Thesis of Doctoral (PhD) Dissertation

ANALYSIS OF GREENHOUSE GAS EMISSIONS AND DROUGHT AND THEIR IMPACTS ON THE AGRICULTURAL SECTOR

Dissertation

Safwan Mohammed

Supervisor:

Dr. Endre Harsányi

Associate professor

UNIVERSITY OF DEBRECEN

Kálmán Kerpely Doctoral School

Debrecen

2021

1. INTRODUCTION

The Earth's atmosphere is full of gases, some of which are greenhouse gases (GHGs); these gases trap the sun's heat and keep earth warm for life. Even though GHGs exist naturally, human activities have released huge amounts of it, leading to more trapping of the sun's heat, which exceeds the needs of the earth, and which is known as "global warming - GW". This global warming has directly affected weather patterns on a global scale, causing "climate change - CC". In this context, the United Nations Framework Convention on Climate Change (UNFCCC) defined CC as a "change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods". However, CC has been shown to be a shifting of weather conditions over the long term, which could be recognized by changing rainfall, temperature and other climate components (*Mohammed et al.*2020).

Reddy (2015) summarized the main indicators of CC as follows: 1) an increase in temperature, 2) an increase in ocean heat content, 3) an increase in sea level and surface temperatures, 4) an increase in continentality, 5) tropospheric temperature, 6) a decrease in sea ice, 7) a decrease in snow cover, and 8) a decrease in sea ice glaciers

Consequently, the sunlight trapped by the earth's atmosphere - in other words, reflected heat (infrared) - cannot pass freely to the atmosphere due to a layer of GHGs, which already exist due natural and human causes (Figure 1). As a result, the earth's temperature is increasing (i.e. GW). In this context, GHGs contribute in different ways to GW; for instance, the contributions of CO_2, CH_4, and N_2O are 60%, 15%, and 5%, respectively (*IPCC* 2007). In terms of heat trapping (global warming potential (GWP)), N_2O is 298 times more effective than CO_2, and CH_4 25 times more. More details regarding GHGs will be discussed in the following paragraphs.

In central Europe, drought incidents have become more active and larger, correlated with raised temperatures and shortages of rainfall, as reported by many researchers, including *Bartholy et al.* (2013) in Hungary, *Kern et al*. (2016) in Central Europe, and *Cheval et al.* (2014) in Romania.

As in other European countries, Hungary is subjected to CC, where drought episodes have started to hit Hungary regularly in the last few decades (*Mohammed et al.*2020*; Alsafadi et al.* 2020, *Mohammed & Harsányi*.2019)

Successive steps have been taken toward adjustment of GHGs emissions in all sectors. However, few of them have discussed this topic from several relevant perspectives on a national scale. Thus, the main aims of this research were to:

1. Track GHG emissions from the agricultural and energy sectors in the EU between 1990 and 2016, to highlight the changes and the impact of different climate polices, with special focus on the agricultural sector.
2. Track current and future GHGs from agricultural sector in Hungary.
3. Track the development of drought in Hungary between 1960 and 2010 as one of the consequences of a global increase in GHG emissions.
4. Analyze the impact of agricultural drought on maize and wheat production on a regional scale in Hungary.
5. Track CO_2 emissions from two different agricultural ecosystems on a regional scale (Debrecen vs Tehran)

Overall, the research goals will answer the following ***questions***:

1- Is there a negative trend in GHGs emissions from the agricultural and energy sectors in the EU?
2- Is there a negative trend in GHGs emissions from agricultural sectors in the Hungary?
3- How did drought episodes evolve in Hungary between 1961 and 2010?
4- How has drought affected crop production in Hungary?
5- Can different climate regions affect the CO_2 emissions from the agricultural sector?

2. MATERIAL AND METHODS

2.1.Study framework

The range of this research varies from the continental scale to the farm scale. Firstly, GHGs emissions were addressed in EU countries, then at the Hungarian level (country level), and finally on a local scale (i.e. Debrecen), while national (Hungary) and regional scales (Debrecen) were chosen for tracking the impact of GHGs emissions in the agricultural sector.

2.2.Data collections

GHGs emissions data in thousands of tonnes of CO_2 equivalent were collected from The Organization for Economic Co-operation and Development (OECD) website (https://stats.oecd.org/), for EU countries (Austria; Ireland; Portugal; Slovenia; Estonia; Greece; Luxemburg; Italy; Spain; Belgium; the Czech Republic; Denmark; Finland; France; Germany; Hungary; Latvia; Lithuania; Netherlands; Poland; Slovak Republic; Sweden; the United Kingdom). Data included: GHGs emissions by countries, GHGs emissions by agricultural and energy sectors. For tracking GHGs emissions from different sectors in Hungary, the GHGs emissions data (thousand tonnes) was obtained from the Hungarian Central Statistical Office (1985-2016) (https://www.ksh.hu/docs/eng/xstadat/xstadat_annual/i_ua002a.html). The total cultivated area and total production of maize, and wheat from 1960 to 2016 for Hungary were collected from http://www.ksh.hu/docs/hun/xstadat/xstadat_hosszu/h_omf001b.html?fbclid=IwAR2IpocoIaPDJ6azp9hNlps-uJqXb0s6OnWMMGvn6jZur3NlTbybZAp0rxo; also the available data on a county scale was collected for 2000 to 2018 . The standardized precipitation index (SPI), and the standardized precipitation evapotranspiration index (SPEI), were collected from the Climate of the Carpathian region project-CARPATCLIM platform (1961-2010). In this database Hungary was covered by 1045 gridded points (at spatial resolution: 0.1°x 0.1° grid (10 km × 10 km)), as shown in Figure 1. Each grid represents the SPI/SPEI values over 3-, 6-, and 12-months in the form of a two-dimensional array. The data quality and homogeneity were ensured by the CARPATCLIM team (*Szalai, Vogt*, 2011).

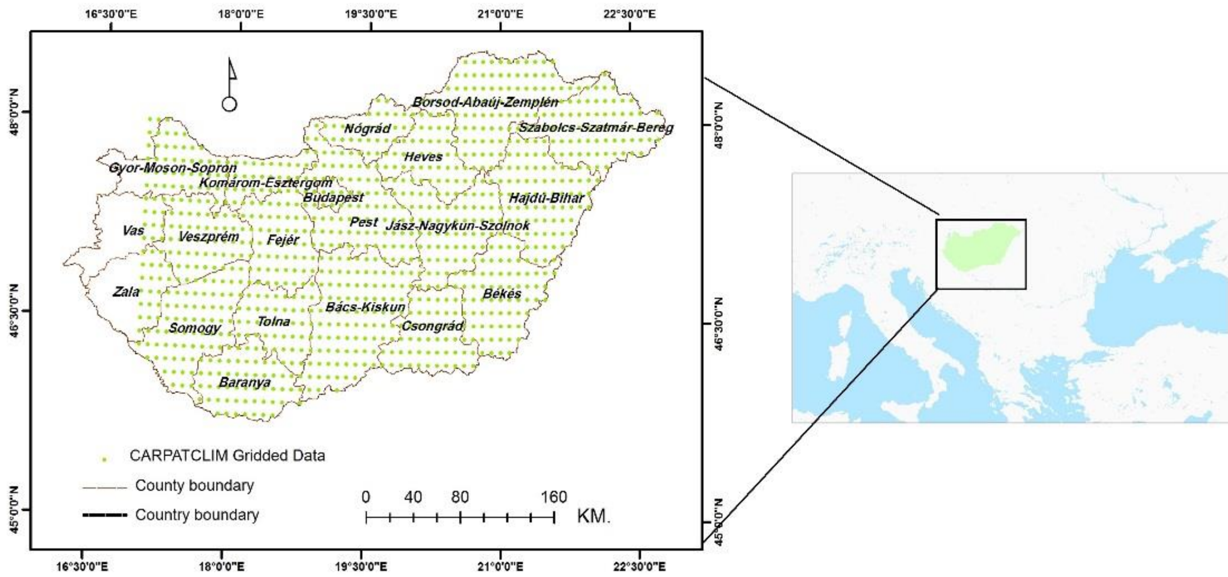

Figure 1. Distribution of gridded points over Hungary**.**

2.3.Data analysis

Trend of each emited poullotient was analyzed using the Mann–Kendall (MK) test. The MK test is a non parametric test with no-assumptions about data distribution which calculated as follow:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} singn(x_j - x_k) \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. \mathbf{1}$$

S: MK test statistics, x_j, x_k annual values for studied varible in years j and k (j > k).

Also, Sen's slope method (Sen, 1968) was applied to estimate the value of change by time (i.e. slope), which calculated as follow:

$$q_i = \frac{x_j - x_k}{j - k} \; for \; i = 1,2,3 \ldots . n \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \mathbf{2}$$

The well-known indices SPI and SPEI were employed for drought analysis over Hungary. The SPI is based on gamma distribution and can be calculated as follows (*Mc Kee et al*., 1993):

$$g(x) = \frac{1}{B^a \acute{\Gamma}(a)} x^{a-1} e^{-x/B} \qquad for \; x > 0 \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. \mathbf{3}$$

where: $g(x)$: gamma probability density function (pdf), *x* Rainfall, *a*: shape parameter (*a*> 0), *B*: scale parameter (*B*> 0), $\acute{\Gamma}(a)$: the gamma function.

Since the gamma function is not defined for zero (*x*= 0), and a rainfall distribution may contain zero values, the following function is used to calculate the cumulative probability:

$$H(x) = q + (1 - q)\, G(x) \ldots\ldots\ldots\ldots \mathbf{4}$$

where *q* refers to a probability of a zero value and is calculated as follows:

$$q = \frac{m}{n} \ldots\ldots\ldots\ldots \mathbf{5}$$

where m shows the number of zero values in the time series of length n.

The cumulative probability *H(x)* is transformed into a standard normal random variable Z, which is calculated as the inverse of the standard normal cumulative distribution function. Finally, to switch from gamma distribution to normal distribution as a random variable Z, we use the following equations:

$$Z = SPI = -\left(t - \frac{2.515517 + 0.802853t + 0.010328t^2}{1 + 1.432788t + 0.189269t^2 + 0.001308t^3}\right) for\ 0 < H(x) \leq 0.5 \ldots\ldots\ldots\ldots \mathbf{6}$$

$$Z = SPI = +\left(t - \frac{2.515517 + 0.802853t + 0.010328t^2}{1 + 1.432788t + 0.189269t^2 + 0.001308t^3}\right) for\ 0 < H(x) < 1 \ldots\ldots\ldots\ldots \mathbf{7}$$

$$t = \sqrt{In(\frac{1}{(H(x))^2})} \quad for\ 0 < H(x) \leq 0.5 \ldots\ldots\ldots\ldots \mathbf{8}$$

$$t = \sqrt{In(\frac{1}{1 - (H(x))^2})} \ for\ 0 < H(x) < 1 \ldots\ldots\ldots\ldots \mathbf{9}$$

where the SPI values for drought classifications are as can be seen in Table 1. The positive values indicate wet conditions, while negative values indicate drought conditions (less than median rainfall) (*Mohammed* et al. 2020)

Similarly, to the SPI, the SPEI (*Vicente-Serrano et al* 2010) uses monthly rainfall data, but also employs the impact of temperature by using the Thornthwaite equation (Thornthwaite 1948). Thus, the probability density function could be shown as follows:

$$f(x) = \frac{\alpha}{\beta}(\frac{x - \gamma}{\alpha})^{\beta - 1}\left[1 + (\frac{x - \gamma}{\alpha})^{\beta}\right]^{-2} \ldots\ldots\ldots\ldots \mathbf{10}$$

where $\boldsymbol{\alpha}$, $\boldsymbol{\beta}$, and $\boldsymbol{\gamma}$ are parameters related to the equation. With some mathematical steps, SPEI can be defined as:

$$SPEI = W - \frac{C_0 + C_1W + C_2W}{1 + d_1W + d_2W^2 + d_3W^3} \ldots\ldots\ldots\ldots \mathbf{11}$$

C_0, C_1, C_2, d_1, d_2, d_3 are constants and can be obtained from *Vicente-Serrano et al* (2010), and SPEI values for drought classifications can be seen in Table 1.

Table 1. Drought categories based on Agnew's scheme (*Mohammed et al*. 2020).

SPI and SPEI values	**Drought category**
> 0	Free drought
0 to -0.5	Half drought
-0.5 to -0.84	Lower drought
-0.84 to -1.28	Upper moderate drought
-1.28 to -1.65	Up drought
> -1.65	Mega drought

For tracking drought trends over Hungary, SPI and SPEI 3-, 6-, and 12- month scales for the1045 gridded points (i.e. 6207 gridded points in total) for the M-K test were applied at the 95% confidence level. Also, the Sen slope was determined for tracking drought magnitudes for both hydrological and agricultural drought. For illustrating drought trends over Hungary, the results of the M-K test were keyed to ArcMap software to produce the spatial distribution of the gridded points that show significant trends, as well as the decadal changes of the SPI/SPEI-3, -6, and -12 (*Mohammed* et al. 2020).

In order to determine the spatial and temporal changes in the drought pattern (i.e. the agricultural drought pattern and the hydrological drought pattern) principal component analysis (PCA, *Rencher*, 1998) was applied. Mathematically, PCA relies upon an eigenvector decomposition of the covariance or correlation matrix. In this research, a varimax rotation is performed to address the problem of variables loading moderately (or equally) on one or more of the axes. Finally, all results were keyed to GIS software for map productions.

Total drought duration (TDD) refers to all drought events that hit the study area (N_i) where SPI/SPEI is less than zero for a certain period of time (*Alsafadi et al*. 2020; *Fang et al*. 2018). The TDD is expressed as follows:

$$\text{TDD } (\%) = \frac{n_i}{N_i} \times 100 \quad \textbf{12}$$

where n_i is drought events, and N_i accumulative month numbers during the monitoring period.

2.4.Impact of agricultural drought evolution on the Hungarian agricultural sector:

In the last few decades, the agricultural sector in Hungary, and in particular, maize and wheat production have witnessed a remarkable yield increase. Thus, we need to remove the bias regarding technological development in the agricultural sector. So, the impact of drought (i.e. agricultural drought indices (SPI-3, SPEI-3, SPI-6, SPEI-6)) on crop

productivity was analysed using the Standardized Yield Residual Series (SYRS) as proposed by *Potopová et al.*, (2016), by using the following equation:

$$\mathbf{SYRS}_{c,r,y,t} = \frac{(y^{T}_{c,r,y,t} - \varphi^{T}_{c,r,y,t})}{\mathrm{X}^{T}_{c,r,y,t}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\mathbf{13}$$

where $\boldsymbol{c}$: crop, $\boldsymbol{r}$: region, $\boldsymbol{y}$: year, $\boldsymbol{t}$: timescale, $\boldsymbol{T}$: year, $\mathbf{SYRS}_{c,r,y,t}$**:** Standardized Yield Residual Series, $y^{T}_{c,r,y,t}$: detrended value of crop yield, $\varphi^{T}_{c,r,y,t}$: mean of $y^{T}_{c,r,y,t}$, $\mathrm{X}^{T}_{c,r,y,t}$: standard deviation of $y^{T}_{c,r,y,t}$. The classification of the SYRS is given as follows (Table 2):

Table 2. SYRS classification

Yield	$\mathbf{SYRS}_{c,r,y,t}$
Acceptable	$-0.5 < \mathbf{SYRS}_{c,r,y,t} \leq 0.5$
Low impact	$-0.5 < \mathbf{SYRS}_{c,r,y,t} \leq -1.0$
Upper low impact	$-1.0 < \mathbf{SYRS}_{c,r,y,t} \leq -1.5$
Exceed impact	$-1.5 < \mathbf{SYRS}_{c,r,y,t} < -2.0$
Mega impact	$\mathbf{SYRS}_{c,r,y,t} \leq -2.0$

In this research we investigated the impact of agricultural drought on maize and wheat yields, by using the above-mentioned method.

After calculating the SYRS, the crop yield resilience to drought ($\boldsymbol{CYR_T}$) was analysed using the following equation (*Guo et al*. 2019):

$$\boldsymbol{CYR_T} = \frac{y^{O}_{T}}{y^{d}_{T}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\mathbf{14}$$

where: $\boldsymbol{CYR_T}$: crop yield resilience to drought, y^{O}_{T}: observed crop yield, y^{d}_{T}: de-trended yield in driest year. The classification of $\boldsymbol{CYR_T}$ is given as follows (Table 3):

Table 3. CYR_Tvalue classification

Crop yield resilience to drought	$\boldsymbol{CYR_T}$ **value**
Resilient	$CYR_T > 1$
Slightly non-resilient	$0.9 < CYR_T < 1$
Moderately non-resilient	$0.8 < CYR_T < 0.9$
Severely non-resilient	$CYR_T < 0.8$

Finally, to show the impact of agricultural drought (SPI-3, SPI-6, SPEI-3, SPEI-6) on crop yields (i.e. maize, wheat); the coefficient of determination (R^2) was carried out. For each region, the R^2 value between $\mathbf{SYRS}_{c,r,y,t}$ and agricultural drought (SPI-3, SPI-6, SPEI-3, SPEI-6) was obtained on a monthly scale between 2000 and 2010. Then, the maximum and minimum R^2 values were keyed to GIS to produce the correlation maps.

2.5.A comparative analysis of CO_2 emissions from two different agricultural ecosystems on a regional scale (Debrecen vs Tehran)

Two different climate locations were chosen; the first one in Tehran (T) (Iran) as a representative of a semi-arid climate; while the second one in Debrecen (D) (Hungary) was representative of a continental climate. Almost the same treatments were applied, with some differences in irrigation due to the different crop managements in the two different climates (i.e. irrigation). In both locations the land use was maize cultivation under two types of crop management: a tillage (T) and a non-tillage (NT) system. Gas sampling was performed at 7–10-day intervals at each subplot based on the GHG sampling protocol of GRACEnet Chamber-based Trace Gas Flux Measurement. The static closed chamber method was used to measure the amount of gas emissions. The polyvinyl chloride (PVC) chambers (15 cm diameter, 12.5 cm height) with ports for gas sampling were placed on the soil surface to a depth of 5 cm during the whole monitoring period. Two chambers per subplot/ location (one within the plant row and one in between plant rows) were installed in three replications of each residue treatment, giving a total of 18 chambers for each plot of no-tillage and conventional tillage. The average of two chambers was considered to be the soil surface emissions for the entire subplot. Chambers were only removed during management practices. Gas samples were collected after 24 h of chamber installation to avoid disturbance effects. Gas samples were collected during the day from 9 to 10 am, at 0-, 30-, and 60-min. intervals. After this, samples were analysed in the soil science laboratory (Bouk University-Austria) using gas chromatography. In the Debrecen location (the Latokep field), following the previously described approach, the Testo 535 (0560 5350) CO_2 measuring instrument was used for CO_2. It is appropriate to mention here that soil temperature and soil water content were measured and recorded sequentially with other measurements in both locations.

3. RESULTS

As a part of the UNFCCC (United Nations Framework Convention on Climate Change), the EU-26 committed to keeping net emissions to a 10% increase beyond 1990 levels, as mentioned in the Kyoto Protocol. Thus, in this section, we will track changes in GHG emissions from the agricultural and industrial sector in the EU-26 between 1990 and 2016, where the relevant question was "What was the trend of GHG emissions in the EU-26 between 1990 and 2016?".

3.1.Carbon dioxide emissions from the agricultural sector (AG) within EU

The M-K test and Sen's slope showed that all EU-26 countries witnessed a remarkable reduction (Table 4). The negative but not significant trend was detected in all EU-26 countries except for Estonia, Hungary, Iceland, Latvia, Lithuania, and Spain.

Table 4. Trends in GHG emissions (thousands of tonnes of CO_2 equivalent) from the AG in the EU-26 between 1990 and 2016, and their significance (P<0.05)

EU-26	Changes*	P-value	EU-26	Changes*	P-value
Austria	-41.783	**< 0.0001**	Norway	-17.9024	**< 0.0001**
Belgium	-109.4372	**< 0.0001**	Portugal	-22.9288	**0.0004**
Czech Republic	-113.7134	**< 0.0001**	Slovak Republic	-72.07	**< 0.0001**
Denmark	-95.0117	**< 0.0001**	Slovenia	-6.081	**< 0.0001**
Estonia	-4.4968	0.6206	Sweden	-39.3726	**< 0.0001**
Finland	-16.1237	**0.0007**	Switzerland	-19.9917	**< 0.0001**
Greece	-70.1134	**< 0.0001**	France	-229.8465	**< 0.0001**
Hungary	-13.1877	0.3416	Germany	-268.7552	**< 0.0001**
Iceland	-0.4364	0.3631	Italy	-272.24	**< 0.0001**
Ireland	-90.5264	**0.0002**	Netherlands	-336.4756	**< 0.0001**
Latvia	-7.2289	0.5358	Poland	-285.5101	**< 0.0001**
Lithuania	-19.403	0.1710	Spain	-5.6002	1.0000
Luxembourg	-2.4454	**0.0025**	United Kingdom	-382.1733	**< 0.0001**

** thousands of tonnes of CO_2 equivalent; grey colour indicates the significance level at P< 0.05*

3.2.Carbon dioxide emissions from the industrial (ID) sector within the EU

The M-K test and Sen's slope showed that most EU-26 countries witnessed a remarkable reduction (Table 5). Nonetheless, a negative significant (p< 0.05) trend was detected in Belgium, the Czech Republic, Denmark, Hungary, Ireland, Latvia, Lithuania, the Slovak Republic, Sweden, Switzerland, France, Germany, Poland, Spain, and the United Kingdom (Table 8), while a positive significant (p< 0.05) trend was detected in Norway, Ireland, and Spain. However, a positive, but not significant trend was detected in Austria, Greece, Iceland, and Slovenia.

Table 5. Trends in GHG emissions (thousand tonnes of CO_2 equivalent) from the industrial sector in the EU-26 between 1990 and 2016 and their significance ($p < 0.05$**)**

EU-26	Changes*	P-value	EU-26	Changes*	P-value
Austria	74.449	0.5089	**Norway**	**371.1598**	**< 0.0001**
Belgium	-853.7511	**< 0.0001**	Portugal	23.4421	0.9343
Czech Republic	-1625	**< 0.0001**	Slovak Republic	-671.5617	**< 0.0001**
Denmark	-1063	**< 0.0001**	Slovenia	60.5662	0.0549
Estonia	-103.6771	0.1462	Sweden	-675.6224	**< 0.0001**
Finland	-314.6814	0.1710	Switzerland	-107.3684	**0.0187**
Greece	708.0427	0.2138	France	-2342	**0.0005**
Hungary	-817.3291	**< 0.0001**	Germany	-8489	**< 0.0001**
Iceland	0.6325	0.9671	Italy	-1748	0.2820
Ireland	**270.8153**	**0.0147**	Netherlands	-144.1049	0.4573
Latvia	-152.8869	**< 0.0001**	Poland	-2193	**0.0001**
Lithuania	-200.2695	**< 0.0001**	**Spain**	**2032**	**0.0235**
Luxembourg	-6.6453	0.8690	United Kingdom	-6643	**< 0.0001**

** thousands of tonnes of CO_2 equivalent; the grey colour indicates the significance $P < 0.05$.*

3.3. Current and future GHGs emission from agricultural sector in Hungary

In general, 10% is the contribution of agricultural sector to total GHGs emissions in Hungary. Nonetheless, 65% of the total N_2O originated from agricultural sector in Hungary.

The current GHGs emission from agricultural sector in Hungary showed a positive trend for both CO_2, and N_2O, while a negative trend for CH_4 (Fig.2)

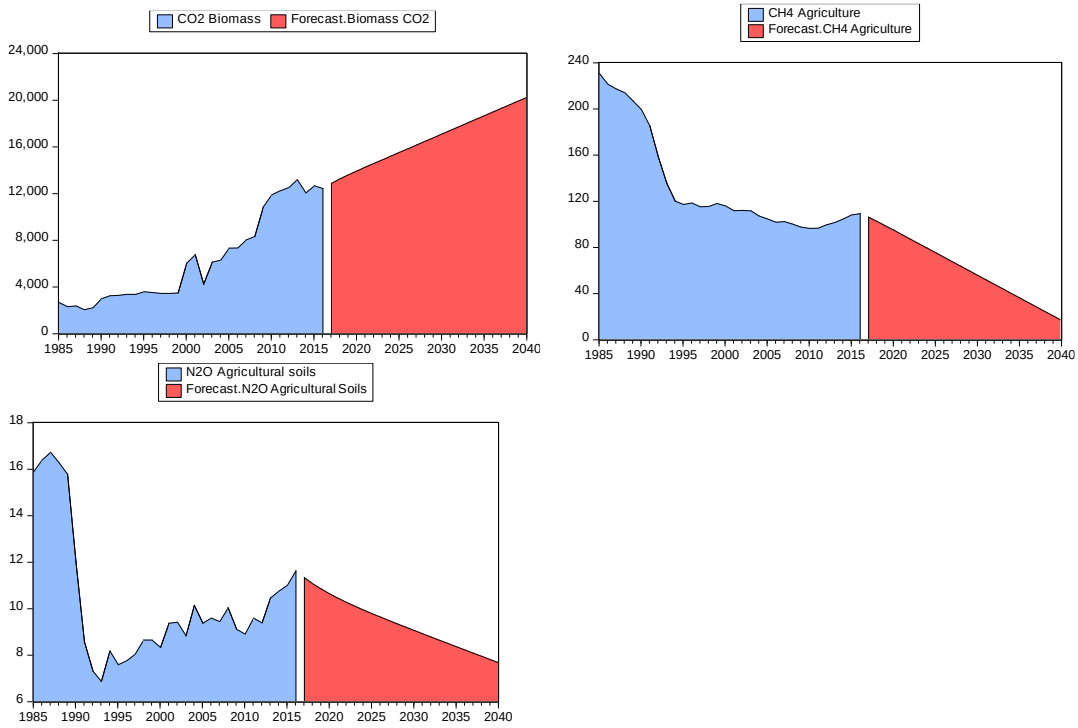

Figure 2 Current and future GHGs emissions from agricultural sector in Hungary

In this research, we applied ARIMA model (Autoregressive integrated moving average) to predict future GHGs emissions from agricultural sector in Hungary. Results, indicate clearly a gradual increase of CO_2 emission from agricultural sector in Hungary till 2040. In contrast, CH_4, and N_2O showed a remarkable decrease between 2016-2040.

3.4. Drought analysis of Hungary and its impact on the agricultural sector

The M-K trend test for the SPI (-3, -6) and the SPEI (-3, -6) showed that the eastern part of Hungary was less prone to agricultural drought, while agricultural drought in the western part was more pronounced. Figure 3 shows a negative trend of the Sen slope analysis (shown in brown) in the western part, where most of the studied points have a significant trend ($p > 0.05$).

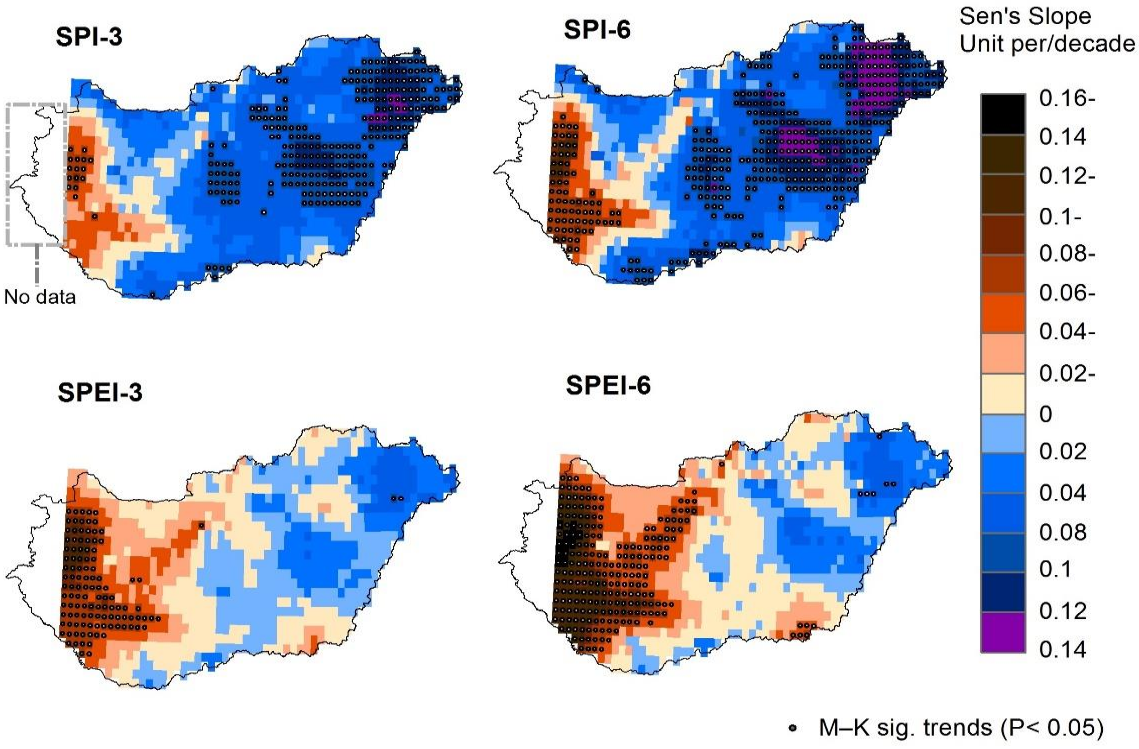

Figure 3. Agricultural drought trends (Sen's slope estimator M-K statistic test) in Hungary between 1961 and 2010; significant trends at P<0.05 illustrated by black points.

As illustrated in Figure 5, the frequency of agricultural drought (TDD) between 1961 and 2010 for SPI-3 and SPEI-3 (i.e. the 3-month time-scale) demonstrates that the central part (Bács–Kiskun), and the eastern northern part (i.e. Veszprém) (red colour) were the areas most subjected to agricultural drought. Almost the same results were obtained for SPI-6 and SPEI-6, but with a greater spatial extent, as can be seen in Figure 4. Based on the TDD-SPEI-6, it can be concluded that Hungary tends to be frequently hit by waves of

drought. However, the differences between the outputs of two indices (SPI, SPEI), here and in the other following sections, can mainly be attributed to the direct impact of evapotranspiration, which SPI did not calculate (*Alsafadi et al*. 2020).

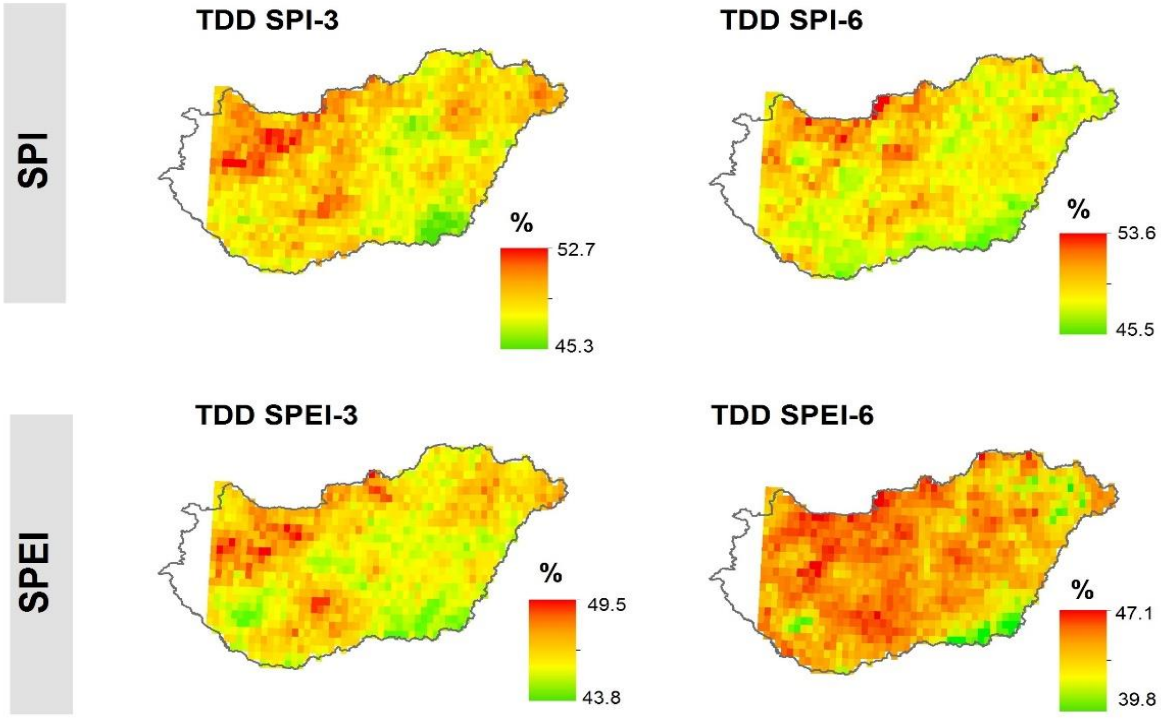

Figure 4. TDDs distribution of SPI/SPEI-3-6 in Hungary between 1961 and 2010.

Drought stress had a great impact on crop production, not only in Hungary, but also in many parts of the world. Thus, we analysed the interaction between drought and crop yield for maize and wheat by using two indices: the standardized yield residual series (SYRS), and the crop yield resilience to drought (CYR_T). Fig. 5 shows the most affected subregion by drought in Hungary in terms of maize, while Fig. 6 shows the most affected subregion by drought in Hungary in terms of wheat.

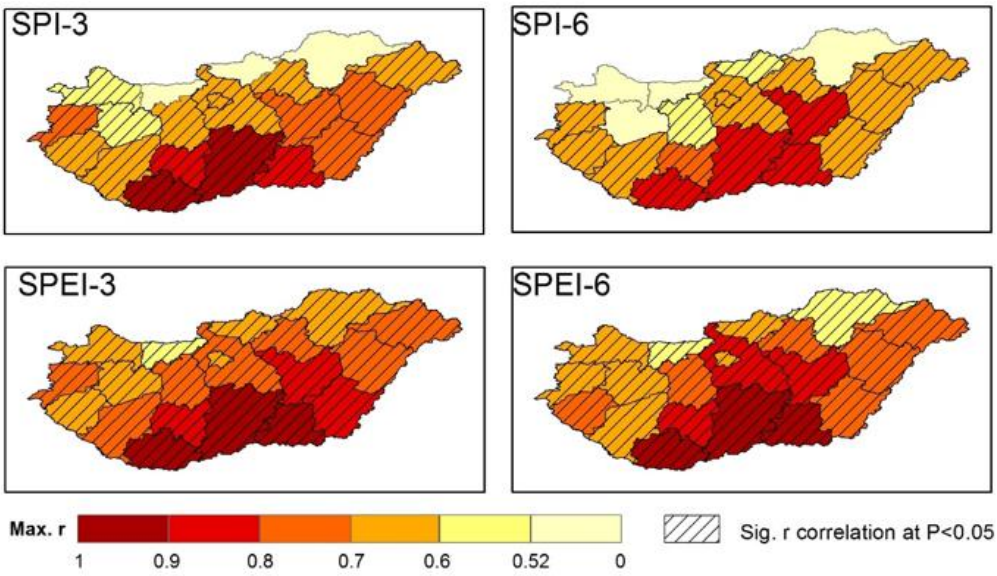

Figure 5. The highest corelations between agricultural drought indices (SPI-3, SPEI-3, SPI-6, SPEI-6) and SYRS for maize in the Hungarian regions between 2000 and 2010.

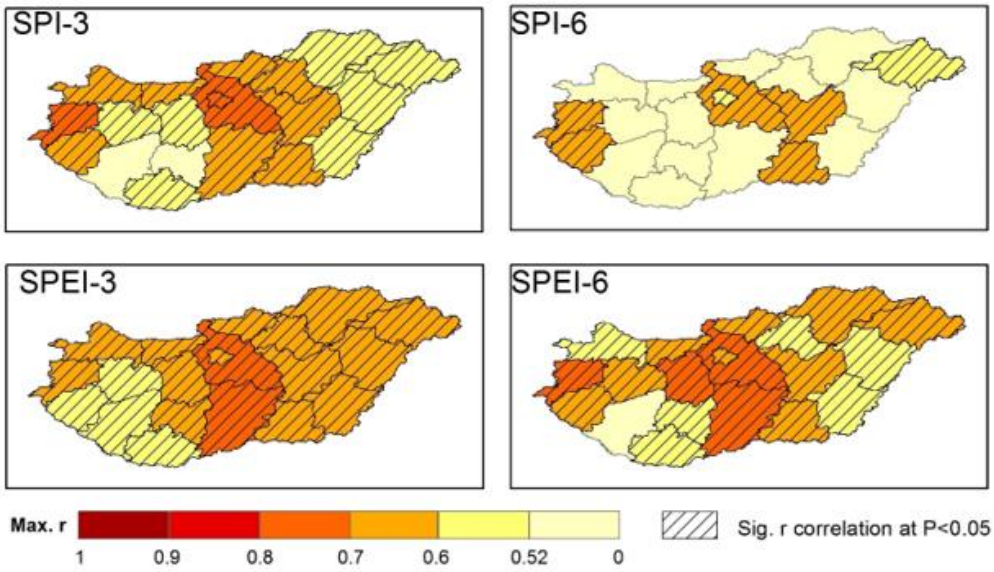

Figure 6. The highest corelations between agricultural drought indices (SPI-3, SPEI-3, SPI-6, SPEI-6) and SYRS for wheat in the Hungarian regions between 2000 and 2010.

3.5.comparative analysis of CO_2 emissions from two different agricultural ecosystems on a regional scale (Debrecen vs Tehran)

The main aim of this section is to give an overview of difference in emissions between two agroecosystems. The first one is a continental region represented by Debrecen (Latokep field), while the second is an arid region represented by Tehran (field of the Faculty of Agriculture). The measurements were caried out in two different maize fields: 1) tillage (T), 2) and non-tillage (N), between 02.08.2018, and 13.09.2018.

On a daily scale, the results showed a statistical difference (p<0.05) among treatments in the first, second, fourth, and fifth sampling dates (Table 6). For the third sampling date (10.08.2018), no significant differences were detected between the Tehran treatments, while in the sixth sampling date a statistical difference (p<0.05) was detected among locations (i.e. Debrecen vs. Tehran) regardless of the treatment types (i.e. T, N). Notably, the highest emissions were recorded in the tillage field in Tehran (C3), which ranged between 648±270 and 445±202. Meanwhile, the lowest emissions were recorded in the non-tillage field in Debrecen (C1), which ranged between 159± 48.8 and 66.33±16.20 (Figure 7).

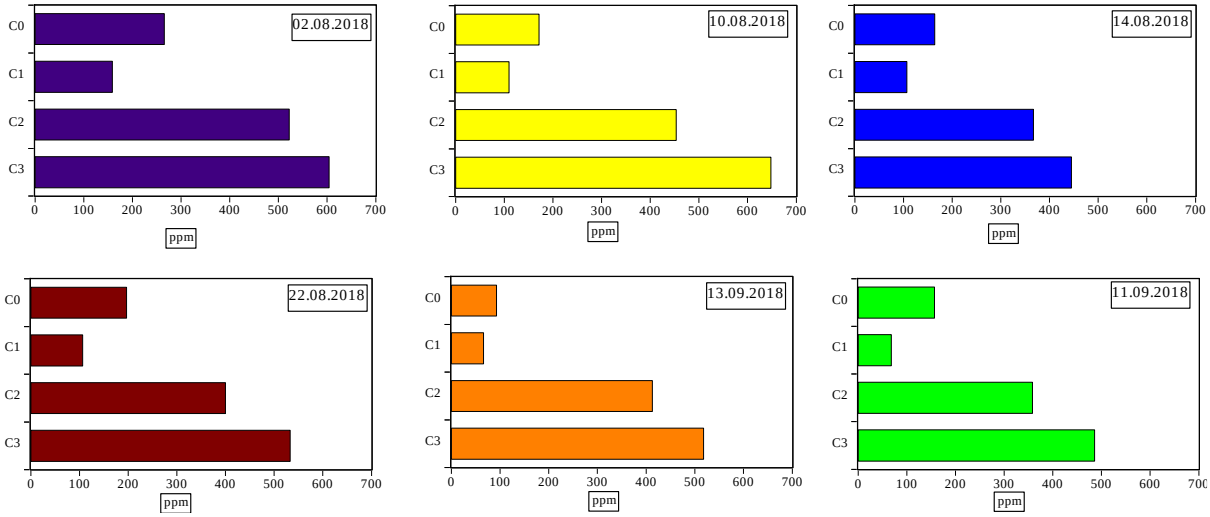

Figure 7. Daily soil CO_2 emissions data (ppm) with respect to treatments; C0: tillage field in Debrecen; C1: non-tillage field in Debrecen; C2: non-tillage field in Tehran; C3: tillage field in Tehran

Table 6. Statistical analysis of soil CO_2 emissions data (ppm) using the Fisher LSD test. Means with the same letter are not significantly different (p<0.05).

Field*		**02.08.2018**	**10.08.2018**	**14.08.2018**	**22.08.2018**	**11.09.2018**	**13.09.2018**
T. Debrecen	C0	265.7^{A}± 82.7	171.7^{A}±41.4	164.3^{A}±60.1	196.7^{A}±128.5	157.0^{A}±68.4	93.00^{A}±7.55
N. Debrecen	C1	159^{B}± 48.8	110.0^{B}±26.1	107^{B}±15.13	106.7^{B}±20.6	68.0^{B}±17.3	66.33^{A}±16.20
N. Tehran	C2	522^{C}± 190	453.5^{C}±123.	367^{C}±200	400.0^{C}±124	358.2^{C}±143.	413^{B}±179
T. Tehran	C3	604^{D}± 176	648^{D}±270	445^{C}±202	533^{D}±210	486^{D}±196	518.0^{B}±158.8

(T: tillage, non-tillage N) (n= 3 for each sampling date)

For further investigation of the difference among the means of the treatments, we applied the Fisher individual tests as presented in Table 7. The results can be summarized as follows:

1- On a daily scale, no statistical differences ($p<0.05$) were detected among treatments from the same geographical locations e.g. C1 - C0, and C3 - C2.
2- No statistical differences ($p<0.05$) were detected between the non-tillage field in Tehran (C2), and the tillage field in Debrecen (C0), which reveals that emissions from non-tillage agricultural lands in dry and semi-dry regions are almost similar to emissions from tillage fields in continental regions.

Table 7. Fisher individual tests for differences in the means of the treatments ($p<0.05$)

Difference of Levels	**02.08.2018**	**10.08.2018**	**14.08.2018**	**22.08.2018**	**11.09.2018**	**13.09.2018**
	P-Value					
C1 - C0	0.372	0.629	0.642	0.448	0.413	0.792
C2 - C0	0.052	0.051	0.126	0.109	0.087	**0.011**
C3 - C0	**0.017**	**0.005**	**0.045**	**0.018**	**0.013**	**0.002**
C2 - C1	**0.012**	**0.023**	0.060	**0.032**	**0.023**	**0.008**
C3 - C1	**0.004**	**0.002**	**0.021**	**0.005**	**0.004**	**0.002**
C3 - C2	0.490	0.153	0.528	0.271	0.252	0.313

(C0: tillage field in Debrecen; C1: non-tillage field in Debrecen; C2: non-tillage field in Tehran; C3: tillage field in Tehran)

4. NEW SCIENTIFIC RESULTS

This research demonstrates the following new scientific results:

1- In the EU scale, a significant ($p< 0.05$) reduction of GHGs were tracked between 1990 and 2016, from industrial and agricultural sector. However, the most significant ($p< 0.05$) reduction was noticed in the United Kingdom (-382.1733 thousand tonnes of CO_2 equivalent) and the Netherlands (-336.4756 thousand tonnes of CO_2 equivalent).

1- Future projection by ARIMA indicate clearly a gradual increase of CO_2 emission from agricultural sector in Hungary till 2040. In contrast, CH4, and N_2O showed a remarkable decrease between 2016-2040.

2- The M-K test results showed that total CO_2 emissions were reduced significantly ($p<0.05$) by -1114 thousand tonnes/year. Similarly, the total N_2O emissions were subject to a significant decrease ($p<0.05$) of -0.35 thousand tonnes/year.

3- Drought frequency analysis reveals the eastern northern part and central part as the most affected regions by drought. Also, this study highlighted the exposure of the western part of Hungary to drought, where the drastic years are 1970-1973, 1990-1995, 2000-2003, and 2007.

4- The western and southern regions of Hungary were more subject to maize yield losses (SYRS), while wheat yield reduction was less pronounced in comparison with maize.

5- The highest maize yield losses (i.e. SYRS ≤ -1.50) in 2003 were recorded in southern part. Wheat yield losses due to drought were experienced in 2003 and 2010. However, the highest impact of drought on crop reduction (i.e. highest correlation between SYRS and crop yield) was recorded in August for central and eastern part of Hungary.

6- The CYR_T showed that the maize and wheat yields were severely non-resilient ($CYR_T< 0.8$) in the central and western part of Hungary. Nonetheless, across Hungary, wheat crop is more resilient to drought events than maize.

7- Climate conditions (Debrecen vs. Tehran) and agricultural practice (Tillage vs. Non-tillage) have a significant impact on CO_2 emission from agricultural soil.

5. PRACTICAL UTILIZATION OF THE RESULT

1- GHGs reduction across Hungary and national strategy

Until recently, policies in many countries were driven by economic growth; meanwhile, few plans were drawn out to mitigate environmental degradation, including minimizing GHGs emissions. As Hungary is required to reduce GHGs emission by 10 % by 2020 compared to 2005 levels (the baseline), the output of this research highlighted the most emitted sectors across Hungary. Thus, the outcome could serve as a starting point or baseline for implementing some actions toward minimizing GHGs from various sectors. Also, this research could be used to develop a national plan for climate adaptation and climate mitigation from different sectors in Hungary. Notably, the results could support the government work through the Hungarian Adaptation Strategy (NAS); the National Decarbonization Roadmap (NDR); and the Climate Awareness Plan in a national level (CAP).

2- Risk assessment of climate change on agricultural sector

This study demonstrates the most affected subregion by drought and highlighted the affected crops by agricultural drought in terms of agriculture. Maize and wheat were severely non-resilient to drought ($CYR_T < 0.8$) in the following regions: Baranya, Budapest, Fejer, Nograd, Pest, Somogy, Szabolcs-Szatmar-Bereg, Tolna, and Zala. Such a result stresses the importance of a climate change adaptation plan for the sustainability of the agroecosystem. Thus, a national plan accompanies by some action on a sub-regional scale could mitigate climate change. Also, the adaptation of some agricultural technology such as precision agriculture in the affected area by drought could increase crop resilience and enhance natural resource management.

3- Minimizing GHGs emission from agricultural sector over Hungary

Our results showed that the CO_2 emission from traditional system was higher than conservation one. Thus, the output recommended the conservation agricultural system (CAS) for reducing the total emission. Along with: 1) enhancements of Climate-Smart Agriculture (CSA), and 2) application of management practices that reduces soil organic matter decomposition rates.

All in all, our work come along with the new National Climate Change Strategy NCCS-2 action plan of Hungary, especially with NDR and CAP.

6. REFERENCES:

1. *Adrienn, V. S.- Janos, N.* :2012. Effects of nutrition and water supply on the yield and grain protein content of maize hybrids. Australian Journal of Crop Science, 6(3), 381.
2. *Bartholy, J.- Pongrácz, R.- Hollósi, B.*:2013. Analysis of projected drought hazards for Hungary. Advances in Geosciences, 35.
3. *Cheval, S.- Busuioc, A.- Dumitrescu, A.- Birsan, M. V.*:2014. Spatiotemporal variability of meteorological drought in Romania using the standardized precipitation index (SPI). Climate Research, 60(3), 235-248.
4. *Guo, M.- Li, J.- Wang, Y.- Long, Q.- Bai, P.*:2019. Spatiotemporal Variations of Meteorological Droughts and the Assessments of Agricultural Drought Risk in a Typical Agricultural Province of China. Atmosphere, 10(9), 542.
5. *IPCC.*: 2006. IPCC Guidelines for National Greenhouse Gas Inventories, prepared by the National Greenhouse Gas Inventories Programme, Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). Available at.: http.://www.ipcc-nggip.iges.or.jp/public/2006gl/.
6. *Kern, A.- Marjanović, H.- Barcza, Z.*:2016. Evaluation of the Quality of NDVI3g Dataset against Collection 6 MODIS NDVI in Central Europe between 2000 and 2013. Remote Sensing, 8(11), 955.
7. ***Mohammed**, S. A.- Harsányi, E.*:2019. Drought cycle tracking in Hungary using Standardized Precipitation Index (SPI). Acta Agraria Debreceniensis, (2), 97-101.
8. ***Mohammed**, S.- Alsafadi, K.- Al-Awadhi, T.- Sherief, Y.- Harsanyie, E.- El Kenawy, A. M.*:2020. Space and time variability of meteorological drought in Syria. Acta Geophysica,
9. ***Mohammed**, S.- Alsafadi, K.- Daher, H.- Gombos, B.- Mahmood, S.- Harsányi, E.*:2020. Precipitation pattern changes and response of vegetation to drought variability in the eastern Hungary. Bulletin of the National Research Centre, 44, 1-10.
10. ***Mohammed**, S.- Alsafadi, K.- Takács, I.- Harsányi, E.*:2020. Contemporary changes of greenhouse gases emission from the agricultural sector in the EU-27. Geology, Ecology, and Landscapes, 1-6.

11. *Potopová, V.- Štěpánek, P.- Možný, M.- Türkott, L.- Soukup, J.:*2015. Performance of the standardised precipitation evapotranspiration index at various lags for agricultural drought risk assessment in the Czech Republic. Agricultural and Forest Meteorology, 202, 26-38.
12. *Reddy, P. P.:*2015. Climate resilient agriculture for ensuring food security (Vol. 373). New Delhi.: Springer India.
13. *Szalai, S.- Vogt, J.:*2011, October. CARPATCLIM–high resolution gridded database of the Carpathian Region and calculation of drought indices as a contribution to the European Drought Observatory. In WRCP Conference (pp. 24-28).

UNIVERSITY of DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

Registry number: DEENK/7/2021.PL
Subject: PhD Publication List

Candidate: Safwan Mohammed
Doctoral School: Kálmán Kerpely Doctoral School
MTMT ID: 10065524

List of publications related to the dissertation

Foreign language scientific articles in Hungarian journals (1)

1. **Mohammed, S.**, Harsányi, E.: Drought cycle tracking in Hungary using Standardized Precipitation Index (SPI).
Agrártud. Közl. 2, 97-101, 2019. ISSN: 1587-1282.
DOI: http://dx.doi.org/10.34101/actaagrar/2/3685

Foreign language scientific articles in international journals (9)

2. Alsafadi, K., **Mohammed, S.**, Habib, H., Kiwan, S., Hennawi, S., Sharaf, M.: An integration of bioclimatic, soil, and topographic indicators for viticulture suitability using multi-criteria evaluation: a case study in the Western slopes of Jabal Al Arab-Syria.
Geocarto Int. 35 (13), 1466-1488, 2020. ISSN: 1010-6049.
DOI: http://dx.doi.org/10.1080/10106049.2019.1583291
IF: 3.789 (2019)

3. **Mohammed, S.**, Alsafadi, K., Ali, H., Mousavi, S. M. N., Kiwan, S., Hennawi, S., Harsányi, E., Pham, Q. B., Linh, N. T. T., Ali, R., Anh, D. T., Thai, V. N.: Assessment of Land Suitability Potentials for Winter Wheat Cultivation by Using a Multi Criteria Decision Support-Geographic Information System (MCDS-GIS) approach in Al-Yarmouk Basin (S Syria).
Geocarto Int. Epub, 1-17, 2020. ISSN: 1010-6049.
DOI: http://dx.doi.org/10.1080/10106049.2020.1790674
IF: 3.789 (2019)

4. Zanella, A., Ponge, J. F., Andreetta, A., Aubert, M., Bernier, N., Bonifacio, E., Bonneval, K., Bolzonella, C., Chertov, O., Costantini, E. A. C., de Nobili, M., Fusaro, S., Giannini, R., Junod, P., Katzensteiner, K., Kwiatkowska-Malina, J., Menardi, R., Mo, L., **Mohammed, S.**, Schnitzler, A., Sofo, A., Tatti, D., Hager, H.: Combined forest and soil management after a catastrophic event.
J Mt Sci. 17 (10), 2459-2484, 2020. ISSN: 1672-6316.
DOI: http://dx.doi.org/10.1007/s11629-019-5890-0
IF: 1.55 (2019)

UNIVERSITY of DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

5. **Mohammed, S.**, Hassan, E., Abdo, H. G., Szabó, S., Mokhtar, A., Alsafadi, K., Al-Khouri, I., Rodrigo-Comino, J.: Impacts of rainstorms on soil erosion and organic matter for different cover crop systems in the western coast agricultural region of Syria.
Soil Use Manage. Epub, 1-38, 2020. ISSN: 0266-0032.
DOI: http://dx.doi.org/10.1111/sum.12683
IF: 1.69 (2019)

6. **Mohammed, S.**, Alsafadi, K., Daher, H., Gombos, B., Mahmood, S., Harsányi, E.: Precipitation pattern changes and response of vegetation to drought variability in the eastern Hungary.
Bull Natl Res Cent. 44 (1), 87-96, 2020. EISSN: 2522-8307.
DOI: http://dx.doi.org/10.1186/s42269-020-00306-y

7. **Mohammed, S.**, Alsafadi, K., Al-Awadhi, T., Sherief, Y., Harsányi, E., El Kenawy, A. M.: Space and time variability of meteorological drought in Syria.
Acta Geophys. 68, 1877-1898, 2020. ISSN: 1895-6572.
DOI: http://dx.doi.org/10.1007/s11600-020-00501-5
IF: 1.395 (2019)

8. Alsafadi, K., **Mohammed, S.**, Ayugi, B., Sharaf, M., Harsányi, E.: Spatial-Temporal Evolution of Drought Characteristics Over Hungary Between 1961 and 2010.
Pure Appl. Geophys. 177, 3961-3978, 2020. ISSN: 0033-4553.
DOI: http://dx.doi.org/10.1007/s00024-020-02449-5
IF: 1.586 (2019)

9. **Mohammed, S.**, Fallah, R. Q.: Climate Change Indicators In Alsheikh-Badr Basin (Syria).
Geography, environment, sustainability. 12 (2), 87-96, 2019. ISSN: 2071-9388.
DOI: http://dx.doi.org/10.24057/2071-9388-2018-63

10. **Mohammed, S.**, Alsafadi, K., Takács, I., Harsányi, E.: Contemporary changes of greenhouse gases emission from the agricultural sector in the EU-27.
Geology, Ecology, and Landscapes. 2, 1-6, 2019. EISSN: 2474-9508.
DOI: http://dx.doi.org/10.1080/24749508.2019.1694129

Foreign language conference proceedings (2)

11. **Mohammed, S.**, Alsafadi, K., Mousavi, S. M. N., Harsányi, E.: Drought Trends in Syria from 1900 to 2015.
In: 4th International Congress of Developing Agriculture, Natural Resources, Environment and Tourism of Iran 13-15 Feb. 2019, Tabriz Islamic Art University, In cooperation with Shiraz University and Yasouj University, Tabriz Islamic Art University, [Tabriz], 1-8, 2019.

12. Mousavi, S. M. N., **Mohammed, S.**, Nagy, J.: Evaluation climate change in Hungary.
In: 4th International Congress of Developing Agriculture, Natural Resources, Environment and Tourism of Iran 13-15 Feb. 2019, Tabriz Islamic Art University, In cooperation with Shiraz University and Yasouj University, Tabriz Islamic Art University, [Tabriz], 1-7, 2019.

UNIVERSITY of DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

Foreign language abstracts (3)

13. Mousavi, S. M. N., **Mohammed, S.**, Nagy, J.: Study Impacts of Drought Waves on Agricultural from 1991 to 2015 in Iran.
In: Eleventh International Conference on Climate Change: Impacts & Responses 16-17 April 2019 Pryzbyla Center, The Catholic University of America, Washington, D.C., USA, The Catholic University of America, Washington, 1, 2019.

14. **Mohammed, S.**, Mirzaei, M., Törő, Á., Manouchehr, G. A., Harsányi, E.: Tracking CO2 Emission from Tow Agricultural Lands under Maize cultivation in Two Different Climate Regions.
In: ICOS Belgium Science Conference : Book of abstracts, Antwerp University, Antwerp, 30-31, 2019.

15. **Mohammed, S.**, Mousavi, S. M. N., Alsafadi, K., Bramdeo, K.: Tracking GHG emission from agricultural and energy sectors in the EU from 1990 to 2016.
In: Abstract book 18th Alps-Adria Scientific Workshop. Ed.: Zoltán Kende, Csaba Bálint, Viola Kunos, Szent István Egyetemi Kiadó Nonprofit Kft., Gödöllő, 24-25, 2019. ISBN: 9789632698182

List of other publications

Foreign language scientific articles in international journals (8)

16. **Mohammed, S.**, Khallouf, A., Kiwan, S., Alhenawi, S., Ali, H., Harsányi, E., Kátai, J., Habib, H.: Characterization of Major Soil Orders in Syria.
Eurasian Soil Sci. 53 (4), 420-429, 2020. ISSN: 1064-2293.
DOI: http://dx.doi.org/10.1134/S1064229320040109
IF: 1.016 (2019)

17. Ghanem, S., Rukia, A., Sulieman, M. M., Brevik, E. C., **Mohammed, S.**: Dataset on the Mediterranean soils from the coastal region of the Lattakia governorate, Syria.
Data in Brief. 29, 1-23, 2020. ISSN: 2352-3409.
DOI: http://dx.doi.org/10.1016/j.dib.2020.105254

18. **Mohammed, S.**, Abdo, H. G., Szabó, S., Pham, Q. B., Holb, I., Linh, N. T. T., Anh, D. T., Alsafadi, K., Mokhtar, A., Kbibo, I., Ibrahim, J., Rodrigo-Comino, J.: Estimating Human Impacts on Soil Erosion Considering Different Hillslope Inclinations and Land Uses in the Coastal Region of Syria.
Water. 12 (10), 1-25, 2020. EISSN: 2073-4441.
DOI: http://dx.doi.org/10.3390/w12102786
IF: 2.544 (2019)

UNIVERSITY of DEBRECEN

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

19. **Mohammed, S.**, Alsafadi, K., Talukdar, S., Kiwan, S., Hennawi, S., Alshiehabi, O., Sharaf, M., Harsányi, E.: Estimation of soil erosion risk in southern part of Syria by using RUSLE integrating geo informatics approach.
Remote Sensing Applications: Society and Environment. 20, 1-13, 2020. ISSN: 2352-9385.
DOI: http://dx.doi.org/10.1016/j.rsase.2020.100375

20. **Mohammed, S.**, Khallouf, A., Alshiehabi, O., Pham, Q. B., Thuy Linh, N. T., Thai, V. N., Anh, D. T., Harsányi, E.: Predicting soil erosion hazard in Lattakia governorate (W Syria).
International Journal of Sediment Research. 36 (2), 207-220, 2020. ISSN: 1001-6279.
DOI: http://dx.doi.org/10.1016/j.ijsrc.2020.06.005
IF: 2.577 (2019)

21. **Mohammed, S.**, Al-Ebraheem, A., Holb, I., Alsafadi, K., Dikkeh, M., Pham, Q. B., Linh, N. T. T., Szabó, S.: Soil Management Effects on Soil Water Erosion and Runoff in Central Syria?A Comparative Evaluation of General Linear Model and Random Forest Regression.
Water. 12 (9), 1-19, 2020. EISSN: 2073-4441.
DOI: http://dx.doi.org/10.3390/w12092529
IF: 2.544 (2019)

22. **Mohammed, S.**, Habi, H., Ali, H., Alhenawi, S., Kiwan, S., Ghanem, S., Alsafadi, K., Brevik, E. C., Sulieman, M. M., Harsányi, E.: Soils of the Southern Syria: A big database for the future land management planning.
Data in Brief. 2, 1-39, 2020. ISSN: 2352-3409.
DOI: http://dx.doi.org/10.1016/j.dib.2020.105832

23. **Mohammed, S.**, Alkerdi, A., Harsányi, E., Nagy, J.: Syrian crisis repercussions on the agricultural sector: case study of wheat, cotton and olives.
Reg Sci Policy Pract. 12 (3), 519-537, 2019. ISSN: 1757-7802.
DOI: http://dx.doi.org/10.1111/rsp3.12222

Foreign language abstracts (2)

24. Mousavi, S. M. N., Bramdeo, K., **Mohammed, S.**, Nagy, J.: Studying the relationships of various agronomic traits in maize using correlation analysis.
In: Abstract book 18th Alps-Adria Scientific Workshop. Ed.: Zoltán Kende, Csaba Bálint, Viola Kunos, Szent István Egyetemi Kiadó Nonprofit Kft., Gödöllő, 116-117, 2019. ISBN: 9789632698182

UNIVERSITY AND NATIONAL LIBRARY
UNIVERSITY OF DEBRECEN
H-4002 Egyetem tér 1, Debrecen
Phone: +3652/410-443, email: publikaciok@lib.unideb.hu

25. **Mohammed, S.**, Khallouf, A., Almesber, W., Harsányi, E.: Assessment of Soil Erosion Risk by Using CORINE model: Case Study of Lattakia Governorate, Syria.
In: 1st Young Researchers' Conference - Erosion and Torrent Control ETC 2018, Belgrade University, Belgrade, 1, 2018. ISBN: 9788672992823

Total IF of journals (all publications): 22,48
Total IF of journals (publications related to the dissertation): 13,799

The Candidate's publication data submitted to the iDEa Tudóstér have been validated by DEENK on the basis of the Journal Citation Report (Impact Factor) database.

07 January, 2021

DEBRECENI EGYETEM
Egyetemi és Nemzeti Könyvtár