Impact of crop site geographic altitude on drought indices of field crops in Hungary

A termőhely földrajzi paramétereinek meghatározó szerepe szántóföldi növényfajok aszályindexének alakulásában Magyarországon

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Abstract: Growth and development of field crops is highly influenced by the water availability of the crop site. In an assessment study at the MATE University, the magnitude of aridity in relation with the geographic location of the crop site has been evaluated. Six field crop species (Sugar beet *Beta vulgaris*, winter barley *Hordeum vulgare*, winter wheat *Triticum aestivum,* maize *Zea mays*, potato *Solanum tuberosum*, and alfalfa *Medicago sativa*) were involved in the research. Data bases of twelve meteorological stations (Békéscsaba, Budapest, Debrecen, Miskolc, Mosonmagyaróvár, Nagykanizsa, Nyíregyháza, Pécs, Siófok, Szeged, Szolnok, Szombathely) representing major geographic areas of Hungary were used in the evaluation. PAI indices of the stations involved were combined with vulnerability indices of the field crops studied. Upon the results of the study cereals proved to be the most tolerant, while potato and maize were highly influenced by aridity x vulnerability interactions. Considerable impact could be seen in the case of alfalfa and sugar beet. The geographic altitude of the crop site was in negative correlation with the magnitude of drought indices.

Keywords*: field crops, altitude, crop site, drought, vulnerability*

Összefoglalás: A szántóföldi növények növekedésében és fejlődésében döntő szerepe van a termőhely vízellátottságának. A MATE növénytermesztési kutatásaiban vizsgálták a termesztett növényfajok és a termőhely földrajzi paraméterei által meghatározott ariditási értékek összefüggését. Hat növényfaj (cukorrépa *Beta vulgaris*, őszi árpa *Hordeum vulgare*, őszi búza *Triticum aestivum,* kukorica *Zea mays*, burgonya *Solanum tuberosum*, és lucerna *Medicago sativa*) termesztési paramétereit elemezték tizenkét termőhely (Békéscsaba, Budapest, Debrecen, Miskolc, Mosonmagyaróvár, Nagykanizsa, Nyíregyháza, Pécs, Siófok, Szeged, Szolnok, Szombathely) meteorológiai állomásainak adatbázisán. A vizsgálat során az aszályindexek (PAI), illetve a sérülékenységi indexek (VI) kölcsönhatásait tanulmányozták. A kapott eredmények alapján igazolható volt, hogy a kalászos gabonák aszálytűrő képessége volt a legnagyobb, a kukoricáé és a burgonyáé pedig a legkisebb. A lucerna és a cukorrépa vízellátottsági kitettsége is jelentős volt. A termőhely földrajzi paraméterei közül a tengerszint feletti magasság az aszályindexekkel negatív korrelációt mutatott.

Kulcsszavak*: szántóföldi növények, földrajzi paraméterek, termőhely, aszály, érzékenység*

1 Introduction

All live systems depend on water availability. Water budget of crop sites is a determining factor regarding plant growth and development. Water deficiency of crops is labelled as aridity, however the physiological state my range from water scarcity to drought (Várallyay 2006). All physiological processes depend on the presence of moisture, like photosynthesis, osmosis, turgor, transpiration, respiration, as well as growth and development, and propagation. Water supply may have an influence in all of them. Aridity in general may obstruct growth and development, however drought is the most sever from among all types of water scarcity.

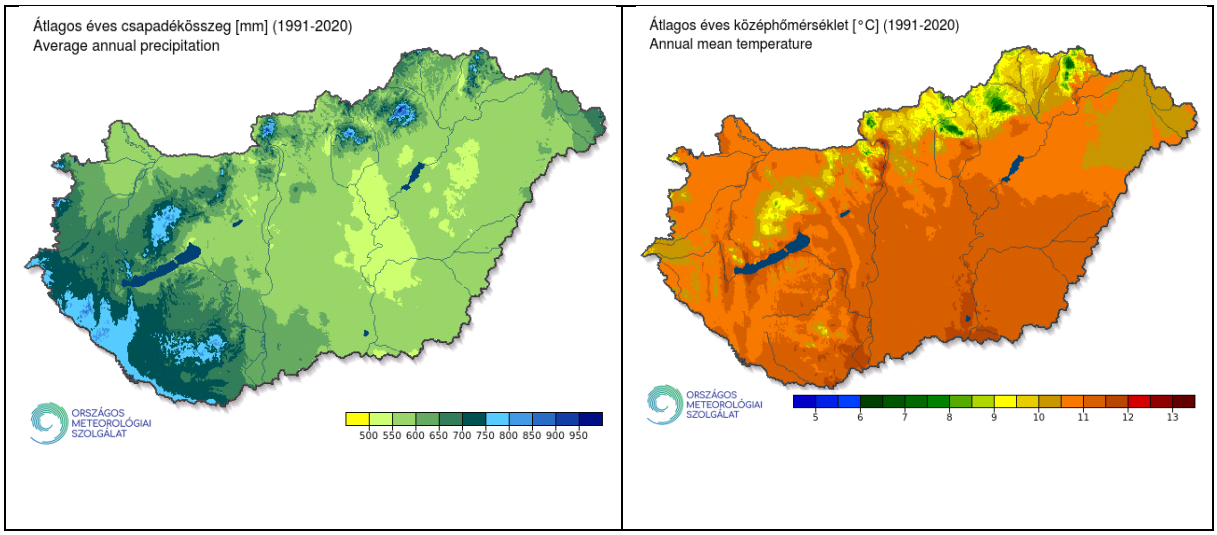

Figure 1 *Annual mean precipitation and temperature in Hungary on a 30 years' timescale (OMSZ 2022)*

Definition of droughts can be assessed in three main ways (Jolánkai et al 2012). Meteorological drought, hydrological drought and agricultural drought. The latter can be defined shortly, that drought is a phenomenon when a plant suffers irreversible physiological damages.

There are various assessments for quantification of water scarcity. Aridity indices are numerical indicators of the degree of dryness of the climate at a given location. A number of indices have been used in various parts of the world, like Köppen and Thornthwaite indices (UNEP 1992). These indicators serve to identify, locate or delimit regions that suffer from a deficit of available water, a condition that can severely affect the effective use of the land for such activities as agriculture or stock-farming. In Hungary the Pálfai Drought Index PAI is extensively used in agrometeorology (Pálfai 1990; Lakatos-Szalai 2010). In all aridity indices climatic components are expressed in mathematical formulas. Geographic locations in this context are very seldom examined upon the basis of crop site altitude, however the elevation may have a profound role in the utilization of natural water resources by the vegetation and so by the crop plants produced.

Agricultural crops have diverse reactions to water availability conditions. According to their taxonomy, life cycle, evapotranspiration patterns and the crop site characteristics, crop plants can be clustered to various vulnerability groups. The present study is dealing with the interaction between aridity and climatic vulnerability of some of the major field crop species of Hungary, as well as to evaluate changes in the aridity indices in relation with the geographic altitude of the crop site.

2 Materials and Methods

An assessment study has been done at the MATE University, Gödöllő to evaluate and identify the main factors of aridity. Almost all major field crop species were involved in the study, from which six species (Sugar beet *Beta vulgaris*, winter barley *Hordeum vulgare*, winter wheat *Triticum aestivum,* maize *Zea mays*, potato *Solanum tuberosum*, and alfalfa *Medicago sativa*) have been evaluated and presented. Crop vulnerability values (VI) were based on the mathematical model of Tarnawa et al (2010). In the survey databases of the Hungarian Meteorological Service (OMSZ) and the Ministry of Agriculture (AM) have been used (KSH 2022, OMSZ 2022). The use of Pálfai Drought Index (PAI) has been applied during the survey (Pálfai 1990, Bihari et al 2012). PAI values have been evaluated in a context of long-term databases. Regional evaluations were done respecting the databases of 12 meteorological stations chosen randomly to represent most of the regions of the territory of Hungary (Vermes 2011, Tarnawa et al 2012).

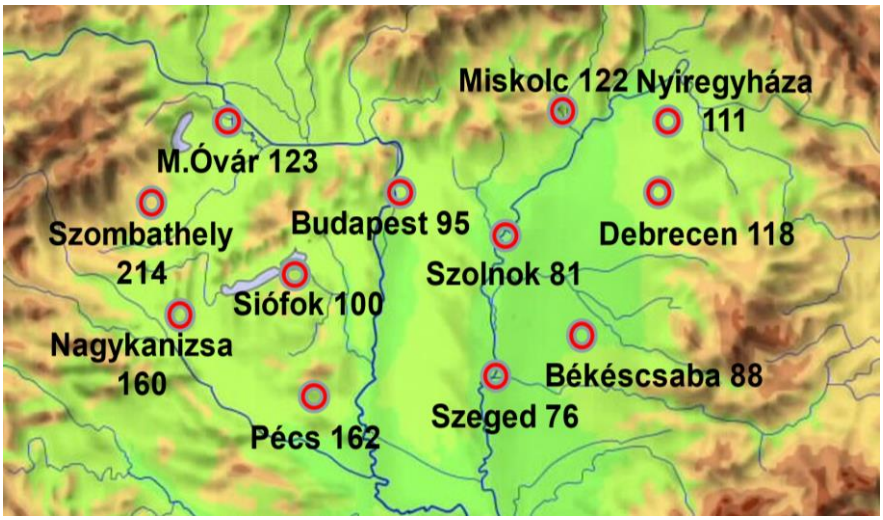

Figure 2 *Geographic altitude data of some meteorological stations in Hungary involved in the study, m*

Figure 2 presents geographic altitude data of twelve meteorological stations representing the territory of Hungary. Evaluating the long-term data bases the methodology of the state of the World's land and water resources for food and agriculture – Systems at breaking point (FAO 2021) was used. For statistical evaluations standard methods were applied; correlations, regression analysis, offered by Microsoft Office 2006.

3 Results and discussion

Pálfai Drought Indices of certain meteorological stations of the OMSZ Hungarian Meteorological Service (Békéscsaba, Budapest, Debrecen, Miskolc, Mosonmagyaróvár, Nagykanizsa, Nyíregyháza, Pécs, Siófok, Szeged, Szolnok and Szombathely) calculated on 50 years' averages were processed for each crop species studied. The results presented in Table 1 verify detectable differences between locations.

Twelve meteorological stations were randomly chosen to represent various levels of drought probability. The highest PAI indices were found in the case the central and the South-Eastern part of Hungary, while in the mountainous locations westward smaller figures were observed.

Table 1 Drought x crop vulnerability interactions regarding twelve meteorological stations and six field crop species based on 50 years' average

PAI (°C/100 mm)		wheat	winter barley	maize	potato	alfalfa	sugar beet	mean
VI indices		5,6	5,8	7,3	6,5	7,6	7,7	6,75
Békéscsaba	5.47	5,5	5,6	6,4	6,0	6,5	6,6	6,11
Budapest	5.85	5,7	5,8	6,6	6,2	6,7	6,8	6,30
Debrecen	4.91	5,3	5,4	6,1	5,7	6,3	6,3	5,83
Miskolc	4.18	4,9	5,0	5,7	5,3	5,9	5,9	5,47
Mosonmagyaróvár	4.69	5,1	5,2	6,0	5,6	6,1	6,2	5,72
Nagykanizsa	3.79	4,7	4,8	5,5	5,1	5,7	5,7	5,27
Nyíregyháza	5.23	5,4	5,5	6,3	5,9	6,4	6,5	5,99
Pécs	4.22	4,9	5,0	5,8	5,4	5,9	6,0	5,49
Siófok	5.07	5,3	5,4	6,2	5,8	6,3	6,4	5,91
Szeged	5.88	5,7	5,8	6,6	6,2	6,7	6,8	6,32
Szolnok	6.02	5,8	5,9	6,7	6,3	6,8	6,9	6,39
Szombathely	3.79	4,7	4,8	5,5	5,1	5,7	5,7	5,27
mean	4.92	5,2	5,4	6,1	5,7	6,3	6,3	5,83

Studying the interactions between drought and vulnerability the data suggest that crop species in accordance with their water consumption patterns and physiological characteristics may have a rather diverse performance in relation with the crop site PAI values.

Yield performance of the six crop species had a reducing trend due to the geographic elevation of the crop site. PAI x VI interactions have shown constant reduction of the crop yields. The trendline of this reduction was labelled by a strong linear regression. The lowest altitude was that of the Szeged crop site with 76 m above sea level, while the highest one of Szombathely had a geographic elevation of 214 m. The reason of this trend may be due to the annual mean temperature and the average precipitation of the location as this can be detected by the data of Fig 1. Central part of the lowland proved to have a higher temperature mean belonging to the annual 10-11 ºC isotherm range, while the same locations received an annual 500-550 mm precipitation over the long term.

Figure 3 presents data of the survey where the crop sites belonging to the certain meteorological stations were evaluated by their geographic altitude.

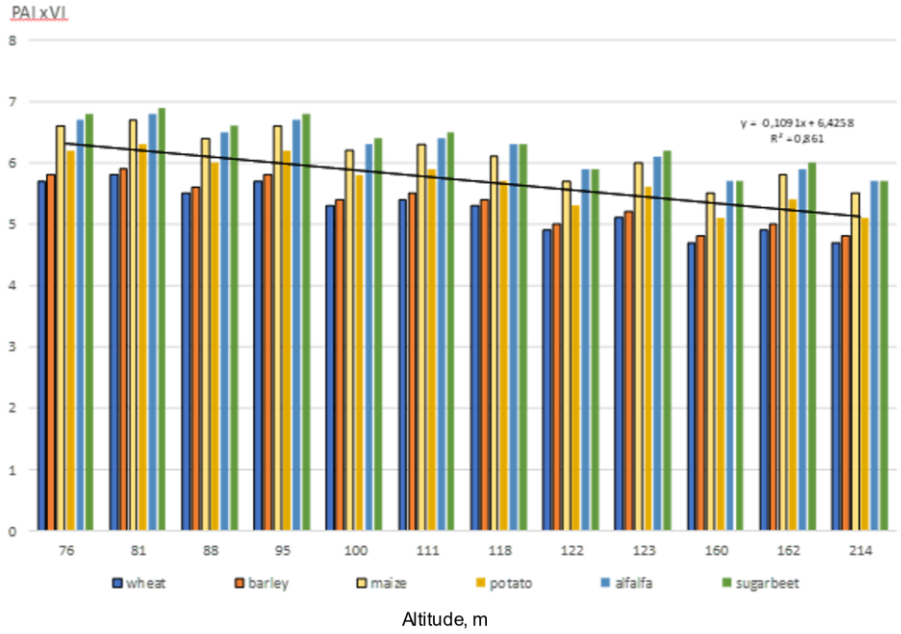

Figure 3 *Drought x crop vulnerability interactions of six field crop species by crop site altitude*

There were some alterations within the records since the most arid areas of the Great Plain belonging to the less than 500 mm range are located by the Szolnok station which is labelled by a higher PAI index than that of the Szeged crop site. Also, the highest altitude of this study at Szombathely with its 214 m had a medium level of PAI drought index. In the case of crop-species the trends were almost consequent but have shown detectable differences in accordance with their vulnerability. The results of the study support the postulate, that cereals were the least susceptible species, while potato and maize were proved to be highly influenced by drought x vulnerability interactions. Strong climatic impact could be detected in the case of alfalfa and sugar beet. Altitude of the crop site was in negative correlation with the magnitude of drought indices.

Figure 4 presents the regression data of the PAI drought indices related to the altitude of the meteorological stations of the crop sites. The equation can be expressed by a polynomial equation that is having a rather strong statistical value.

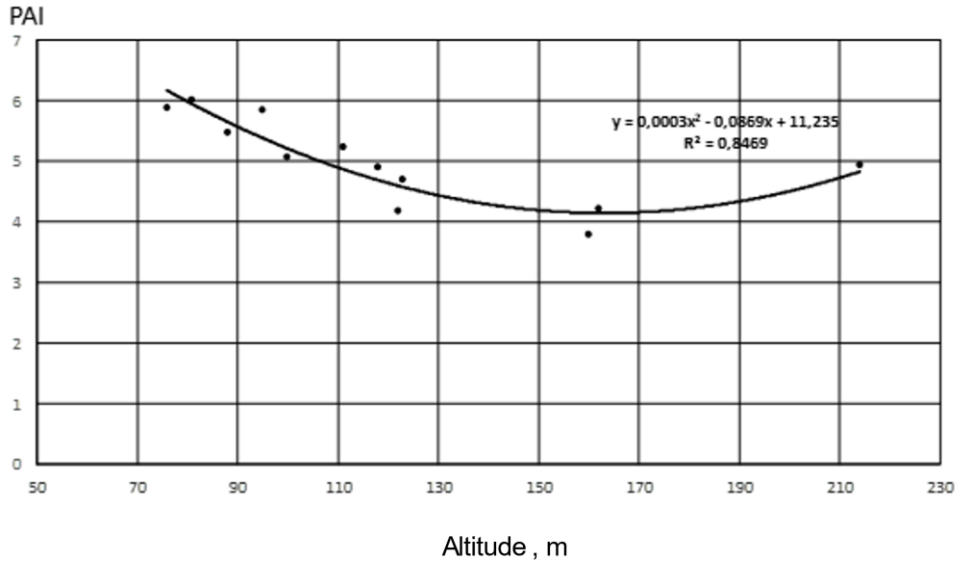

Figure 4 *Changes in the PAI indices due to the geographic elevation of crop sites*

4 Conclusions

As a conclusion of the study, it can be stated, that the geographic location may have a strong influence for the performance of various crop plant species. Certain crops like cereals are less susceptible to crop site conditions, while others, especially those with higher water demand like maize and potato are more exposed to that. Alfalfa and sugar beet were definitely proven to be the most vulnerable crops in this study. The interaction between PAI and VI indices were proved to be useful for characterising the crop site.

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