Impact of agriculture irrigation on the habitat structure and use by Great Bustards *(Otis tarda)* in Natura 2000 site

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Abstract As the whole Palearctic steppe system, its iconic bird, the Great Bustard has also suffered from the expansion of intensive agriculture. The species now typically has stable or growing populations only in protected areas, but negative processes are still prevalent even there. In this study, we present a recent change in a part of the Natura 2000 site designated for the isolated West Pannonian population. In recent years, a total of 2.3 km Center-pivot and laterally moving linear irrigation systems have been built and 4.7 km of underground pipelines have been laid, with which more than 52% of the 1245,5 ha study area was irrigated by 2020. In comparison to 2009, when the study period has started, the sown area of autumn cereals, one of the main breeding habitats, was roughly halved and the proportion of crops unsuitable for breeding was increased. New crops requiring irrigation have emerged with a rate of 30.6% in the last year. Despite the available support, the area of alfalfa, which is the most significant breeding habitat, and is grown almost exclusively in the agri-environmental scheme, has decreased. As a result of habitat degradation, the number of Great Bustard females observed in the area in spring decreased to a small fraction of the beginning. Irrigation farming is expected to increase, as a response to the climate change, but in order to save agro-steppe habitats and their species, the adverse effects of agricultural intensification need to be urgently addressed at both local and European levels.

Keywords: intensive agriculture, agri-environmental scheme, agro-steppe habitat, West Pannonian Great Bustard population, agricultural policy

Összefoglalás Ahogy a palearktikus sztyepp övezet egésze, úgy annak emblematikus madara, a túzok is elszenvedte az intenzív mezőgazdálkodás elterjedését. A fajnak ma már jellemzően csak védett területen vannak stabil vagy növekvő állományai, de negatív folyamatok még ott is jellemzőek. A tanulmányunkkal az elszigetelődött nyugat-pannon populáció számára kijelölt Natura 2000 terület egy részén, a közelmúltban bekövetkezett változást mutatjuk be. Az 1245,5 ha nagyságú vizsgálati területen az utóbbi években 2,3 km összhosszúságú forgó és oldalazó lineár öntözőberendezést építettek, illetve 4,7 km hosszan hidránsrendszereket fektettek, melyekkel 2020-ban a terület 52%-át öntözték. Ennek hatására 2009-hez, vagyis a vizsgálati időszak kezdetéhez képest az egyik fő költőhabitat, az őszi gabonák vetésterülete nagyjából a felére csökkent, és nőtt a költésre alkalmatlan élőhelyek aránya. Új, öntözést igénylő növénykultúrák jelentek meg, melyek területi részaránya az utolsó évben már 30,6% volt. Az elérhető támogatás ellenére csökkent a költőhelyként jelentős lucerna vetésterülete, melyet szinte csak az agrár-környezetgazdálkodási program miatt termesztenek. Az élőhely romlásának következményeként a területen tavasszal megfigyelhető túzoktyúkok száma a korábbi töredékére esett. A klímaváltozás hatására várható az öntözéses gazdálkodás terjedése, de az agrár-sztyepp élőhelyek és fajaik megmentése érdekében a mezőgazdaság intenzifikációjának káros hatásait sürgősen kezelni kell mind helyi, mind európai szinten.

Kulcsszavak: intenzív mezőgazdaság, agrár-környezetgazdálkodás, agro-sztyepp élőhely, nyugat-pannon túzokállomány, agrárpolitika

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Introduction

Agriculture is the primary cause of biodiversity loss worldwide (Dudley & Alexander 2017). One of the most endangered habitats by land use is the Palearctic steppe (Török *et al.* 2020). In addition to the loss of original habitats, the population of species that can adapt somewhat to the changed conditions (so-called farmland birds) is affected also by the intensity of farming in cultivated areas (Donald *et al.* 2001, Reidsma *et al.* 2006, Jerrentrup *et al.* 2017, Traba & Morales 2019). This is especially true for species that are specialized for open habitats (Teillard *et al.* 2015). Irrigation is one of the most common elements of intensive farming practice, and in areas where it is widespread, steppe bird populations are in a less favorable position (Brotons *et al.* 2004, De Frutos *et al.* 2015).

The Great Bustard is an emblematic bird of the agro-steppe habitat, and it has also suffered the negative effects of the spread of intensive agriculture (Horreo *et al.* 2013). It bred in many European countries in the Middle Ages (Glutz *et al.* 1973), since then only isolated populations have survived (Szabó *et al.* 2007, Alonso *et al.* 2009a), and the primary reason for the eradication of countless populations was the agricultural activity (Alonso *et al.* 2003, Faragó 2006, Alonso 2014). Today, stable or possibly growing populations occur only in areas of comparatively better quality, that are usually protected, where near-natural habitats can also be found among patches of arable land (Pinto *et al.* 2005, Pitra *et al.* 2011, Szenek & Végvári 2018), or where significant habitat protection measures have been taken to repress intensive farming, typically by launching an agri-environmental scheme (AES hereinafter) (Martín *et al.* 2012a, Alonso 2014, Faragó *et al.* 2014, Raab *et al.* 2014b), but usually the two are present together.

In agricultural areas, irrigation is particularly detrimental to habitat quality, which also affects Great Bustards. An abundance model tested in Spain (Martín *et al.* 2012b) showed that non-irrigated herbaceous vegetation cover was higher in places visited by Great Bustards than in places where the species was absent, and one of the defining component of the final abundance model was the non-irrigated area. This was confirmed by a study from Gameiro *et al.* (2020) showing that the abundance of Great Bustards is highly dependent on the extent of the agro-steppe habitat in the Iberian Peninsula, and the recent negative change affecting these habitats was the expansion of plantations and irrigated crops. Moreover, a significant reduction or extinction of some Portuguese Great Bustard populations was largely due to irrigation (Pinto *et al.* 2005).

The world's largest nature conservation network, the Natura 2000 network, has been established to protect Europe's endangered habitats and species in order to eliminate harmful processes such as those mentioned above. When designing the network, the Great Bustards received special attention and the 91 Special Protected Areas (SPA) designated for the species under the Birds Directive cover the core areas of the species' most important habitats (EC 2009).
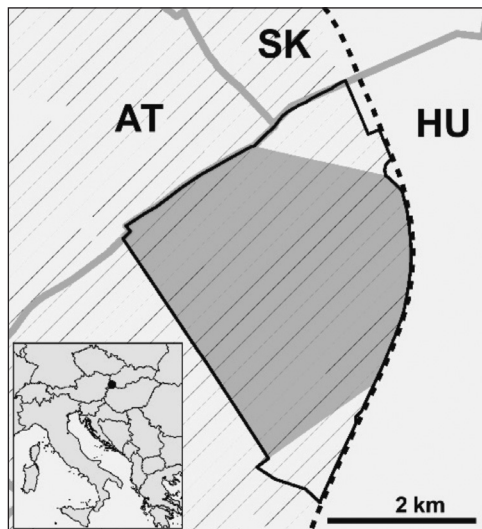
Recently, the burgeon of irrigated crop production in Hungary has accelerated, sometimes even affecting protected areas. This trend is significantly catalyzed by a large-scale agricultural irrigation development program (Hungarian Government 2017). In the present study, we demonstrate what negative change irrigation farming causes in the breeding site of an isolated Great Bustard population, using a particular example.

Material and method

Study species and area

The global population of our study spe-
cies, the Great Bustard amounts to 44,000–
57,000 individuals (Alonso 2014) and is
classified as vulnerable (BirdLife Interna-
tional 2020). The size of the isolated West
Pannon population exceeds 600 individ-
uals (Raab *et al.* 2010. Faragó *et al.* 2014
and own data), whose central habitat is lo-
cated in the area of the Hungarian-Austri-
an-Slovak triple border (Raab *et al.* 2010).
Natura 2000 sites have been designated in
all three countries, which intersect along na-
tional borders. The study area is the most
northern continuous part of the Moson Plain
Natura 2000 site (HUFH10004) in Hun-
gary, which is mainly in conventional field
cultivation *(Figure 1)*. It is bordered on the
east by a motorway, on the north-west by
the Slovak and Austrian state borders, and
on the south-west by fallow lands, a planted
forest and, on a short section, a canal. It cov-
ers an area of 1245.5 hectares. Here, the cal-
careous chernozem soil is typical, which is
excellent for crop production, although due
to the shallow soil layer, the crops can suf-
fer from drought early, but with the appli-
cation of irrigation, however, it is easy and
safe to achieve good yields even in dry years
(Miklay & Molnár 1968). The main crops

Figure 1. Schematic map and location of the
study area. Solid black line – the study
area; grey area – 'bustard counting ar-
ea'; hatched area – Natura 2000 site;
grey line – state border; dashed black
line –highway; HU – Hungary; AT – Aus-
tria; SK – Slovakia

1. ábra A vizsgálati terület térképvázlata és el-
helyezkedése. Folytonos fekete vonal
– a vizsgálati terület; szürke mező – tú-
zokszámolási terület; vonalkázott me-
ző – Natura 2000 terület; szürke vonal
– államhatár; szaggatott fekete vonal
– autópálya; HU – Magyarország; AT –
Ausztria; SK – Szlovákia

grown are cereals, maize and oilseed rape. The area is part of the 'High Nature Value Area',
so local farmers can receive compensations for Great Bustard-friendly farming within the
Hungarian Agri-Environmental Scheme. The total area of land cultivated in this way in the
study area does not currently reach 100 ha (<10% of the study area), these are typically ex-
tensively cultivated alfalfa fields.

The Great Bustard is an extremely sexually dimorphic bird (Alonso *et al.* 2009b), with lek
mating system (Morales *et al.* 2001), and the parental care is exclusively undertaken by the
females (Morales *et al.* 2002). In the spring, their favored habitat is usually cereals through-
out their European range (Faragó 1987, Pescador & Peris 1996, Moreira *et al.* 2004), and de-
pending on whether they are available in their habitat: alfalfa, vetch, pastureland and fallow

land (Faragó 1987, Pescador & Peris 1996, Lane *et al*. 2001, Rocha *et al*. 2013). These are also the main breeding habitats (Petrick 1996, Morgado & Moreira 2000, Rocha *et al*. 2013, Janó & Végvári 2016).

The area fidelity to the breeding sites in female Great Bustards is very high (Alonso *et al*. 2000) and the natal dispersion is low (Martín *et al.* 2008). The Central European Great Bustard populations are considered as facultative migratory, indicating that their migration is triggered by harsh weather (Faragó 1990, Streich *et al*. 2006), however, a kind of seasonal movement is characteristic even for sedentary females (Alonso *et al.* 2000). Female Great Bustards can be observed in the study area from spring to autumn and they are not present in winter (own unpublished data), i.e. the place is of primary importance for reproduction.

Method

A direct and an indirect indicator are used for the spread of agricultural irrigation in the study area. The direct metric is the size of the irrigated area, which was measured only in 2019 and in 2020. The indirect metric is the length of permanently installed irrigation pipes which includes the Center-pivot (also called water-wheel or circle irrigation) and the lateral move (linear move, wheel move or side-roll) irrigation systems and furthermore the underground pipeline with hydrants supplying hose reel irrigation systems. These were measured during their construction. The accuracy of these data, thanks to intensive fieldwork, is estimated to be close to 100%.

Habitat mapping was carried out in the study area every year between 2009 and 2020, during which we identified the main crop grown. Taking into account the irrigation characteristics and breeding site characteristics of a given crop, we grouped or treated them separately as follows: (1) soybean, (2) sugar beet, (3) sorghum species and millet (so far not suitable for breeding and grown almost exclusively by irrigation), (4) maize (not suitable for breeding, can be grown without irrigation, but is irrigated more and more frequently in recent years), (5) oilseed rape (the main winter food for Great Bustards in this region, but not suitable for breeding and recently increasingly irrigated), (6) autumn cereals (one of the most favored crop for breeding, typically grown without irrigation; only winter wheat and winter barley were included, other autumn cereals are usually sown for green fodder, which is not suitable for successful breeding), (7) alfalfa (perhaps the most important cultivated crop for breeding site in our area, the fields included in the study area are mainly supported by AES), (8) other crops (all other crops grown on smaller proportion, most of which are not preferred types of breeding habitats or cultivated in a not-Great Bustard-friendly way), (9) non-arable land (roads, wooded areas, water surface, orchard etc.), (10) unknown (the main crop grown is not known in that year). A suitable data set is not available from 2012.

At least once a month, a complete Great Bustard count was performed in the study area, classifying the individuals according to their sex (Spakovszky 2009). The study area is mainly significant as a breeding site, therefore we examined the spring presence of females. Most females appear at the breeding site in late March (Alonso *et al.* 2000), so only the counts after March 14th were considered. The detection probability of the breeding females

is limited due to the concealing behavior (Magaña *et al.* 2010). Therefore, in order to avoid a distortion (Sanz-Pérez *et al.* 2020), the results of the censuses after April 30th, when the majority of the females in our area are already incubating (Faragó 1983, Petrik 1996), were not taken into account. Despite the relatively small size of the study area, during the active spring period of the females, the whole area cannot be patrolled in such a way that double counting of individuals can be definitely excluded due to visual obstacles, thus the censuses of females were performed only in the 'bustard counting area' *(Figure 1)*. This equals 83.7% of the study area. We provided the average and the standard deviation of the results of repeated censuses for the 15th March – 30th April period, and omitted the years (2012–2014, 2016, 2017), when the number of censuses covering the 'bustard counting area' was less than 3. The association of the number of Great Bustard females with the extent of irrigated area was measured by Pearson's correlation coefficient.

Results

Prior to 2018, the proportion of irrigated surface was below 10% of the study area each year as an estimated maximum according to our field observations. Since 2018, the area of irrigated lands increased rapidly, and by 2020, 52% of the study area had been irrigated *(Figure 2)*. The construction of Center-pivot and laterally moving linear irrigation systems as well as underground pipeline-hydrant systems began in 2017, of which the total length reached 2.3 km and 4.7 km in the study area till 2020, respectively. Since 2016, there has been an interest from farmers in irrigation, resulting in several water wells having been drilled in the study area, but these were not generally used at first (pers. obs.).

  In the study area, new plant species appeared in the crop composition, such as soybeans, sugar beets, sorghum species and millet, which were mostly grown with irrigation (pers. obs.). The area proportion of these new crops was 30.6% in 2020 *(Figure 2)*. The sown area of maize was significant in the past, too, but increased slightly as a result of irrigation. A major change in relation to maize is the widespread use of irrigation, with 84% of the maize fields area being irrigated in 2019 and 75.6% in 2020. The sown area of oilseed rape has decreased, which is assumed not to be related to irrigation, but to market processes making its cultivation less and less profitable in our region, however, it is also grown mainly with irrigation in recent years (pers. obs.). The area of autumn cereals has decreased from 30–40% per year to about 20%. The cultivation area of alfalfa is highly dependent on the AES, as alfalfa is grown almost exclusively on AES-supported arable land. In 2015, it barely reached 1% of the study area because that was an "interim year" between two periods when the AES was out of order. Nevertheless, despite being subsidized, it has never been grown in significant proportions and is even declining in the long run, which shows the competitiveness of intensive farming, including irrigation, against the AES. Furthermore, it was observed that in locations where a significant investment was made to build the new irrigation facility, crops typically grown without irrigation were also irrigated in many cases. For example, in 2020, 40.3% of the winter wheat cultivation area was irrigated, which crop was typically not irrigated formerly.
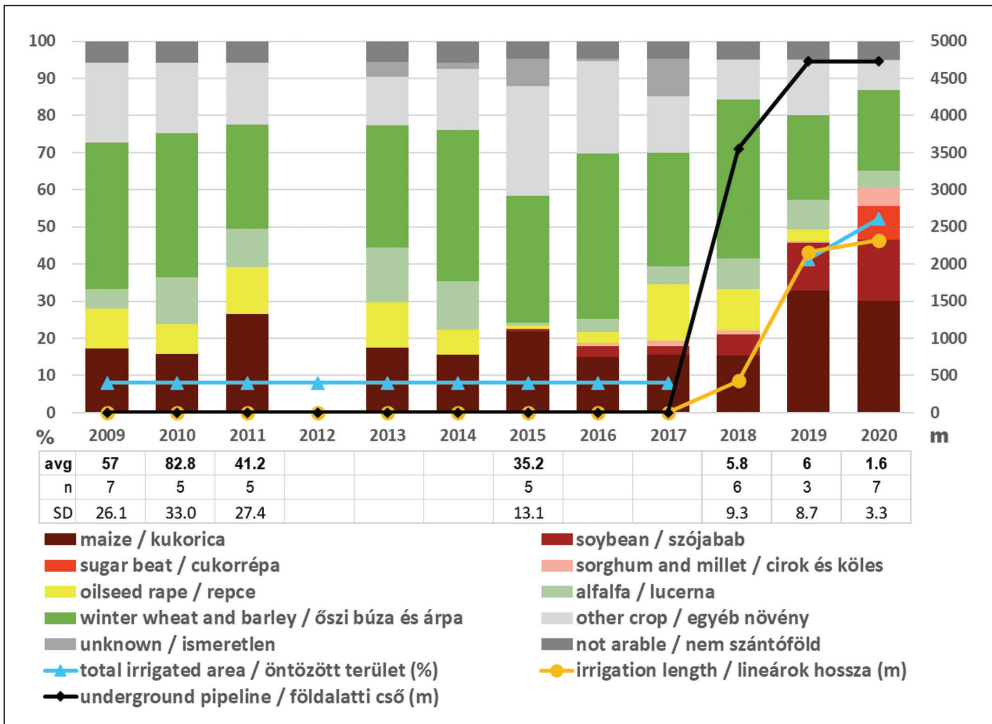
Figure 2. The crop composition and the proportion of the irrigated surface of the study area, the total length of the two main irrigation system, and the average number of the observed Great Bustard females (avg) in the counting area in the given years. n – the number of the Great Bustard counting events between 15th March and 30th April in the given year, SD – standard deviation. The proportion of the irrigated surface before 2018 is expert estimation maximum

2. ábra A vizsgálati terület vetésszerkezete és az öntözött földek aránya, valamint a két fő öntözési rendszer hossza, illetve a túzokszámolási területen észlelt túzoktyúkok átlagos egyedszáma (avg) a vizsgálat éveiben. n – a túzokszámolási alkalmak száma március 15. és április 30. között az adott évben, SD – szórás. Az öntözött terület 2018 előtti értékei tapasztalati becsült maximumok

The number of Great Bustard females observed in the area in the spring decreased significantly during the study period. At the beginning of the study period, dozens of female Great Bustards were usually present in the study area in spring, on average 57 in 2009 (SD = 26.1, n=7), 32.8 in 2010 (SD=33, n=5) and 41.2 in 2011 (SD=27.4, n=5). In contrast, it was seldom possible to count a dozen females at the end of the study period, on average 5.8 in 2018 (SD=9.3, n=6), 6 in 2019 (SD=8.7, n=3) and 1.6 in 2020 (SD=3.3, n=7), respectively *(Figure 2)*. No significant change other than the spread of irrigation and consequently the alteration of habitat structure was observed in the study area, and the decrease in the number of females is strongly correlated with it *(Pearson's r = –0.91, p = 0.011)*.

Discussion

As a result of our work, we demonstrate that irrigation farming in the study area has significantly increased in recent years, resulting to an increase in the proportion of crops that are unsuitable for breeding. In contrast, the proportion of favored breeding habitats has decreased, and thus it can be stated, that the quality of the bustard habitat has effectively deteriorated as a result of irrigation. Although only approximately half of the study area was irrigated, its negative effects are clearly detected on the intervening and adjacent non-irrigated lands, thus reducing the quality of the whole area (Brotons *et al.* 2004). Great Bustards are a long-lived species (Morales *et al.* 2002), so presumably individuals missing from the study area have been forced to other places, and a shrinking habitat may increase mortality and reduce reproduction rates (Morales *et al.* 2002). In the last two years, females have occurred mainly in the south-western and southern parts of the study area in the spring (pers. obs.), where better quality habitats are still available in the nearby fields. Great Bustards are expected to move less and less towards the study area, similarly to the experiences in Villafáfila, Spain, where less bustards moved south from the center compared to other directions because there were irrigated unsuitable habitats in significant extent (Alonso *et al.* 1995).

The West Pannonian Great Bustard population was driven to the verge of extinction in the second half of the 20th century (Raab *et al.* 2010), but by investing a significant amount of energy and resources, we managed to reverse the declining trend and multiply the population in a short time (Faragó *et al.* 2014, Raab *et al.* 2014a). This unique result (Alonso 2014) is now threatened by an incompetently controlled agro-economic development (Palacín *et al.* 2012). Although the habitat-destroying effect of the spread of irrigated farming is clear, it is still feasible that it will remain hidden for a while at population level because the positive effects of diversified conservation activity may outweigh it (Gameiro *et al.* 2020).

As a kind of response to today's climate change, an increase in irrigated areas is expected in some parts of Europe (Riediger *et al.* 2014), e.g. in Hungary the goal is to quadruple the currently irrigated agricultural surface (Hungarian Government 2017). This direction is worrying in two ways. On the one hand, it means a further intensification of agriculture, which is already a serious problem for the ecosystem in general. On the other hand, climate change is expected to reduce access to irrigation water across Europe although to varying extent from region to region (Iglesias & Garrote 2015), leading to an unsustainable shift in agriculture and generating conflicts by using limited water resources (Olesen *et al.* 2011, Moore & Lobell 2014).

The situation of agro-steppe habitats and their species in Natura 2000 areas is more favorable than outside, but negative processes also take place there (Silva *et al.* 2018, Gameiro *et al.* 2020). The general objectives of the Directives (Birds Directive 79/409/EEC, Habitats Directive 92/43/EEC) have not yet been met, but remain highly relevant and are still fit for the protection of species and habitats, as was recently concluded by an evaluation of the Natura 2000 protection system (EC 2016). Therefore, the system needs to be maintained, further developed and supported (Gameiro *et al.* 2020). The authorities and organizations concerned must not disregard the original objectives in their management activities and procedures and must protect agro-steppe species and their habitats (Lane *et al.* 2001, Palacín *et*

al. 2012). In Hungary, the sustainable land use of natural grasslands in Natura 2000 sites has been regulated since 2007 (269/2007 government decree), which prohibits the irrigation of these grasslands. However, similar legislation on the sustainable management of Natura 2000 arable land has not yet been implemented, which has to happen as soon as possible. Within this legislation, it is necessary to provide solutions for the appropriate reductions of harmful effects caused by an intensive agriculture, including irrigation.

Today, the Common Agriculture Policy of the EU is being redesigned, which is perhaps the main tool for moving European agriculture in the right direction. If we are to take biodiversity conservation seriously, the new agricultural policy must reflect on the challenges and take serious steps (Palacín & Alonso 2018, Traba & Morales 2019, Pe'er *et al.* 2020).

Acknowledgements

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