-growing plants in the village Kolíňany in Nitra region
Source: own processing, 2018

The average air temperatures and average precipitation during the vegetation period over a three-year period were analysed according to measurement of the meteorological station located in field conditions on the model area (Figure 3). Values where precipitation reaches lower values than the temperature curve is a period of physiological dryness. This is a period when plant species have a lack of water for their growth and biomass production. This period was identified at the model plantation, especially during the summer months (June and August) - based on three-year measurements of climatic parameters. Nevertheless, the stands reached a balanced production (Table 3). A lot of precipitation in the spring period has provided enough water for plants to produce biomass. The culmination of the shoots formation in *Miscanthus* is the turn of the months of June and July. The average air temperature during the vegetation time was 16.48 ° C. The temperature value is comparable to the data analysed for regional differentiation. The three-year rainfall average during the vegetation period (236.33 mm) is below the eight-year average measured in the Nitra region.

The length of the vegetation period at the experimental plantation in the Nitra region was 196 days (2015 - 184 days, 2016 - 189 days and 2017 - 214 days). The sum of average daily temperatures ≥ 10 ° C was on average 3,317.72. According to the climatic regionalization of Slovakia, this value indicates the location in a very warm to warm, very dry, lowland region.

In Table 3 is documented the evaluation of the production potential of the monitored plants. *Miscanthus* has been observed since the establishment in 2010 and the *Populus* since 2012.

Table 3. Production of dry above-ground biomass by *Miscanthus* ($t.ha^{-1}$) and *Populus* ($t.ha^{-1}$) planting on the research base in Kolíňany, Nitra region

Year / plant	*Miscanthus*	*Populus*
2010	10.95	-
2011	17.5	-
2012	24.85	51.47
2013	27.2	15.97
2014	28.6	41.98
2015	27.95	135.14
2016	33.66	34.67

Source: own processing, 2018

The *Miscanthus* production grows dynamically during the monitor period and in the seventh year of vegetation the average harvest of dry biomass reached 33.66 $t.ha^{-1}$. The slight drop in harvest in 2015 could be affected by low precipitation during June - July (25.2 mm and 16.5 mm). These months are the period when the *Miscanthus* reaches the culmination of growth new shoots. The sum of precipitation during the 2015 vegetation period was only 162 mm.

The cost-effective production yields of *Miscanthus* were confirmed in different regions of Europe (regions differentiated by climate). The authors [1] confirmed in southern Europe, under optimal climatic conditions, the production of above-ground dry biomass of approximately 25-30 $t.ha^{-1}$. In Serbia, on two different soil-climatic sites, the authors [5] reported the yield of *Miscanthus* biomass varies from 15.5-37.5 $t.ha^{-1}$ depending on the soil type. Similarly, authors [2] in their work confirmed that *Miscanthus* production varies depending on environmental conditions, crop management and collection time. The authors [13] confirmed the yield of 26.9 $t.ha^{-1}$ of the *Miscanthus* biomass in the hilly region of Sicily (Italy).

Vegetable year 2012 was the last year of the first and the vegetation year 2015 was the last year of the second three-year cultivation cycle of energy woody plant *Populus* with an average production of 51.47 $t.ha^{-1}$ (2012) and 135.14 $t.ha^{-1}$ (2015). Comparing biomass production during the first and second cultivation cycle were differences in biomass production. The polynomial trending function [11] of the growth of *Populus* biomass points to fluctuations in annual production. This is a three-year cultivation cycle and at the end of this cycle, the biomass is harvested.

Authors [18] also watched the performance of seven hybrid poplar clones on Boian's experimental basis in the soil-climatic conditions of southern Romania. On the basis of their research, they confirmed the equilibrium of production even 15 years after planting in the region.

CONCLUSIONS

The occurrence and impacts of climate change also occur in the regions of Slovakia.

Significant regional rise in air temperature is accompanied by significant changes in other climatic parameters in individual regions, in particular the fall in precipitation and the increase in extreme weather conditions. Such changes lead to influencing the production capacity of energy plants. Therefore, it is necessary to regionally and subsequently locally designate suitable areas for the foundation and cultivation of plantations of energy plants in order to achieve economically profitable production.

For the cultivation of the energy grass *Miscanthus* and the energy woody *Populus*, the climatically most tolerant regions are situated in the southern and south-eastern regions of Slovakia. By contrast, the northern regions are less suitable for climatic factors. In the Žilina and Prešov regions, the short vegetation period required to achieve high yields of biomass was detected. In terms of air temperature during the vegetation period, favorable conditions were indicated in the Bratislava and Nitra region. There is also a lower average precipitation during the culmination of biomass production of these plants. However, the production performance of model plants was not affected by the lack of precipitation. A lot of precipitation in the spring period has provided enough water for plants to produce biomass. Average air temperature during the vegetation period was 16.48 ° C in field conditions in the village of Kolíňany (Nitra region). The three-year precipitation average of the experimental site during the vegetation period (236.33 mm) is below the eight-year average measured in the Nitra region (423.39 mm). Growth of *Miscanthus* production increased dynamically and in the seventh year of vegetation the average yield of dried biomass reached 33.66 $t.ha^{-1}$. The *Populus* plantation reached an average biomass yield of 135.14 $t.ha^{-1}$ after the second cultivation cycle. Under the climatic conditions of the Nitra region, efficient biomass production was achieved on the model plantation of energy plants on unused agricultural land as an alternative source for further energy recovery.

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