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THE FEASIBILITY OF COOPERATION TO COMPLY WITH LAND USE CHANGE OBLIGATIONS IN THE MAROSSZÖG AREA OF SOUTH HUNGARY

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Abstract

In many years excess water inundations generate a major obstacle to farming in the lowland part of Hungary, including the Marosszög area. Diverting water to large distances requires an infrastructure that is costly to develop and maintain. Alternatively, low-lying local land segments could be withdrawn from cultivation and utilized to collect the surplus water. The Ecological Focus Area (EFA) requirement of the EU points to the same direction: it requires that 5% of arable land is converted to other, ecologically more beneficial uses. During the research project it was tested if it is feasible to apply a novel economic policy instrument, an auction to trade land use change obligations, to achieve the EFA requirement in a cost effective way through the cooperation of farmers, while also creating a practical solution to manage the seasonal surplus water cover on land. The research was carried out in an interdisciplinary way: a dynamically coupled fully integrated hydrological model, including surface and subsurface modules, was applied by engineers to better understand the interconnections of land use, local hydrology and the role of the water diversion infrastructure; while a pilot auction exercise was conducted by economists with the participation of farmers to understand if cost reductions can be achieved through cooperation, as opposed to individual fulfilment of EFA obligations. The analysis also revealed which segments of the water diversion network are economic to maintain. It was confirmed that it is possible to improve local water management and satisfy the EFA requirements at a reduced cost if appropriate economic incentives are applied to trigger the cooperation of farmers.

Keywords: Inland excess water, land use adaptation, agriculture, economic instruments, water management infrastructure, auction

INTRODUCTION

Seasonal water surpluses appear in the Tisza valley not only as floods, but also as temporal water coverage and water logging in low lying areas that are otherwise protected from floods (van Leuween et al., 2008). These excess water occurrences are slow but complex hydrological extremities, which affect surface and subsurface soil conditions (Szatmári and van Leuween, 2013). They frequently occur due to meteorological, morphological, land cover, pedological and hydrogeological characteristics (Pásztor et al., 2015) as well as a result of anthropogenic factors (Farkas et al., 2009; Benyhe and Kiss, 2012).

To mitigate the unfavourable agricultural and infrastructural effects of excess water, an extensive defense system of hydraulic structures - mostly pumps and weirs -, and a 42,400 km long channel network is maintained in the lowland parts of Hungary (Kozma and Koncsos, 2011). The benefits provided by water diversion are not commensurate with the otherwise rather elusive maintenance and defense costs (Pinke et al., 2018). There are several explanations for this. After 1990 land ownership and land use changed, earlier large farms that had consisted of thousands of hectares of intensively cultivated mono-culture, were replaced by medium and small sized farms, frequently with a size of only a few dozen hectares, lowering the efficiency of agricultural activities. The price signals provided by commodity, e.g. grain, markets replaced the earlier centrally set prices, introducing revenue risk to farmers. Central budget resources provided for network maintenance have been gradually lowered, reflecting fiscal difficulties as well as a shift in priorities. A shrinking resource base alone may not necessarily be problematic, fragmented land ownership, on the other hand, requires large scale cooperation, which only worked in some exceptional places, typically with the involvement of the local water management associations.

While the state slowly withdraws its resources from the field (VTOSZ, 2011), half-heartedly it continues to contribute to the maintenance of the water management system (OVF, 2016, chapter 5.5.2), thereby maintaining a false image that excess water drainage for agriculture is a public task. Practical experience, however, suggests that the systems cannot be maintained and operated on previous high levels due to the shrinking financial resources. In theory, there are two main types of solutions. 1) Farmers would have to contribute substantially to the financing of the infrastructure. They are hesitant, however, because they do not any more believe that high quality services would be provided in exchange for their payment. It is also uncertain if their increased payment would be justified by improved productivity. 2) The networks would need to be scaled back to a lower size that is easier to maintain from currently available resources. This also requires a parallel change in farming activities, as parcel characteristics would change in locations where the network is abandoned. Furthermore, the actual network modifications need to be determined, but this type of optimization requires information on the adaptation possibilities of farmers, which is not readily available to the managers of the water network.

The goal of the research was to test if the second option (shrinking the network to ensure that it is in line with reduced financial resources) can be pursued through innovative policy solutions in a way that is efficient both economically and from the perspective of altered land use. The Ecological Focus Area (EFA) requirement of the EU was picked as the driving force of change as it requires that 5% of arable land is converted to other, ecologically more beneficial uses (Viaggi and Vollaro, 2012). Farmers were involved in a pilot exercise in which they participated in a hypothetical market where they were allowed to trade the EFA obligation with each other. In other words, Farmer A could pay Farmer B so that the latter fulfils the EFA obligation of Farmer A by converting his own land. As a result, transformed land would not need to be served by the water management infrastructure any more, while it was expected that compliance with EFA would become cheaper. In addition, it was important to understand exactly which land parcels would be transformed away from intensive agriculture, to see if this shift is in harmony with local hydrological conditions. To support information on the latter, a hydrological modelling analysis was carried out for the study area.

STUDY AREA

The pilot area of the study is in the Marosszög geographical region in the South of Hungary, along the last stretch of the Maros River before it reaches the Tisza River. The geographic area under study (Fig. 1) is an approximately 120 km^2 large watershed delineated by the Maros River on the South, by the Sámson-Apátfalvy-Szárazér on the east, an irrigation channel on the north and the Makói main channel on the west. It belongs to the Great-Plain- and within that to the Alsó-Tiszavidék geographic area. Makó town also lies within the perimeters of the area. The terrain is flat, the maximum altitude difference is less than 10 meters and ranges from 75 m to 85 m above Baltic Sea Datum. However, the area has a slope towards west and south, as the receiving water body is the Maros River on the south-west of the area. The origin of the terrain is related mainly to fluvial activity, but eolian originated loess formation can also be found on the north-eastern part of the area (Deák, 2012). The Maros River played the major role in the formulation of the terrain in the Holocene, which has been ceased by the river regulations of the early 20th century. Old river-reaches and oxbows can be found on the area, which are prone to collection of runoff.

The textural types of the top soil are mainly loam, with a clay-loam intrusion from the north-west. This pattern partially stands for the deeper layers as well;

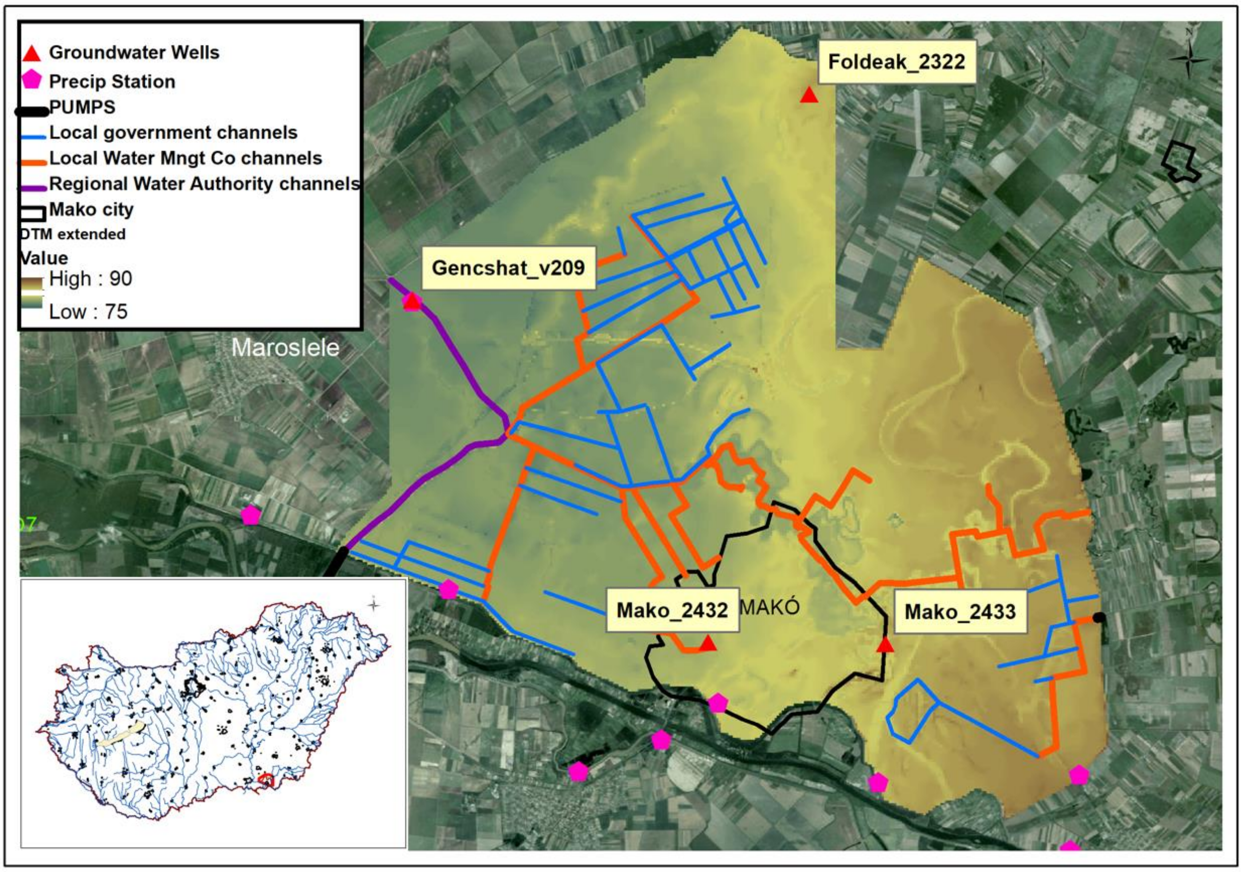

Fig. 1 Modelled pilot area with altitudes and the modelled channel network

however, in a large part of the eastern-middle part of the area the particle size distribution of deeper layers (> 3 meters depth) is dominated by the relatively larger fractions, as it is the alluvial deposition of the Maros River, generally known as coarse sand (Deák, 2012; Pásztor et al., 2015).

The area has a continental climate, with significant seasonal variations and large temperature range. The measured minimum temperature in the last century at Szeged (OMSZ) was -29.1 °C, the maximum was 39.7 °C, the coldest month is January, with an average temperature of -1.3 °C, the hottest month is July with an average temperature of 21.8 °C. The average yearly precipitation is 532.2 mm, the wettest month is June with 67.4 mm and the driest is January with 29.6 mm on average. The number of sunshine hours ranges between 1700-2400 per year. The average yearly actual evapotranspiration is 500-550 mm (VITUKI, 1972).

At present 80-83% of the study area is in agricultural use, of which 98% is used for intensive agriculture (crops and vegetables), reaching a historical peak after centuries of adaptation. The area is moderately, but regularly (every 3-5 years) affected by excess water inundation.

METHODS

The methodological concept

The research was designed as a participatory process with the involvement of farmers from the pilot area in the Marosszög. The local water management association (Tisza-Marosszög Vízgazdálkodási Társulat, TIMAVGT, www.timavgt.hu) ensured that farmers became aware of the research project and they were willing to contribute to it, thereby incorporating local knowledge and experience into the analysis.

Decision on land use/crop choice is based on a balance of productivity and the cost of maintaining necessary conditions for the production. These decisions are frequently distorted because the different subsidies together with the compensation against the losses due to external natural circumstances usually override the need for adaptation to the natural local endowments of the land. This is reasonable on the production level of individual farmers, while such an economic frame may be considered irrational by many who see the adverse effects of such policies. This contradiction supports the outsiders' view that there is no way to discuss common issues with farmers in a truly rational way.

The aim of the research was to create a situation where farmers' land use adaptation / crop choice decisions are inspected in a coherent economic frame in order to test the hypothesis that as opposed to individual, farm level optimization, the cooperation of farmers results in 1) better overall financial outcome for them and 2) a land use pattern that better suits local conditions.

This hypothesis was tested by creating a decision sphere based on a perceived "threat" from a then upcoming EU regulation. This policy process was the Common Agricultural Policy (CAP) regime to enter into force in 2014, which originally envisioned a 7% requirement for Ecological Focus Areas (EFA) as part of Pillar I green payments. Later this number was lowered to 5%, and exemptions were also provided, but within the research the 7% value was used.

From an agricultural production point of view, the EFA regulation is a forced reduction of the production intensity. Compared to the prior status quo, it generates an unavoidable burden in the form of revenue reduction for the farmers as they switch to lower revenue land use or lower value crop (The research did not deal with the net effect of the regulation including environmental gains that could be positive). The EFA regulation was applied in the research because it meant a credible future change for the farmers, therefore the possible ways to mitigate its negative effect proved to be a sensible "down to earth" question to them, offering a suitable common ground for discussions.

The economic approach was supported by hydrological simulations carried out for the pilot area, which served a better understanding of the magnitude, coverage and dynamics of the unfavourably saturated soils and surface inundations. In the absence of precise and detailed monitoring data, the simulation results of the inundations were verified by the field experience of farmers. This discussion also proved useful to create a common understanding and bonding between the researchers and the farmers. In a later stage of the research 1) the economic information that was gained from the test of the economic policy instrument and 2) the inundation frequency and coverage information of the hydrological simulation was combined to identify the financially sustainable and unsustainable elements of the channel system. Below the hydrological as well as the economic methods are described in detail.

Applied instruments – Hydrological simulation

The goal of the hydrological simulation was to understand the effect of the drainage channel network on groundwater, soil moisture conditions and surface water coverage frequency. The model calculations also helped to relate the drainage network to land use and to compare it with the judgement of farmers on which parcels are most likely to be converted from agriculture to EFA in case of external regulatory requirements. Various climate, water governance and land use scenarios were also tested to see the sensitivity of results.

The detailed spatio-temporal simulation of excess water inundation poses a number of challenges. Small relief, undrained sinks and the flow modification effect of surface water coverage prohibit the usage of methods purely based on flow hierarchy. Both surface runoff calculations and instream flow routing are necessary, as water movement can be neglected neither on terrain nor in the complex drainage network. In case of excess water, the subsurface processes are as important as the surface accumulation (Kozma et al., 2014). Finally, the above-mentioned processes occur simultaneously and influence one another. Up to date, only fully coupled/integrated hydrological models (Daniel et al., 2011; van Leeuwen et al. 2016) are 1) appropriate to deal with such complex hydrological phenomenon and 2) to analyse different water governance scenarios.

In this research the WateRisk Integrated Hydrologic Model (WR IHM) was applied, which was developed with the aim to study the hydrologic extremities (flood, excess water, drought) dominant in the low land parts of Hungary (Kozma and Koncsos, 2011; Jolánkai et al., 2012). The WR IHM is a distributed parameter, fully coupled hydrologic model. It simulates the major processes of the local-regional hydrologic cycle in parallel: precipitation processes (rainfall, interception, snow accumulation), evapotranspiration, channel and overland flow as well as unsaturated zone and shallow groundwater movement. The physical basis of the algorithm means that arbitrary climatic-land use-water governance scenarios can be set up through the adjustment of model elements (channel network, pumps, weirs), boundary conditions (e.g. precipitation, temperature time series) and model parameters (e.g. crop-specific surface roughness, leaf area index and root zone depth) (Kozma et al., 2012).

The simulations result in a temporal series of maps for all modelled components (surface water coverage, groundwater levels, stream and channel depth profiles, etc.). Furthermore, the quantitative description of flow and storage processes enables the application to calculate comprehensive volumetric water budget. This covers all surface and subsurface components and processes involved in the model system (e.g. channel discharges, pumped volumes, groundwater-channel interaction, infiltrating fluxes, evapotranspiration, surface water coverage). These features make the WateRisk application a substantial support tool for decision-making.

For the current analysis the model has been set up with a 50 by 50 meter grid (resulting in ~48000 computational cell), driven by the available digital terrain model, also 50x50m resolution (FÖMI, 2012). The channel network has been recreated in its whole extent, including the secondary channels, but not including the ditches along the agricultural plots. Approx. 125 km of channel have been included in the model. Channel cross-sections and longitudinal sections have been provided by the local water authority (Lower-Tisza-District Water Directorate - Alsó Tiszavidéki Vízügyi Igazgatóság - http://www.ativizig.hu/), including weirs, and pumping stations, with operation levels. As current roughness values were not available (only consultations with local water managers) a relatively rough Manning value of 0.05 have been used uniformly on the channel network for current conditions. This has been supported by site visit experience. The channel system drains the Szárazér channel gravitationally, and at high flow conditions the Makó pumping station lifts the collected excess water from the channel into the Maros River. Land cover was derived from the CORINE land cover maps (EEA, 2013). Precipitation data were also given by the local water authority for over 10 stations in the area for the 1998-2000 period. Precipitation, temperature and relative humidity data for the 1991-2000 period for the Szeged station was provided by the National Meteorological Service (Országos Meteorológiai Szolgálat https://www.met.hu/en/idojaras/).

Due to the complexity of the described processes and limited data availability, the formal full calibration of the model is not viable. Instead some of the key hydrological variables have been used to manually adjust the defining model parameters. Such hydrological variables are the measured groundwater levels and scattered and uncertain field observations of water coverage patches.

The state of the groundwater table plays an important role in the water cycle of the area. Water coverage extent and durations for example show high sensitivity to groundwater depth (Koncsos et al., 2011). Therefore, it is important to set the model parameters well in order to give proper groundwater table simulations. There are only two groundwater monitoring wells located in the economic auction pilot area, both being in Makó. Thus a larger area has been included in the hydrological model to include two more groundwater well time series to the calibration process. We expressed the agreement of measured and simulated groundwater level time series with common model efficiency criteria (Moriasi et al., 2007): the Pearson correlation coefficient (R^2), the root mean square error (RMSE) and the Nash-Sutcliffe model efficiency (NSME).

Scenario development

In the second phase of the project, scenario development was undertaken to generate a framework of the model simulations and to create a basis for the interpretation of the model results. We considered several alternatives for the three main affecting factors: climate, water governance scenarios and land use. Instead of setting up all the possible combinations, based on expert judgement we chose the 15 most relevant climate-water governance-land use variants.

Climatic scenarios: The IPCC SRES A2 and B2 emission scenarios (IPCC, 2000) were selected to examine the effects of possible climatic changes of the next 100 years on the water budget of the pilot area. These two scenarios have significantly different emission trends regarding the main greenhouse gases, therefore they have been selected to provide a range of possible changes, given that the uncertainty of the predictions is high. In the Marosszög pilot area the climate scenarios were implemented as simple temperature, precipitation and relative humidity time series for the 2070-2100 period. These time series were developed by different regional climate models, applied by the Prudence project (Christensen, 2005). Three such climate model results were examined and compared locally to the measured time series of the control period. These were Hadley Centre adeha, adehb, adehc data, the Sweden's Meteorological and Hydrological Institute's (SMHI) results and the Danish Meteorological Institute's (DMI) data. Both annual precipitation and seasonal distribution were compared. The comparison shows that there are huge variations between the modelled climate data for either annual sums, averages or seasonal distributions. Based on this, we decided that two climate models will be used for certain hydrologic simulations. Hadley Centre adeha data was selected to drive the WR-IHM model for all of the examined scenarios, and DMI was selected to drive certain model scenarios in order to see the range of effect that the driving data can cause on the model outcome. All together six climate scenarios were set up, named as C1 – control period, C2 – IPCC A2, C3 – IPCC B2, and their combinations with the HC adeha and DMI model results.

Water governance scenarios: four Scenarios were developed for water governance. The first (WG1) is taking the assumption that the maintenance of the drainage system (Fig. 1) will be on the same level as today. The second case (WG2) assumes that there are no channels on the area, which was developed to give a reference for the effectiveness of the channel network. The third water governance scenario (WG3) was developed in order to simulate the effects of a water retention focused water governance on the whole water budget of the pilot area. For this a simple weir system was implemented on the drainage network, without any sophisticated regulation mechanism. This variant represents an extreme solution for 1) avoiding groundwater drainage and 2) implementing channel storage, even at the price that it would often cause flooding in many areas. The last scenario (WG4) was an optimistic case, assuming that there will be more funding for maintenance of the channel network in the future. In this scenario, an increased conveyance capacity of the channels was modelled by setting the Manning roughness of the channels to the typical value of well-maintained channels.

Land use scenarios: Three versions were developed regarding the land use of the pilot area. The current land use (LU1) where simplifications have been applied to the CORINE database. 18 classes were set up all together, agriculture being the largest coverage. Suburbs of Makó town also cover a significant area, while natural vegetation is small (wetlands). For future scenarios, forests were inserted to the model in places where significant water coverage durations were modelled. Under LU2 scenario 7% of the area was changed from agriculture to forest, while under LU3 scenario around 12% of the agricultural vegetation was changed to forest.

Applied instruments - Economic exercise

The economic policy instrument proposed for the Marosszög area is a market to trade land use change obligations, implemented through an auction (Weikard et. al., 2012) that can promote the common fulfilment of the EFA requirement by several farms together. It helps farmers to select the actual pieces of land for conversion, while also serving as a payment mechanism from beneficiaries (farmers whose land continues to be used for crop production) to those land owners whose land is converted. Under the concept farmers bid a portion of their land for land-use change, supplying a price tag for compensation. The farmers whose bids are accepted receive the equilibrium price from the auction for each hectare. The compensation is paid from a fund to which the owners of unconverted land have to contribute, equally after each hectare.

Initially 32 farmer interviews were carried out in order to gain an in-depth understanding of local issues and perspectives on farming and ecology, and to distribute initial information about the project. The discussion resulted in a conciliated excess water inundation map of the area that served as the basis of common understanding of the issue. Then the concept was explained in detail, followed by an auction, and finally sharing and discussing results. All of the meetings were assisted by professional facilitators to make sure farmers remained motivated through the process and they understood the presented concepts. On hypothetical examples it was illustrated that cooperating with each other can lead to an overall lower cost than if each farmer fulfilled the requirement on its own. It was explained how a farmer with good quality land and high yields can pay another farmer with low quality land to fulfil the 7% obligation for the both of them in a way that is beneficial for both parties. The farmers understood this mechanism and afterwards the economic instrument (the auction) was described.

During the exercise farmers bid a portion of their land for land-use change, supplying a price tag for compensation. The actual portion depends on the farmer. Some farmers may offer all of their land, while others may not bid at all, knowing that they would be paying someone else to change their land use instead. Farmers may bid different pieces of their land at different prices. Those farmers that did not wish to participate in the bid, did not have to, they would then carry out the required land use conversion on their own land.

From the bids a supply curve is constructed showing the marginal cost of land use change (Ungvári and Kis, 2013). This curve is used to determine the equilibrium price of converting the required number of hectares. The farmers whose bids are accepted would receive this equilibrium price for each hectare. The compensation is paid from a fund to which the owners of unconverted land have to contribute, equally after each hectare.

The owners of unconverted arable land receive a dual benefit: they pay a lower price to other farmers than the opportunity cost of conversion (= lost profit) on their own land, and the local water balance may also improve. The owners of converted land receive revenue from other farmers as part of the economic policy instrument, and fetch some land use benefits (e.g. profit from grazing; revenue from timber), possibly coupled with a payment under the Common Agricultural Policy. Before the auction, the farmers needed to be well informed about these cash flows. The owners of converted land will not any more generate revenue from intensive crop production, but – since they submit lower than average prices at the auction – this displaced revenue can be safely assumed to be lower than the average for the Marosszög. In other words, areas with low productivity are converted, while areas of higher productivity remain intensively cultivated.

22 farmers with total cultivated land of 1778 hectares participated in the exercise, a little less than 20% of the case study area. 2 farmers, with 76 hectares, decided that they would not engage in the cooperation, that is, they would rather change land use on their own plots, as they had some low quality land, and likewise, they would refrain from offering the land use change service as part of the auction exercise, even though they were aware of the potential financial benefits. Their decision was likely due to lack of trust in the smooth operation of the scheme or limited understanding of the concept.

The results of the economic exercise contributed to a simplified cost-benefit analysis in which the costs of maintaining the channels were compared to the benefits quantified as the profits generated by the agricultural activity enabled by shifting the land-use change obligation to other plots of land. Both the costs and benefits were assessed as annual values.

RESULTS

Hydrological model calibration

Main tendencies of the measured groundwater levels have been described reasonably well by the model, however some of the extreme water levels were either under-, or overestimated in different parts of the area. Table 1 highlights the model efficiency values of the three considered monitoring wells for the 1998-2000 period (note that in case of groundwater table simulations we haven't find any widely accepted guidelines for model performance in the literature). The simulation provided moderately good performance in the agricultural areas for Földeák and Gencshát wells, while inadequate for Makó well located in the settlement. In latter case, possible ignored local effects (water withdrawal and concentrated infiltration, impervious areas, etc.) can explain the bad performance. Further information about the model set up and calibration is found in Jolánkai (2013).

Table 1 Model efficiency measures of groundwater levels for the calibration period 1998-2000

Model efficiency measure	Groundwater well Gencshát v209	Földeák 2322	Makó 2433
R^2	0.74	0.93	0.32
RMSE	0.78	0.49	0.79
NSME	0.45	0.41	-1.30

Figure 2 shows the observed and simulated relative changes of water level relative from the beginning of 1998. Groundwater level during the 1999 excess water flood is underestimated by the model, while the next year the simulated level follows reasonably well the trends of measured water table changes at the Földeák monitoring well.

There is no comprehensive satellite or aerial photograph based water coverage data from the area, therefore the justification of model results has been carried out in an untraditional way. Within the frame of the project, local stakeholder forums have been held to discuss future landscape management options and to assess the validity of economical tools to support future decisions with regard to management options. During these forums the local farmers were asked to evaluate the

simulated maximal water coverage map. The result of this qualitative assessment is shown in Figure 3. The general opinion of the farmers about the spots of water coverage has been reaffirming. There have been spots however, where the model showed water coverage that was not confirmed by farmers. Also there have been areas, where they could not give feedback, as they did not have relevant knowledge. The farmers also indicated areas where water coverage had been experienced, but the model did not show any sign of water on the surface. The overall conclusion is that the order of magnitude of the water coverage is well estimated, while the fine spatial distribution of ponds is not so well described. Given that the soil structure of the area is rather inhomogeneous, this is not so surprising.

Hydrological simulations

As Table 2 shows, water coverage extent varies on a wide range if all the scenarios are treated together. However, if the effects of climate change, land use change and water governance change are being examined separately, a different picture emerges. Climate change has the strongest effect on the water coverage. Compared to C1, the area of water coverage in the affected areas drops to about 11 % of the total area on average in scenarios C3. Scenario C2 shows an enormous drop of water coverage (14.2 to less than 1%) according to the HC model, which may seem unrealistic. The DMI model shows a more than 50% rate of change in average water coverage in scenario C3, which is larger than the similar value for the HC similar results. It is likely that the real change would be between these values, given that the real climatic conditions are between the two regional climate model predictions with respect to the control period. The

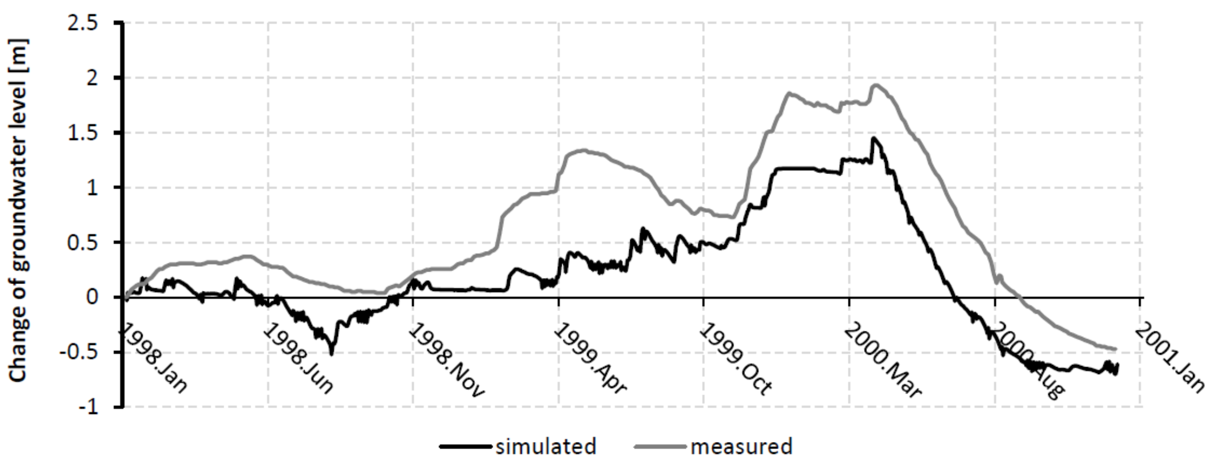

Fig. 2 Calibration results for the Földeák groundwater well – relative change of the measured and simulated water table

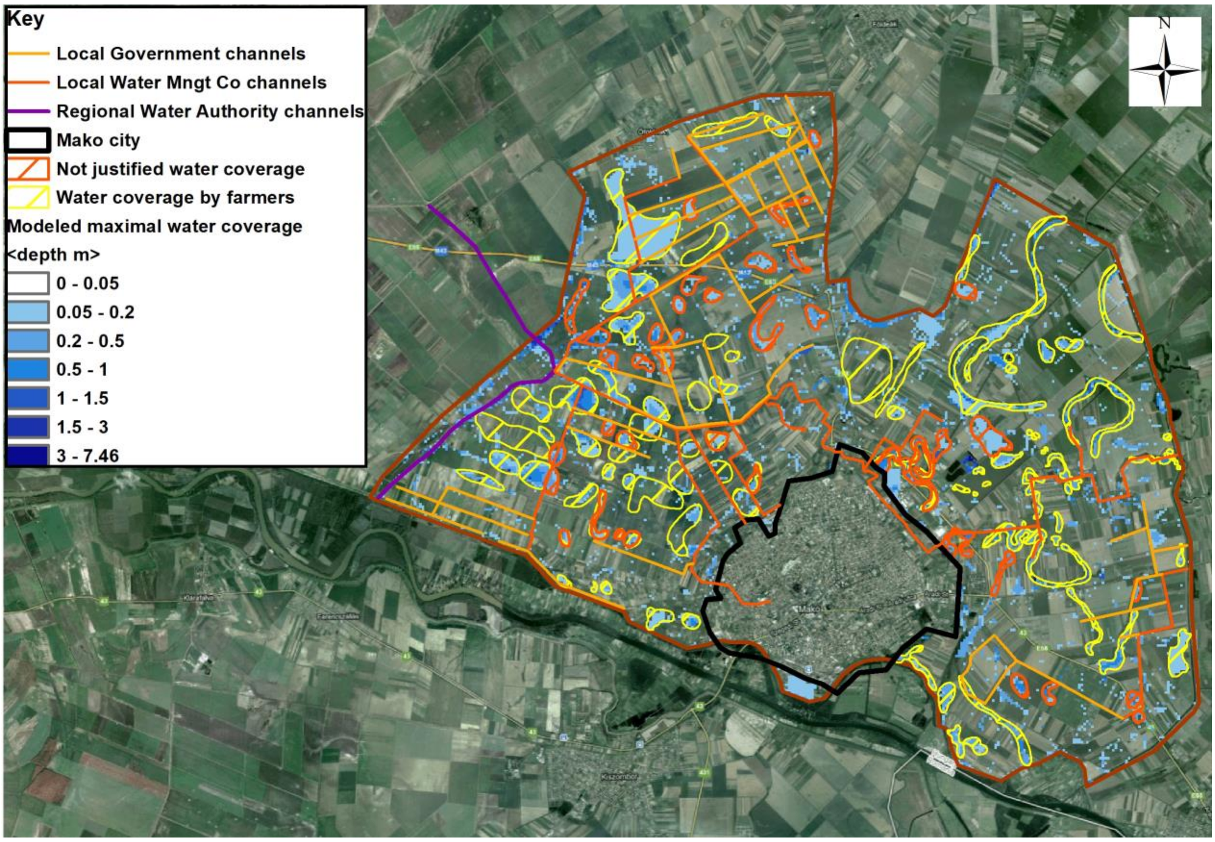

Fig. 3 Confirmed modelled maximal water coverage (1998-2000) by the local farmers in the Marosszög pilot area

Table 2 Water coverage durations (km^2) and the proportion of the coverage of the whole area (%) according to the investigated scenarios (HC: Hadley Centre adeha data, C1: control period, C2: IPCC A2, C3: IPCC B2, WG1: current water governance, LU1: current land use)

Scenarios	Duration of coverage [days]						Total [km^2]	Proportion of the whole area [%]
	0-7	7-14	14-21	21-28	28-60	60-365		
HC-C1-WG1-LU1	14.6	1.7	0.4	0.1	0.1	0.0	17.0	14.2
HC-C2-WG1-LU1	0.9	0.0	0.0	0.0	0.0	0.0	0.9	0.8
HC-C3-WG1-LU1	13.1	0.1	0.0	0.0	0.0	0.0	13.2	11.0
HC-C1-WG1-LU3	15.0	1.6	0.3	0.1	0.1	0.0	17.0	14.2
HC-C1-WG1-LU2	14.7	1.7	0.3	0.1	0.1	0.0	16.9	14.1
HC-C2-WG1-LU2	0.9	0.0	0.0	0.0	0.0	0.0	0.9	0.8
HC-C3-WG1-LU2	13.1	0.1	0.0	0.0	0.0	0.0	13.2	11.0
HC-C1-WG3-LU1	15.0	1.8	0.3	0.1	0.2	0.5	17.9	15.0
HC-C1-WG2-LU1	25.6	2.4	0.5	0.2	0.2	0.0	28.9	24.2
HC-C1-WG4-LU1	14.5	1.7	0.4	0.1	0.1	0.0	16.8	14.1
HC-C2-WG4-LU1	0.9	0.0	0.0	0.0	0.0	0.0	0.9	0.8
HC-C3-WG4-LU1	12.9	0.1	0.0	0.0	0.0	0.0	13.0	10.9
DMI-C1-WG1-LU1	14.6	1.9	1.3	1.5	2.0	2.4	23.6	19.7
DMI-C3-WG1-LU2	8.9	0.4	0.2	0.1	0.2	0.2	9.9	8.3
DMI-C3-WG1-LU1	8.7	0.4	0.2	0.2	0.3	0.3	10.0	8.4

number and duration of significant water coverage appearance on the area drops drastically in both climate scenarios (Fig. 4).

According to the model, land use change does not have a significant effect on the water coverage, as the change of water coverage in this LU scenario is only around 0.1 percent. This can be due to the fact that groundwater levels are generally deep under the surface for all scenarios. Therefore, it is not the groundwater table that is the primary reason for the occurrence of the excess water, but rather the huge amount of precipitation (or the fast snow melt) and the limited infiltration capacity of the soils (e.g. frozen soils).

The effects of water governance improvement have a similarly minor effect on water coverage durations. The improved conveyance of the channels (scenario WG4) has an effect of approximately 1 percentage point on the total water coverage compared to water retention / channel storage (WG3), while no effect compared to the baseline (WG1). As expected, the no channel scenario (WG2) has a significant effect on coverage: 70% increase of total area covered, while the number of days of duration increased by 1, which can have huge implications on plant development.

Pilot auction exercise

As it was already explained, an auction driven land-use change policy was the policy instrument that was tested with the participation of farmers from the Marosszög area. By the time the exercise took place, farmers were well aware of the project, the hydrological modelling efforts as well as the upcoming EFA requirements. During the exercise two scenarios were assessed: 1) individual compliance with the EFA requirement, i.e. all farmers have to set aside 7% of their land for EFA purposes, and discontinue traditional crop production on these parcels, 2) cooperation with each other through auction based common compliance with the 7% requirement.

20 farmers with 1702 hectares of land participated in the exercise. 7% of this area equals to 119 hectares, this is the targeted volume of land use change. Farmers made bids offering (some of) their land for land use change to others at prices specified by them in EUR/hectare/year. Some farmers differentiated their plots based on productivity, and offered different bids for different pieces of land. Altogether 55 bids were received. From the bids a supply curve was constructed, showing the price at which the cumulative quantity of land use change is offered (Ungvári and Kis, 2013). The constructed supply curve is monotonically increasing. The price at which 119 hectares of land conversion was offered happened to be 180 EUR/hectare/year. Thus, under the scheme, farmers who agreed to change their land use on behalf of others, would charge 180 EUR for each hectare per year as a service to those farmers who did not want to execute the land use change on their own parcels.

Because of the 7% criteria, every hectare of converted land enables continued crop production on 13.3 hectares of land - the 7% target implies that out of 100 hectares, 7 hectares is converted while 93 hectares stays in cultivation, thus the ratio of 93/7=13.3 results. Therefore, those farmers that choose to pay others to change land use instead of them, have to pay 13.5 EUR/year (180/13.3=13.5) for each hectare of their cultivated land in exchange for this service. Farmers thought that these results were reasonable.

Assuming that the offered bids were equal to the lost profit of the corresponding land, it was estimated that if each of the 20 farmers complied with the EFA requirement on their own, the lost profit would have been about 32,200 EUR/year for the total cultivated area – this would have been the cost of compliance. In case the farmers cooperate with each other, the total cost declines to 20,100 EUR/year – the 38% difference between the two solutions represents the economic advantage of common compliance.

There are additional, unquantified changes in costs and benefits that are partly the result of land conversion, and partly driven by the auction, as the selected regulatory instrument:

– The benefits of crop production are lost on the converted land, but benefits for other uses may appear (e.g. timber production). Since the quality of the converted plots is below average, the profitability of crop production is probably low; for some farmers cultivating these areas may even create a loss that is balanced by the CAP subisidies - the only reason for farming here. Thus, land use change in itself may improve the financial positions of farmers, if they continue to receive the CAP subsidies while they do not any more suffer a loss on their sub-prime land.

– The auction will enlarge these gains since it leads to the conversion of the worst 7% of the total case study area, while without this solution the worst 7% of each farm

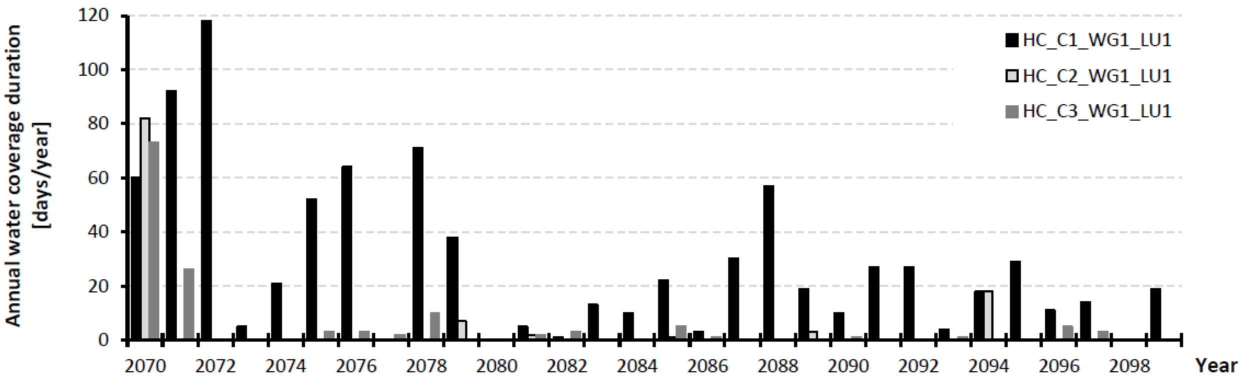

Fig. 4 Water coverage time series for the Marosszög pilot action. Effects of climate change according to the HC model

would be converted, therefore in the latter case the average productivity of the converted land would be higher.

– Once land is converted, the excess water diversion channels that used to serve the converted areas can be terminated, thereby saving some of the costs of their maintenance and operation. Also, less water needs to be pumped in case of a wet season when higher than normal precipitation coincides with relatively low temperatures and limited evaporation. The instrument, again, may make these gains more pronounced, since land gets converted in a more concentrated pattern – i.e. in a lower number of larger plots, rather than in a larger number of small plots –, making it more likely that some of the channels are not needed any more.

As far as distributional impacts are concerned, in principle everyone is better off. The voluntary nature of the policy instrument means that there are no adverse outcomes for participants - they only participate with bids that improve their position.

The state can also be better off, mainly due to avoided excess water inundation related damages, which under the current regulation are partially compensated by the government. Most of the land that is converted under the proposed scheme is subject to longer than average periods of excess water cover, therefore damage compensation following the land conversion can be substantially lower than today. On the other hand, the same locations may prove drought-resistant in dry years, which offers an economic advantage, but the current study does not address this issue.

Finally, it should be mentioned that organizing and operating the auction policy also entails costs – so called transaction costs – which should be kept low so that on balance the economic gains are not erased by the cost of implementation. Relatively low administrative requirements and large size (many farmers and lots of involved land) will help to keep transaction costs low.

A simplified cost benefit analysis

Costs and benefits were estimated and compared to determine the economic balance of the scheme. Costs are associated with channel maintenance while benefits are associated with farming activities. For the analysis it was assumed that excess water cover fully destroys the crops (generally true, but not always). Based on the team's interaction with local farmers it was concluded that the profitability of crop production falls between 170 and 600 EUR/hectare/year with a median value of 400 EUR/hectare/year. This is how much may be lost due to too much surface water.

With the help of the TIMAVGT water management association the researchers calculated the cost of maintaining and operating the channels, separately for the larger territorial networks and the local networks consisting of narrower branches. During the calculations the frequency distribution of the inundations were also considered. The maintenance costs of the territorial network channels were estimated at 30,000 EUR/year. This network, however, serves both the farms and the city of Makó, thus it makes sense to share the costs in some proportion. If all EUR 30,000 is to be covered by the farmers, then the benefits that they enjoy stay below this cost level, and it would not be rational to continue to maintain this network. However, if they are responsible to pay only 10% of the costs (in proportion to the diverted water that is of agricultural origin, while 90% originated from the city of Makó) then a net balance of EUR 24,000 results annually. Therefore, under any reasonable cost allocation between the farms and the (local) government, it is worth maintaining the territorial channels, as the benefits in most years substantially exceed the costs.

Table 3 The annual costs and benefits of maintaining the excess water drainage networks in the model area (EUR/year for the case study area, annualized)

	Benefit	Cost	Balance
Channel type	Avoided inundation loss in the agriculture	Maintenance and operating cost of the channels	
Territorial networks	27,000	30,000 / 3,000	-3,000 / 24,000
Local networks	11,000	18,000	-7,000

The local branches of the network generate net costs, i.e. a loss on average. Behind this average, however, there is notable deviation. There are plots with above average quality of soil that allow for vegetable production, a highly profitable activity. In these locations it generally makes sense to retain the local channels, but otherwise, most of the network is not worth maintaining. Therefore, decisions on maintenance should be not uniform, but case specific. Farmers are in the best position to decide if the local network segments that they use are worth maintaining at specific cost levels, or not. They will make a rational decision if they face their true share of channel maintenance and operation costs. The common compliance with the 7% EFA target also helps to determine the fate of local network segments, since the parcels without valuable crop production are revealed, and these areas do not need channels.

CONCLUSION

The proposed economic instrument, the auction for land use change obligation, offers a clear and direct economic advantage to the farmers with respect to complying with the Ecological Focus Area (EFA) requirement of the reformed Common Agricultural Policy (CAP). By cooperating with each other they can satisfy the CAP requirements at a lower cost compared to individual compliance. Once they start cooperating with each other on land use related matters, discussions of traditional agricultural practices that were abandoned during the decades of large-scale, industrialized agriculture can also take off. These discussions already started to emerge after the auction exercise, when farmers realized that the pilot scheme offers financial advantages and a more reasonable land use for the local community.

The results of the hydrologic modelling show that the concentration of the Ecological Focus Areas to the most excess water prone stretches of the landscape would not eliminate the inundation itself. The adaptation, however, decreases agricultural damage substantially, while reducing the drainage needs, therefore providing additional economic and environmental benefits. Drainage needs are also further reduced under climate change scenarios. Furthermore, increased conveyance due to improved maintenance of the channels does not reduce water coverage significantly. These results, coupled with the analysis of the auction outcome suggest that some of the local branches of the water network are not worth maintaining. The territorial network channels, on the other hand, provide benefits in excess of their cost.

The stable concentration of EFAs in the low lying areas means that EFAs end up in the sites with the highest potential ecological value. It also prevents the annual reallocation of EFAs that is allowed by the current regulation, even though this could eliminate much of the potential ecological benefits. The stable location of EFAs, including wetlands, ensures an increased level of ecosystem services in the form of pest control, pollination, nutrient reduction etc.

The farmers endorsed the auction scheme quickly and they were satisfied with the results of the experiment. But most importantly the experimental auction process produced a credible value for the conversion as a service that they can supply to each other using their least productive land segments. A discussion took place after the presentation of the results. It showed that revealing a price information through a mechanism that is understandable and acceptable to farmers initiated a constructive dialog about the local rationality of a more sophisticated land and water management. Moreover, it triggered the participants' own calculations about the possibilities they can create for themselves. This type of thinking was not experienced earlier in this context. During the discussion they raised, for example, the question of trading between other districts for realizing further gains/cost reductions.

The results also underline the importance of the EU Water Framework Directive approach that calls for the re-evaluation of the operation rationale of the water infrastructure (water services) in place and the identification of the stakeholder groups. Once water users, in this case farmers, face the true cost of the services they consume, they will be able to decide if the use of these services, and thus the maintenance of the underlying infrastructure, is indeed worth for them. These decisions will also have an impact on land use, increasing the level of ecosystem services beneficial for society.

Lastly, an important lesson from the exercise is that entrepreneurs and enterprises are absolutely open to market based solutions, even in areas where traditionally command and control regulations are applied.

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