Costs and benefits of land use adaptation to inundation scenarios in the Cibakháza-Tiszaföldvár floodplains

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1 Introduction

This document is part of the Interreg DTP project ”Reducing the flood risk by examining the restoration of flood plains in the Danube river basin”. It belongs to Work package 4.3 (Cost Benefit Analysis of Pilot areas integrating ESS) and analyses the costs and benefits of the restoration of the Cibakháza-Tiszaföldvár floodplain area from its current status of intensive agricultural cultivation.

The analysis applies the methodology - ESS-CBA DECISION SUPPORT MODEL AND METHODOLOGY (2020) that was developed under the same work package. The CBA calculations of the Cibakháza-Tiszaföldvár floodplain case are supported by an MS Excel based tool, The Danube Floodplain ESS extended Cost Benefit calculation and impact structure Module.

The document describes the main features of the project and the analysed scenarios in chapter 2, supporting the understanding of the analysis. The various cost and benefit items are depicted in detail in chapters 3 through 7, the conclusions are drawn in chapter 8.

The analysis of the Cibakháza-Tiszaföldvár case study site is a presumed one. The Covid pandemic related changes in the project’s activity made it possible during the final phase of the project. Given this late modification, no prior technical planning investigations were made, no actual infrastructural elements were designed to cope with particular hydraulical regimes. Similar is the case from the land use scenarios’ perspective, presumed cultivation modes were delineated without in-depth analysis of the actual practices at the site. The analysis gives broad estimates on the perceived costs and benefits of the site’s use under different hydrological and land use regimes and use an estimation of the necessary infrastructure development to exclude the possibility of flood damages beyond the study site area.

The analysis describes the economic calculations of REKK based on the inputs of experts from KÖTIVIZIG, WWF Hungary and the HNPI, albeit the economic analysis uses and interprets these inputs to fit to a coherent calculation methodology.

2 Key aspects of the analysed scenarios

Our analysis covers the combination of 2 land use and 4 hydrological scenarios, in total 8 versions, as portrayed in Table 1.

Table 1 The analysed scenario combinations

Land use	Tisza dyke along the Cibakháza-Tiszaföldvár floodplain			
	No modification	Demolished dyke	Sluiceway	Flood gate
Current land use (CS)	BAU	CS_all	CS_sluiceway	CS_gate
Future, modified land use (RS)	RS_none	RS_all	RS_sluiceway	RS_gate

In case of the BAU scenario current conditions will continue, same land use and the area will stay protected from floods by the main defense lines along the river.

As detailed in chapter 4.1, current land use (CS) is cropland dominated, while the intended future land use (RS) has a lower share of croplands, and more grassland and forests.

Under the “no modification” option the Cibakháza-Tiszaföldvár floodplain is not reconnected to the river. Under the „demolished dyke” scenario it is reconnected and high waters can enter the floodplain area without obstacle. In case of the “sluiceway” version only floods exceeding the 30 year return period will be able to enter the floodplain area, while the “flood gate” scenario relies on a flood gate to cut the peak of the flood and release only the peak into the floodplain area. With the exception of the “no modification” scenario all measures require local defense lines on the border of the floodplain, to avoid flooding external areas unintentionally.

In all scenarios we calculate the following costs and benefits (when applicable):

- Costs of infrastructure development (estimated by the dyke around the case study floodplain area)
- Farm income from land use in the Cibakháza-Tiszaföldvár floodplain (net income from agricultural and forestry activities, with special considerations on CAP support), adjusted for inundation damages due to floods released into the floodplain
- Flood related costs along the Tisza, including defense costs and catastrophe damage (excluding damages that take place in the Cibakháza-Tiszaföldvár floodplain)
- Land use based carbon emissions / sequestration

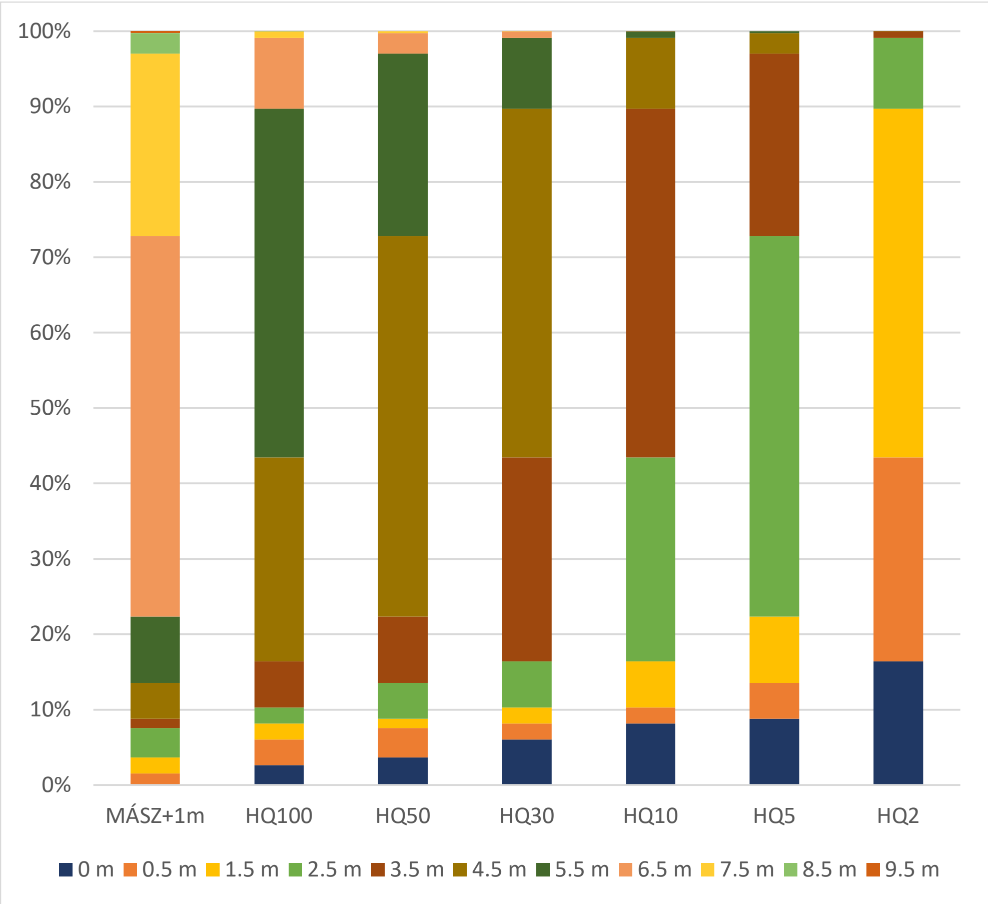
All financial values are calculated in present value to ensure comparability among the scenarios. A 2% real discount rate is applied for the calculation of present values, and the analysed period covers the next 50 years. There are some costs and benefits the economic value of which was not possible to express, these are described in chapter 7 as non-monetised items.

3 Costs of local defense line development

Depending on the flood levels (from HQ2 to HQ100) at which inundation of the Cibakháza-Tiszaföldvár floodplain area is intended in an orderly way, different scale of levee development is necessary to protect the territories that lie further behind the presumed case study site.

The length of the borderline around the presumed study area is 19.5 km. The below figure shows the distribution of the necessary levee heights to keep flood water inside the area.

Figure 1 Distribution of necessary levee heights around the case study site at different flood heights



Levee development costs are proportional to the volume of the necessary soil/building material. According to actual levee developments in the area two types of levee cross-section were utilized: for the containment of the HQ30-HQ100 water levels the slope ratio of the embankments is 1:3 with 5 meters of levee-top width and for the HQ2-HQ10 water levels the slope ratio is 1:2 and the top-levee width is 3 meters.

The necessary volume of soil grows exponentially with the height increase. This is reflected in the estimated cost of the different construction scenarios. These numbers are broad estimates for theoretical comparison and they do not contain specific elements that would be associated with the actual locality of the area.

Table 2 The volume based cost of levee development scenarios on the border of the delineated area

Inundation scenario	MÁSZ+ 1m	HQ100	HQ50	HQ30	HQ10	HQ5	HQ2
Estimated costs, million HUF	6 580	5 067	4 573	4 084	1 962	1 670	823

Levees need land to be built on that may incur costs as well. The cost of land purchase is calculated separately because this element is necessary only if there was no agreement on future land use with current land owners. Levee slopes can be utilized as pasture further on as it was the deal for example in an Austrian case of flood polder development at Mittersill. Consequently, the land purchase cost is an upper estimate of this potential cost element. Land prices are discussed in the Fokorúpuszta study (REKK, 2020), where an average value of 1.66 million HUF/hectare was used.

Table 3 The cost of land acquisition for the levees

	MÁSZ+1 m	HQ100	HQ50	HQ30	HQ10	HQ5
Land size, hectare	86	68	62	56	30	26
Aquisition cost, million HUF	142	113	103	94	49	43

4 Farming and forestry

4.1 The structure of land use

The definition of the land use scenarios analysed was a two-stage process. A floodplain elevation driven delineation was created by the project partners that were analysed by the previously applied methodology. Based on the initial results a streamlined version was created by the REKK staff. At the initial stage two land use scenarios have been compared: current land use (CS scenario) and expected future land use (RS-intermediate scenario). The surface cover of the various land use categories are summarised in Table 4. The shift between CS and RS-intermediate indicates reduced crop production, substantially more grassland and forest, and the introduction of orchards and large scale vegetable production.

Table 4 Land cover of the two land use scenarios (hectare)

Land use	CS	RS-intermediate
Arable land (crops)	1939.6	1230.3
Grassland	103.8	609.5
Deciduous forest	23.6	249.0
Orchards		40.3
Large scale vegetable production		48.3
Total	2067.0	2177.3

From an economic perspective neither intensive orchards nor vegetable production would make sense in the pilot floodplain area. The respective areas would be under water in every other year on average. The corresponding damage would be much higher than the net income that can be attained with these farming activities. Moreover, as these cultivation methods have high production value their increased territory dragged the overall balance into negative that make the adaptation scenario less resilient than the current one.

This contradictory modelling result has two main reasons. The floodplain elevation based delineation can’t take into consideration that the planned embankment along the study site overwrite the perceived inundation conditions. On the other hand, damage calculations are based on the ÁKK methodology, where intensive orchards are considered as the widely maintained form. The initial land use plan considers “floodplain orchards”, which are more resistant to regular inundation, but they also delivers lower yields that currently doesn’t make it as a cultivation choice for land owners at places with similar hydrological conditions. These floodplain orchards have very special local characteristics that make the yield/loss relationship too uncertain to apply it in the calculation model. This is more realistic to assume that these orchards are maintained as a supplementary benefit at the most suitable places in areas dominated and calculated by other cultivation types. In our analysis therefore we assume that these floodplain orchards offer the same economic profile as deciduous forests, therefore their area has been reallocated to the forest category (Table 5). Similarly, instead of large scale vegetable production we apply the arable land (crops) category to this area.

As due to some technicalities the total area under RS is larger than under CS, under the modified RS land cover we also reduced the area of each land use category proportionately, in order to enable comparison between the results of the CS and RS scenarios (Table 5).

Table 5 Modified land cover of the two land use scenarios (hectare)

Land use	CS	RS
Arable land (crops)	1939.6	1213.8
Grassland	103.8	578.6
Deciduous forest	23.6	274.6
Orchards		---
Large scale vegetable production		---
Total	2067.0	2067.0

4.2 Net income from farming and forestry

We have estimated the net income (revenues minus costs) for all three land use categories. Our calculations reflect average years, without inundation damages. The latter will be covered in the next subchapter (4.3).

The majority of the area is used for crop production in both land use scenarios. As discussed in REKK (2020), based on the 2014-16 years of the FADN (2018) report the post tax result of wheat/sunflower rotation, typical for this region, is about 330 EUR/year. This is an average value with significant annual variation, and approximately 70% of it is generated by agricultural subsidies. In the analysis we assume the same annual net income, and we use the current EUR/HUF exchange rate of 360 to calculate its value in HUF. Thus our assumption is that the subsidy makes up 75 thousand HUF/hectare/year and net income from crop production is equal to 45 thousand HUF/hectare/year.

Farmers on grassland are also eligible to agricultural subsidies, and similarly to crop production, those subsidies amount to about 75 thousand HUF/hectare. Within the FADN (2018) system the net income from grassland is not included on its own, only together with crop production and/or animal husbandry. We know from REKK (2020) that grassland management without subsidies is barely profitable, if at all. This is indicated by the lack of interest (or very modest interest) in renting such areas. Therefore for this land use category we assume a small nominal net income of 5 thousand HUF/hectare/year.

When calculating the income for forestry activities we relied on the interim results of the BIOSCREEN project (2021). Within the project a bio-economic model has been developed for Hungary, supported by data on forest growth and forest economics, the latter encompassing various costs of forest management activities and prices of different timber selections (fire wood, pulp wood, logs for industrial use). When calculating the net income from forestry for the Cibakháza-Tiszaföldvár floodplain, we made the following assumptions:

- We consider all forests (both the existing 23.6 hectares and the envisioned 274.6 hectares) as new forests, planted at present.
- All planting costs are covered by government subsidies, therefore we assumed 0 costs for the land owner for this activity.
- We assumed a mix of oak and poplar forests, with a 50:50 ratio of land cover.

- There is no harvesting (final cut) during the analysed 50 year period, but we take account of the timber value of the forest at the end of the period. There is, however, thinning in each decade, according to timber growth tables.

The net income generated from forest management (excluding the income supplement provided by the state) at the end of each decade is summarised in Table 6. The last row includes the annualised net income. If this net income was available for each year of the analysed 50 year period then the present value of this stream of cash flow would be equal to the present value of the sum of the thinning revenues and the final value of the timber stand. 2% real discount rate was used for the present value calculation.

Table 6 Net income (revenues minus cost) of forestry activities, mixed forest

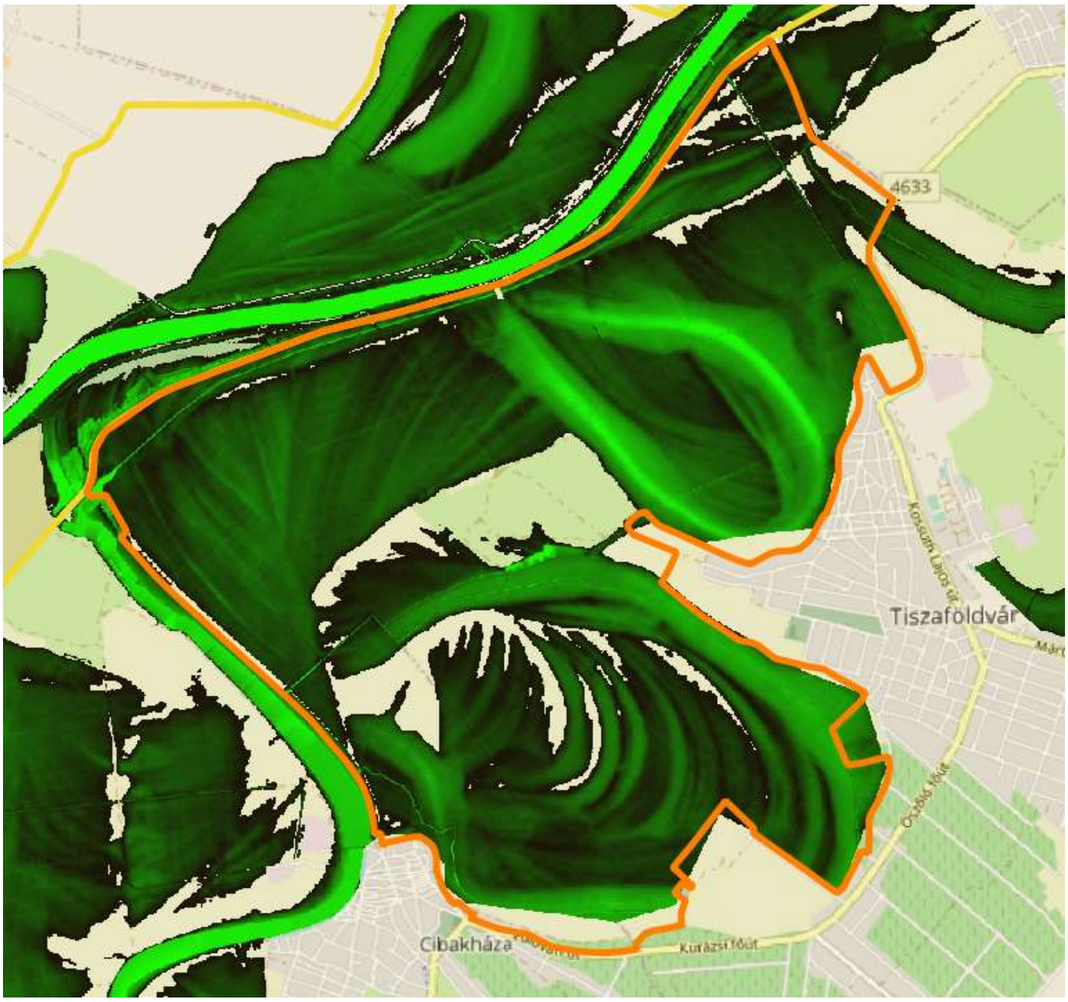
Income generating activity	Net income per hectare (thousand HUF/hectare)	Net income for the 23.6 hectares of the CS scenario (million HUF)	Net income for the 274.6 hectares of the RS scenario (million HUF)
Thinning, year 10	178	4.2	48.9
Thinning, year 20	615	14.5	168.8
Thinning, year 30	1000	23.6	274.7
Thinning, year 40	830	19.6	227.8
Thinning, year 50	892	21.0	244.9
Value of the standing timber	4699	110.9	1290.2
Annualised net income for the 50 year period	113	2.7	31.1

In addition, income supplement is available to farmers that decide to pursue afforestation, to make up for the lost income from discontinued agricultural activities. This income is available for up to 12 years and its value is 432 EUR/hectare/year (source: Magyarország Kormánya (2016)). We take account of this income stream within the CBA.

4.3 Inundation losses

The Cibakháza-Tiszaföldvár floodplain area is planned to be regularly inundated, and this generates damage to farming activities (cropland and grassland). In case of forests we assume that water resistant species are planted which can cope with regular temporary inundation, therefore no forest damage is expected. The level of agricultural damage is different in each location within the area, and its value can be calculated based on the value at risk (potential maximum damage), the water depth specific fractional flood damage curve, and the actual water depth. Therefore a combination of land use data, the economic value of each land use category, flood damage curves and inundation maps was required to calculate the damage of a given inundation event. The economic value of both land use category (cropland, grassland) as well as the fractional damage curves were obtained from the ÁKK methodology. Inundation maps were generated by Dávid Béla Vizi of KÖTIVIZIG, and he also provided valuable assistance by computing the surface area covered by a specific water depth for each land use category and each inundation event, the latter corresponding to a specific flood return period. Figure 2 provides an illustration of the water depths in the floodplain area associated with a 2-year return period flood.

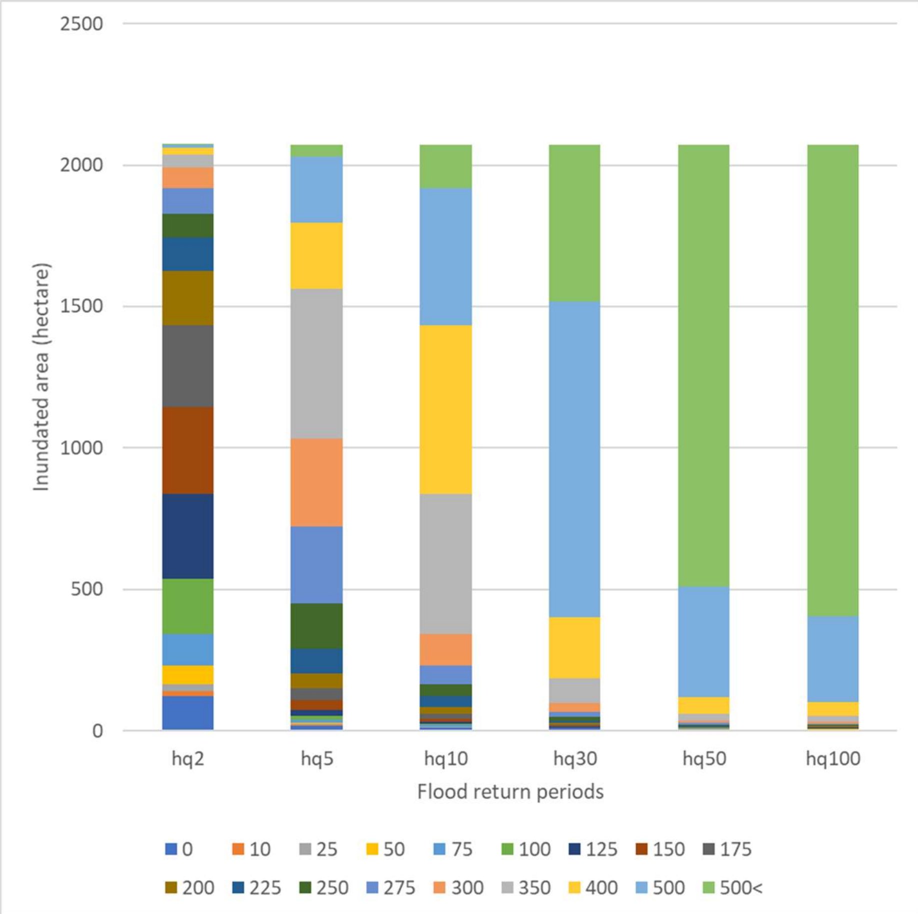
Figure 2 Water depths at the Cibakháza-Tiszaföldvár floodplain related to 2 year return period floods



Legend: The orange line delineates the case study area, no inundation outside it is perceived. The colouring shows the water depth differences from zero to 3.5 meters at the bottom of once functional river bends.

Figure 3 gives an example of how many hectares of the Cibakháza-Tiszaföldvár floodplain belong to given inundation depths under various flood return periods. In case of a 2 year return period flood, for example, about 500 hectares have a water depth of less than 100 cms, while the rest of the area is covered by deeper water. In case of a 100 year flood, over 90% of the floodplain area has water cover of at least 400 cms.

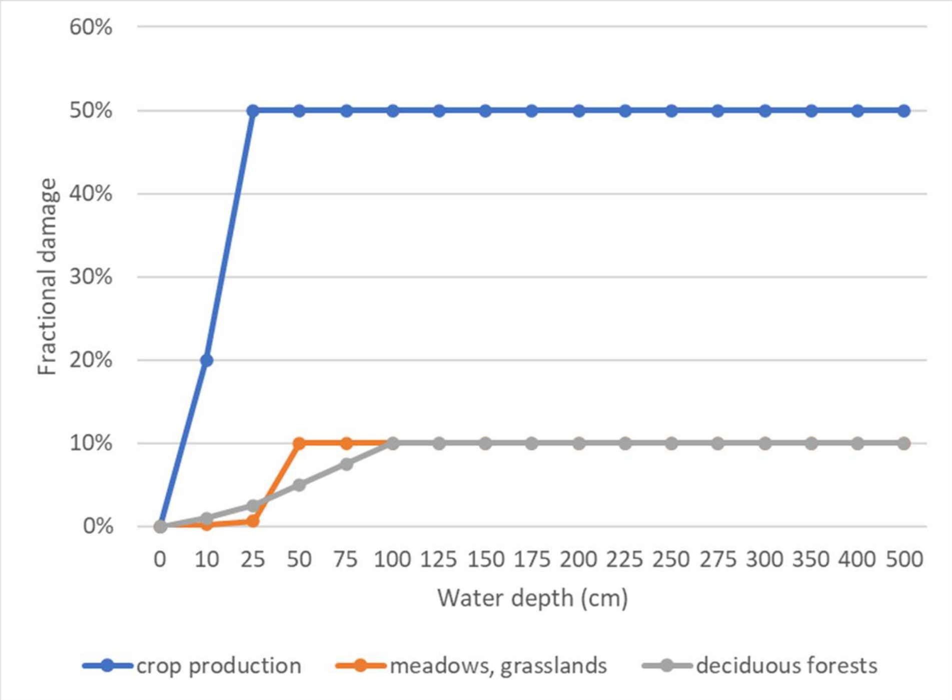
Figure 3 Share of the Cibakháza-Tiszaföldvár floodplain area according to water depth (in cm) at given flood return periods



Note: different colours represent different inundation water depths, in cm.

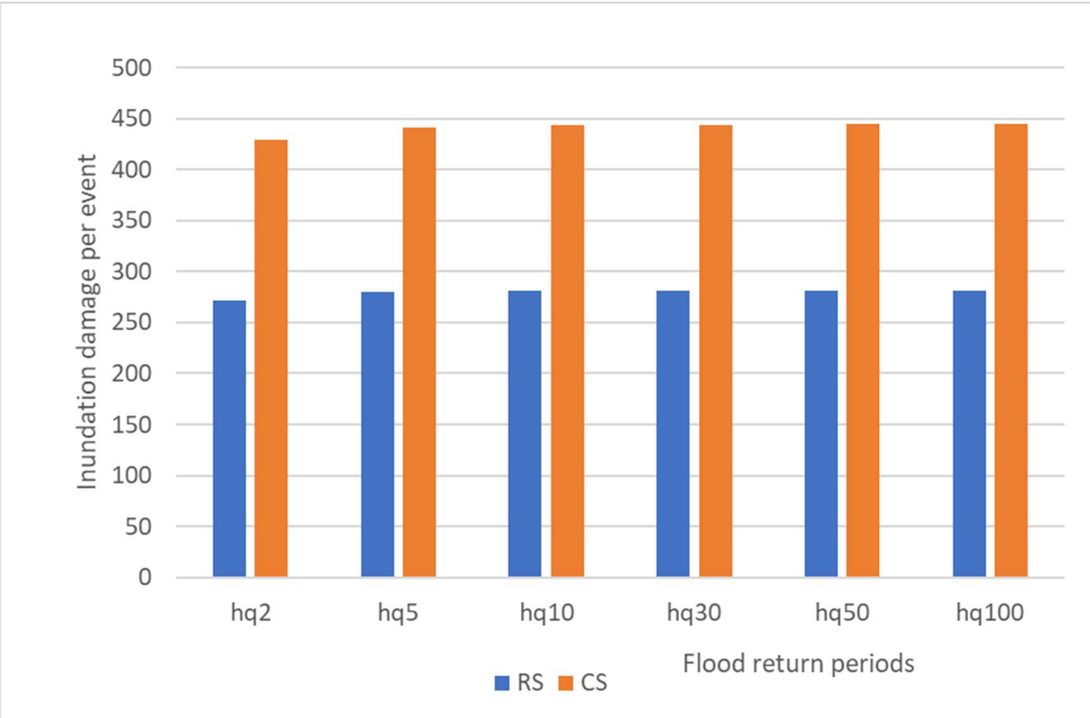
The fractional flood damage curves in Figure 4 show that crop production reaches its peak damage ratio of 50% at a water depth of 25 cm, while for grassland the peak value is 10%, and it is attained at water depths of 50 cm. For forests the peak damage value would also be 10%, but as we explained, we assume no damage for forests.

Figure 4 Fractional flood damage curves



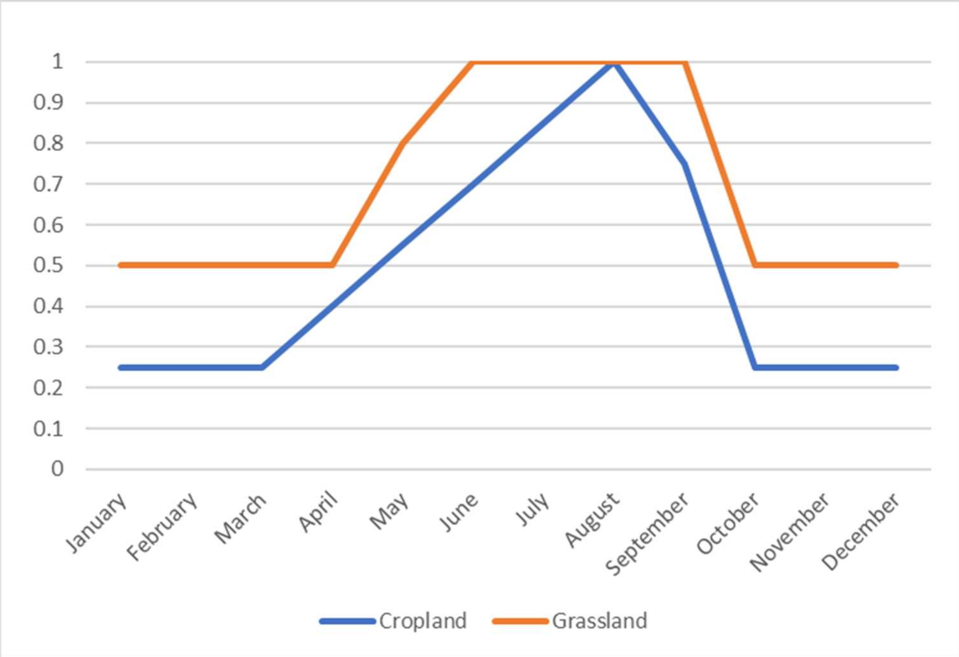
Since already for a 2 year flood event much of the area is covered by water that is at least 1 meter deep, a lot of cropland related damage takes place at a high frequency. Larger floods generate only modestly higher damages, as depicted by Figure 5. Over 98% of the damage takes place on cropland, and less than 2% on grassland, even though grasslands make up 28% of the total floodplain area.

Figure 5 Inundation damages in the Cibakháza-Tiszaföldvár floodplain for selected flood events (million HUF/flood)



Agricultural inundation damages are highly seasonal. The previous figure represents the maximum potential damage which, according to Ungvári and Kis (2018), would take place in August before some of the major crops are harvested. Inundation damages in other months can be significantly lower, as displayed in Figure 6. In the absence of a detailed statistical analysis (or future forecasts) of the seasonality of floods with different return periods, we assume an even distribution of all types of floods thorugh the year. This results in a multiplier of 0.48 for cropland and 0.69 for grassland, implying inundation damages of 408.9-426.3 million HUF for the CS, and 256.9-269.0 million HUF for the RS scenario, depending on the flood return period.

Figure 6 Seasonal damage as a ratio of the maximum inundation damage



Using the seasonality adjusted inundation damage data we can calculate the annualised level of inundation damages. This calculation depends on which return period floods are allowed to enter the floodplain area (which depends on the level of the Tisza dyke or the sluiceway, or the operation of the floodgate). Table 7 shows the results accordingly. As expected, under the land use structure of the RS scenario damage is already lower than in case of the CS scenario, due to having converted some of the cropland into meadows and forests. For frequent inundations, however, these values are still substantial. In case there is only forest and grassland in the RS scenario (all remaining cropland is turned into grassland) then the annualised damage drops to much lower levels. If only forests are present, then the damage is zero.

Table 7 Annualised damage in the floodplain area as a function of which floods are released (million HUF/year)

Which return period floods appear in the Cibakháza-Tiszaföldvár floodplain	CS	RS

hq2-hq100	209.6	132.3
hq5-hq100	148.3	93.8
hq10-hq100	63.7	40.3
hq30-hq100	28.4	17.9
hq50-hq100	11.4	7.2
hq100	6.4	4.0

4.4 Net income of land use from the farmer's perspective

Looking at the net income of crop production vs. afforestation from the perspective of farmers (Table 8), calculated as present value, forest management has a considerable advantage on average land[1]. On a 50 year time horizon the value of timber is expected to be higher than the net income from cropland, and this is not fully compensated by the difference between the long term agricultural subsidies and the short term income supplement for afforestation. We can assume that many farmers are not aware of the current favourable economics of afforestation and they keep cultivating land with average of below average productivity, even though afforestation would provide better economic prospects.

Table 8 Comparison of the net income of crop production and forest management, current subsidies

Name	Annual benefit value (HUF/ hectare/ year)	First year	Last year	Present value (HUF/hectare)
Crop production				
Annual CAP support	75,000	1	50	2,403,906
Annual net income from cropland	45,000	1	50	1,442,344
Total				**3,846,249**
Forest management				
Afforestation (after subsidies)				0
Annualised net income from forests	113,438	1	50	3,635,924
Income supplement for new afforestation	155,520	1	12	1,677,571
Total				**5,313,494**

Note: 2% real discount rate has been applied

The current favourable subsidies for afforestation, with 432 EUR/hectare/year of income supplement for the first 12 years, are available until 31 December 2022. Whether, and how they would change from 2023, is not known at this time. Therefore, as a point of reference, we also make a calculation with the previous level of income supplement for afforestation, 172 EUR/hectare/year. The results

[1] The same would apply to low quality land, while the best pieces of cropland would probably favour crop production as opposed to forest management.

are displayed in Table 9. In present value terms forest management continues to be more attractive than crop production, but since the majority of the actual revenue takes place decades from today, many farmers would choose a stable current income as opposed to a higher, but less certain future income.

Table 9 Comparison of the net income of crop production and forest management, previous subsidies

Name	Annual benefit value (HUF/ hectare/ year)	First year	Last year	Present value (HUF/hectare)
Crop production				
Annual CAP support	75,000	1	50	2,403,906
Annual net income from cropland	45,000	1	50	1,442,344
Total				**3,846,249**
Forest management				
Afforestation (after subsidies)				0
Annualised net income from forests	113,438	1	50	3,635,924
Income supplement for new afforestation	155,520	1	12	667,922
Total				**4,303,845**

4.5 Net income after inundation losses

By multiplying the size of the area covered by the three different land uses with the net income per hectare (chapter 4.2) we arrive at the annual average net income provided by all land use categories of the Cibakháza-Tiszaföldvár floodplain, as depicted in Table 10.

Table 10 Annual(ised) net income without flood damage (million HUF)

	CS	RS
Cropland	87.3	54.6
Grassland	0.5	2.9
Forest	2.7	31.1
Total	90.5	88.7

While the annualised net income is almost the same in the two scenarios, once the annualised inundation damage (Table 7) is subtracted, the attractiveness of the RS scenario becomes obvious (Table 11). If only 50-100 year floods are released into the floodplain area, then the two scenarios are more or less equivalent, but in case of more frequent inundations, RS prevails.

Table 11 Annualised net income of land use activities after inundation losses for the Cibakháza-Tiszaföldvár floodplain area (million HUF)

Which return period floods appear in the Cibakháza-Tiszaföldvár floodplain	CS	RS
hq2-hq100	-119.2	-43.7
hq5-hq100	-57.8	-5.1
hq10-hq100	26.7	48.3
hq30-hq100	62.1	70.7
hq50-hq100	79.1	81.5
hq100	84.1	84.6

5 Monetised flood risk along the Tisza

The same methodology has been applied to calculate the economic value of flood risk (reduction) as for the Middle Tisza Pilot case study at Fokorúpuszta (REKK, 2020). The methodology is presented in detail in the Annex of the report.

We know from Ungvári and Kis (2018) that in case of the Tisza, floods with return periods of at least 30 years pose substantial risk to properties. Therefore we did hydraulic and economic modelling of 9 relevant scenarios: three flood return periods (30, 50, 100 years) and three variations on the dyke along the Cibakháza-Tiszaföldvár floodplain (no modification, sluiceway, flood gate). Under the sluiceway scenario the floods would freely enter the floodplain area, moderately reducing the water level in the river bed. Under the flood gate scenario the opening of a flood gate would be timed to cut the peak of the flood. The total cost of each scenario is displayed in Table 12. Evidently, the flood gate has a more beneficial impact than the sluiceway. In case there is no dyke at all between the floodplain and the river, the flood related benefits are expected to be the same as in the case of the sluiceway scenario.

Table 12 Summed cost of flood defense and catastrophe damage for specific flood events for sections of the Tisza impacted by the Cibakháza-Tiszaföldvár floodplain (million HUF)

Return frequency	No modification of the dyke	Sluiceway	Flood gate
hq30	2,711	2,708	2,686
hq50	12,542	11,533	10,217
hq100	42,003	41,451	37,525
Annualised value of all floods together	885	865	789

6 Land use based carbon emissions and sequestration

In this chapter we look at changes in greenhouse gas emissions (GHG) and carbon sequestration, as an ecosystem service generated by the floodplain restoration. We assess the GHG impacts of land use change, but disregard the emissions arising from any construction activities, such as demolishing existing dyke sections, building new dykes, or constructing a flood gate. The same methodology is applied as in REKK (2020).

For the purpose of Danube Floodplain climate analysis the TESSA toolkit has been recommended. The TESSA toolkit makes further reference to the Tier 1 methods of the Intergovernmental Panel on Climate Change (IPCC). However, even those methods require data that is not readily available, therefore we relied on other, even further simplified calculations, which, on the other hand, are also based on the IPCC methods.

We made use of the National Inventory Report for 1985-2016 (NIR, 2018) and its Annexes submitted by Hungary to the UNFCCC. We divided the total sector and land use specific GHG figures by the corresponding land area published by the Central Statistical Office of Hungary. We received average GHG figures per hectare. These results are Hungary specific, though there is some variation of the carbon balance of different land use locations even within the same land use category, which makes our results less precise compared to strictly following the IPCC Tier 1 methods.

According to NIR (2018) croplands sequestered 379 kt of CO_2 in 2016. This figure, however, is misleading since activities on cropland (e.g. cultivation with machines, application of fertilisers, pesticides, manure) represent an important source of emissions. Total agricultural emissions, in 2016 reached 6878 kt of CO2e (CO_2 equivalent), the most important components of which include enteric fermentation, manure management and agricultural soils, the latter is related to the use of fertilisers. If we add emissions from agricultural soils (3472 CO_2e in 2016) to the sequestered CO_2 then we receive 3093 kt CO_2e of net emissions. Dividing this figure with the 2016 croplands of 4,332,400 hectares, a unit emission figure of 0.714 ton/hectare/year appears. This is the figure that we will continue to use.

In 2016 there was 783,200 hectares of grassland in Hungary, while the corresponding net emission figure from NIR (2018) is 14 kt of CO_2e. Therefore there is a unit emission of 0.018 ton/hectare/year.

Concerning forests, 3141 kt of carbon-dioxide was sequestered in 2016 on 1,940,700 hecares, resulting in a unit figure of 1.618 ton of CO_2 removal per year per hectare. However, this is an average figure, which corresponds to mature forests. For new afforestation reaching this level of sequestration takes 10-15 years, after that it will surpass this benchmark. For the sake of simplicity, we assume constant CO_2 sequestration.

Pairing actual land use figures (hectares) with unit emission / sequestration figures we arrive at the annual carbon balance of the area (Table 13). Land use change from arable land toward meadows and forests generates substantial CO2e emission savings, of about 915 tons/year.

Table 13 Annual CO2e emissions of the current and planned land use

	Land cover (hectare)			Annual CO2e emissions (ton/year)		
	CS	RS	CO2e emisson / removal (ton/ hectare/ year)	CS	RS	Difference
Arable land (crops)	1939.6	1213.8	0.714	1384.9	866.6	-518.3
Meadows	103.8	578.6	0.018	1.9	10.4	8.5
Deciduous forest	23.6	274.6	-1.618	-38.1	-444.3	-406.2
Total	2067.0	2067.0		1348.6	432.7	-915.9

When determining the economic value associated with CO2 emissions, we continue to follow the approach developed and applied by the EBRD, just like in REKK (2020), as we believe that this is a methodologically sound approach that well approximates the true cost of carbon emissions (and vice versa, the actual benefit of carbon sequestration).

The EBRD (2019) has adopted a carbon pricing approach under which the carbon impact of all projects is assessed using a “shadow price”. The shadow price considers all socials costs as opposed to market based CO_2 emission allowance prices which reflect the operation of a carbon market that is to a large extent driven by the number of carbon allowances made available to market participants by regulation. The latter price fluctuates, it’s movement driven by supply and demand, independently of the true cost that the release of CO_2 into the atmosphere generates. The shadow carbon price is incorporated into decision making, when the costs and benefits of a new investment are assessed, it puts a value on greenhouse gas emissions, thus correcting for the market failure of not fully considering the externalities caused by the emission.

Regarding the actual cost level, the EBRD follows the recommendations of the High-Level Commission on Carbon Prices (https://www.carbonpricingleadership.org/). This commission was created in 2016 with the explicit purpose of benchmarking the cost of pollution. The recommended carbon price range is 40-80 USD/ton of CO_2 for the year 2020, rising to 50-100 USD/ton of CO_2 by 2030. Beyond 2030 carbon prices are increased by 2.25% per year. All of these values are in real terms, in 2017 prices. Thus any inflation of the US dollar would result in further increase of the nominal value of the shadow price. The EBRD carries out a sensitivity analysis by applying both the lower and the upper edge of the price range during its CBA calculations. We checked EBRD resources to see if the shadow carbon prices have been updated for the last two years, but EBRD continues to use these same figures as in 2019.

An important recent development, however, is that in the most relevant greenhouse gas market, the EU ETS market, prices for CO2 allowances have more than doubled for the last two years, rising from about EUR 25 to an average price of around EUR 60 for September and October 2021. These prices are in line with the above described EBRD benchmarks.

The RS scenarios have lower net carbon emissions than the CS scenarios, due to the increasing carbon sequestration of forests and lower emissions from croplands, as the size of the latter declined. The value of land use change related CO2 emission reduction is calculated by multiplying the difference between the two scenarios with the year specific CO2 shadow price. The results are displayed in Table 14. This monetised value of emission reduction is between 12 and 24 million HUF initially, rising to about 40-80 million HUF by the end of the examined 50 year period. For the purpose of scenarios calculations we use the mid point of the range for each year.

Table 14 The economic value of land use change triggered CO2e emission reduction

Year	Net CO_2 reduction due to land use change	Minimum carbon shadow price (EUR/ton)	Maximum carbon shadow price (EUR/ton)	Minimum CO_2 benefit of land use change (million HUF)	Maximum CO_2 benefit of land use change (million HUF)
2020	915.9	36.0	72.0	11.87	23.74
2021	915.9	36.9	73.8	12.17	24.33
2022	915.9	37.8	75.6	12.46	24.93
2023	915.9	38.7	77.4	12.76	25.52
2024	915.9	39.6	79.2	13.06	26.11
2025	915.9	40.5	81.0	13.35	26.71
2026	915.9	41.4	82.8	13.65	27.30
2027	915.9	42.3	84.6	13.95	27.89
2028	915.9	43.2	86.4	14.24	28.49
2029	915.9	44.1	88.2	14.54	29.08
2030	915.9	45.0	90.0	14.84	29.67
2031	915.9	46.1	92.3	15.21	30.42
2032	915.9	47.3	94.6	15.59	31.18
2033	915.9	48.5	96.9	15.98	31.96
2034	915.9	49.7	99.3	16.38	32.76
2035	915.9	50.9	101.8	16.79	33.57
2036	915.9	52.2	104.4	17.21	34.41
2037	915.9	53.5	107.0	17.64	35.27
2038	915.9	54.8	109.7	18.08	36.16
2039	915.9	56.2	112.4	18.53	37.06
2040	915.9	57.6	115.2	18.99	37.99
2041	915.9	59.0	118.1	19.47	38.94
2042	915.9	60.5	121.0	19.95	39.91
2043	915.9	62.0	124.1	20.45	40.91
2044	915.9	63.6	127.2	20.96	41.93
2045	915.9	65.2	130.3	21.49	42.98
2046	915.9	66.8	133.6	22.03	44.05
2047	915.9	68.5	136.9	22.58	45.15
2048	915.9	70.2	140.4	23.14	46.28
2049	915.9	71.9	143.9	23.72	47.44
2050	915.9	73.7	147.5	24.31	48.63
2051	915.9	75.6	151.2	24.92	49.84
2052	915.9	77.5	154.9	25.54	51.09
2053	915.9	79.4	158.8	26.18	52.36
2054	915.9	81.4	162.8	26.84	53.67
2055	915.9	83.4	166.9	27.51	55.01
2056	915.9	85.5	171.0	28.20	56.39
2057	915.9	87.7	175.3	28.90	57.80

2058	915.9	89.8	179.7	29.62	59.24
2059	915.9	92.1	184.2	30.36	60.73
2060	915.9	94.4	188.8	31.12	62.24
2061	915.9	96.8	193.5	31.90	63.80
2062	915.9	99.2	198.3	32.70	65.40
2063	915.9	101.6	203.3	33.52	67.03
2064	915.9	104.2	208.4	34.35	68.71
2065	915.9	106.8	213.6	35.21	70.42
2066	915.9	109.5	218.9	36.09	72.18
2067	915.9	112.2	224.4	36.99	73.99
2068	915.9	115.0	230.0	37.92	75.84
2069	915.9	117.9	235.8	38.87	77.73
2070	915.9	120.8	241.7	39.84	79.68

Note: EUR/HUF exchange rate of 360 is used during the calculations.

7 Non-monetised aspects

While it has been possible to quantify the economic value of a lot of the key cost and benefit components of the Cibakháza-Tiszaföldvár floodplain scheme, there are some items where lack of available data did not allow quantification. These items are introduced in the current chapter.

Based on the experiences of the workshop focusing on the Fokorúpuszta area the ecosystem-service elements that are not monetized in the study are listed below:

Ecosystem service change that is not monetized
• Biodiversity • Habitat for various species, more robust fauna and flora • Lower pollution • More hunting and more game meet • Increased water infiltration into the soil, ground water recharge • Micro-climate regulation • Increasing recreational, sport, hobby and educational activities • Beekeeping

These benefits also appear in the Cibakháza-Tiszaföldvár floodplain area, as land use is transformed from the currently dominant crop production to a more balanced mix of cropland, grassland and deciduous forest. Some of the more important benefit items are detailed below, together with those non-monetised cost items which are necessary to enable land use change and water retention schemes.

7.1 Beekeeping

More bee families can be sustained in the additional natural area. As over 700 hectares of land would be transformed from cropland to more natural vegetation, this would enable 4-5 beekeepers to make a livelihood, if there is enough interest. Beekeeping, from the perspective of the available area, has been an underutilised opportunity recently, therefore the value that can be assigned to this activity is rather uncertain. We do not make attempts to monetise it. We should also keep in mind that bees not only produce honey, but they also contribute to the productivity of agricultural activities and to a healthy ecosystem.

7.2 Hunting

As the size of the natural area increases, more wild animals will be present. In the Fokorúpuszta case water fowl was more likely to thrive than wild mammals, and we think this would also apply here. Altogether, the value of hunting may increase, but the extent of this change is difficult to predict.

7.3 Recreational, sport, hobby and educational activities

More natural areas may entice more people to spend increasing time in nature pursuing different activities. The area is close enough to Cibakháza and Tiszaföldvár to attract people to jogging, leisure walking, biking. The natural area in the proximity of the river may become an attractive spot for bird watching, but we do not have a basis to estimate the actual number of such visitors. The natural area provides educational potential as well, such as nature trails and on-site biology and ecology classes, school trips and camps.

7.4 Ecosystem improvements

As approximately 700 hectares of cropland is converted into more natural land use, habitat will sustain an increased fauna and flora, it is supposed to exhibit increased biodiversity and more resilience to external disturbances. These are all important, but unquantified improvements.

7.5 Increasing groundwater recharge

Due to the regular inundation of the area more groundwater recharge is expected, contributing to the healthy water balance of the region. Higher groundwater levels are beneficiary both for nearby farmers and the ecology.

7.6 Triggering land use change

Farmers need to be incentivised to give up farming their croplands and switch to grassland, forests or other nature-friendly land uses. There are many different ways of doing this: upfront payments, regular payments, exchange of their land to parcels outside the floodplain area, assistance in adjustment to regular inundation on their land etc. No specific method has been defined for the current analysis, thus we cannot estimate the corresponding cost. It is quite certain, however, that resources would be needed to achieve land use change (both as incentives, and also to cover the costs of initial adjustment). One may reckon the level of these costs by comparing the net income from different land uses, since lost profit would somehow have to be covered, in order to ensure that the financial position of farmers does not worsen.

7.7 Technical measures to connect the floodplain to the river

Various technical measures are needed to ensure the release of water from the river to the floodplain at given flood heights:

- Demolishing a section of the dyke reconnects the floodplain, high waters would enter its area.
- Developing a sluiceway creates a section in the dyke where a given level of water can cut through toward the floodplain.
- Building a flood gate enables the cutting of the peak of the flood without allowing the unrestricted flow of water to the floodplain area.

Any of these engineering solutions can be designed and implemented in multiple ways and at different cost levels, thus they would need to be defined quite precisely before tyring to estimate their costs.

8 Conclusions

Table 15 provides a summary of the costs and benefits of all eight analysed scenarios. Only the monetised items are included. In the case of flood related costs, we do not display the full costs (as those would fall in a different magnitude, and that value has not much to do with the pilot floodplain area), but the difference compared to the BAU.

The yellow rows in the bottom of the table show the total figures (all cost items for all stakeholders added together). The first total row includes transfer payments, the second does not. A transfer payment "is a one-way payment to a person or organization which has given or exchanged no goods or services for it"[2]. As such, a transfer does not represent an actual economic cost or benefit (it can have indirect economic consequences, but those are not nearly as powerful as payments for services or goods). Total benefits / costs including transfer payments are important for individuals and market players, such as farmers, because their financial position is directly influenced by the transfers. Therefore these are important variables if we would like to understand how they view the outcome of given scenarios. From the perspective of the whole economy it is better to consider total benefits / costs without transfers, thus the latter should guide a social cost benefit analysis.

The following conclusions can be drawn based on Table 16:

- The BAU scenario with the current land use and without any hydrological change represents substantial benefits to farmers, although much of it originates from agricultural subsidies (which are transfers). All other scenarios would reduce the benefits enjoyed by farmers, thus a compensation would be necessary.
- Under the RS_none scenario, also without any change in hydrology, the economic position of farmers declines, but only moderately, as they change crop production to less productive meadow management, which is only partly counterbalanced by the shift to more productive forest management. Declining carbon emissions, however, generate substantial (global) social benefits. From the perspective of society this is the most attractive scenario.
- Under CS_all and RS_all the floodplain area is frequently inundated which generates land use specific inundation damages and just as importantly requires the development local defense lines (levees) which turned out to be very expensive. At the same time, the flood related benefits are moderate, they do not compenate the costs related to the local defense line. These are the economically least attractive scenarios.
- Under the sluiceway scenarios (CS_sluiceway, RS_sluiceway) inundation losses are much lower since only floods with a return frequency of at least 30 years are allowed to enter the floodplain area.
- The inundation losses are similar in case of the CS_gate and RS_gate scenarios, but the flood related benefits are much higher, since the peak of the floods are cut. Still, these benefits are not enough to counterbalance the quantified costs of local defense line devepment. Moreover, there are substantial, yet unquantified costs of flood gate construction and maintenance, which further deteriorate the economic position of these scenarios.

In conclusion, compared to the current state (the BAU scenario) only the new land use without any inundation (RS_none) would generate supplemental benefits. All other scenarios are more costly, and neither the flood related benefits or CO_2 emission reductions would be sufficient to compensate the loss of farming income and the flood defense infrastructure investment costs. Whether the non-

[2] https://www.investopedia.com/terms/t/transferpayment.asp

monetised benefits of land use change coupled with frequent inundation would justfify the monetised costs, requires further analysis.

Table 15 Costs and benefits of the inspected scenarios, net present value (million HUF)

				BAU	CS_all	CS_sluiceway	CS_gate	RS_none	RS_all	RS_sluiceway	RS_gate
Stakeholder	**Costs / Benefits**	**Name**	**Description**	**Present value**	**Present value**	**Present value**	**Present value**	**Present value**	**Present value**	**Present value**	**Present value**
State (flood)	Benefits	Reduction of flood related costs	Based on catastrophe damage and flood defense costs together	0	646	646	3,055	0	646	646	3,055
State (flood)	Costs	Local defense line	Along the floodplain area	0	-6,580	-6,580	-6,580	0	-6,580	-6,580	-6,580
State (flood)	Costs	Land purchase for local defense line	Along the floodplain area	0	-142	-142	-142	0	-142	-142	-142
State (flood)	**Net monetised benefit (+) or cost (-)**			**0**	**-6,075**	**-6,075**	**-3,667**	**0**	**-6,075**	**-6,075**	**-3,667**
Farmers	Costs	Inundation losses	Related to agricultural activities in the Cibakháza-Tiszaföldvár floodplain	0	-6,719	-364	-364	0	-4,242	-230	-230
Farmers	Benefits	Annual CAP support	Only cropland and grassland are eligible, forestry is not	4,912	4,912	4,912	4,912	4,309	4,309	4,309	4,309
Farmers	Benefits	Annual net income from cropland		2,798	2,798	2,798	2,798	1,751	1,751	1,751	1,751
Farmers	Benefits	Annual net income from grassland		17	17	17	17	93	93	93	93
Farmers	Benefits	Annualised net income from forests		86	86	86	86	998	998	998	998
Farmers	Benefits	Income supplement for new afforestation	Available for farmers to replace the lost income of discontinued agricultural activities for up to 12 years	0	0	0	0	421	421	421	421
Farmers	**Net monetised benefit (+) or cost (-)**			**7,812**	**1,093**	**7,448**	**7,448**	**7,572**	**3,330**	**7,342**	**7,342**
Global society	Costs	Carbon emissions	Based on shadow price of carbon. Positive value indicates net emisssions, negative value net sequestration.	-1,513	-1,513	-1,513	-1,513	-486	-486	-486	-486
Global society	**Net monetised benefit (+) or cost (-)**			**-1,513**	**-1,513**	**-1,513**	**-1,513**	**-486**	**-486**	**-486**	**-486**
All stakeholders together	***Net monetised benefit (+) or cost (-)***			***6,299***	***-6,496***	***-141***	***2,267***	***7,086***	***-3,231***	***781***	***3,189***
	Net monetised benefit (+) or cost (-) without transfers			***1,387***	***-11,408***	***-5,053***	***-2,645***	***2,356***	***-7,961***	***-3,949***	***-1,541***

Based on our analysis, the current land use is not the most advantageous one from a long term perspective, neither for the public nor, the landowners.

From an annualized perspective the net income of the CS and RS scenarios are very close to each other (Table 10), but the table reveals that in case of the RS scenario the still relatively lower forest cover share provides a significant part of the benefits. Path dependency is a strong force maintaining the status-quo. Meanwhile planting forest among the recent circumstances on an average or below average quality land is more beneficial than sticking to crop production during the same 50-year period. This result is true in both cases if CAP subsidies are taken into consideration or not (Table 8, Table 9). Landowners may not be aware of the changing conditions, or don't have the financial background for managing the necessary change or lack the necessary knowledge or trust in the predictability of the regulation or have long term cultivation contracts.

Also, at the same time there are non-realized benefits attached to forestry as public benefit derived from the value of the carbon sequestration of the forest (Table 13 and Table 14). This potential benefit is in the range of 11-24 million HUF annually, or about 1 billion HUF of present value, based on the shadow price of carbon.

The recent incentive policy on land use could trigger an afforestation process without further considerations. The expansion of a previous table, see (**Hiba! A hivatkozási forrás nem található.**) that such a land use transformation will reduce the damage exposure, that might open up space for other land management arrangements.

Table 16 Annualised damage in the floodplain area as a function of which floods are released (million HUF/year)

Which return period floods appear in the Cibakháza-Tiszaföldvár floodplain	CS	RS
hq2-hq100	209.6	132.3
hq5-hq100	148.3	93.8
hq10-hq100	63.7	40.3
hq30-hq100	28.4	17.9
hq50-hq100	11.4	7.2
hq100	6.4	4.0

From this perspective the provision of further non-monetized benefits hang on the difference between the benefits of carbon sequestration and the cost of installing the necessary infrastructure that protect other areas from the detrimental effect of inundations. Figure 1 and Table 2 show that there is a wide range of infrastructure development costs in relation to the level of the perceived flood risk reduction service. Further details must be clarified whether there is a low-levee-height equilibrium when only the most frequent floods are allowed to a mostly forested area.

The listed topics are recommended for additional research:

- The viability of floodplain cropland use

- Average national net income figures were used for the cropland of the Cibakháza-Tiszaföldvár floodplain, but further research uncovering the profitability of this area would help to finetune the conclusions. Net income in different parts of the floodplain is crucial when the ideal land use is determined.
- We suspect that floodplain forests are economically more attractive than croplands or grasslands, especially when inundation damages are also considered. This notion should be validated with further research.

9 References

REKK (2020) Danube Floodplain Project, WP 4.3: Hungary: Tisza Pilot CBA

National Inventory Report (NIR, 2018) for 1985-2016 of Hungary to the UNFCCC

EBRD (2019) European Bank for Reconstruction and Development. Methodology for the economic assessment of EBRD projects with high greenhouse gas emissions. Technical note.

Szili, Viktor and Szlovák, Sándor (2018): A főbb mezőgazdasági ágazatok költség- és jövedelemhelyzete 2016 = Results of Hungarian FADN Farms 2016.

BIOSCREEN (2021) FOX model development, interim results, before publication.

Ungvári Gábor és Kis András (2018) Közgazdasági döntéstámogatás a Tisza-völgyi árapasztó tározók üzemrendjének kialakításához a Tározó igénybevételek gazdasági hatékonyságát alátámasztó közgazdasági modellek kifejlesztése – tárgyú szerződés keretében a Vállalkozási szerződés üzemirányítás és monitoring hálózat fejlesztés komplex megvalósítására a KEHOP- 1.4.0-15-2016-00016 projekt részeként. Záróanyag – jelentés

Magyarország Kormánya (2016) Felhívás Mezőgazdasági és nem mezőgazdasági földterületen végrehajtott telepítések megvalósítására. A Felhívás címe: Erdősítés támogatása. A Felhívás kódszáma: VP5- 8.1.1-16

10 Annex: Methodology for flood risk calculation

The areas along the Hungarian section of the river Tisza are protected by dykes. Dykes alone, however, are not always sufficient to ensure perfect protection. Large floods require additional defense operations, and a catastrophe may also occur in case a dyke fails or its height is not sufficient to hold the water, and areas are flooded outside the floodplain. These are the two main types of costs associated with large flood events: the costs of defense operations and catastrophe damage in case a catastrophe takes place.

In order to reduce the risk of a flood catastrophe, flood defense development projects are regularly implemented by governments. These projects may consist, for example, of strengthening and raising the dykes, investing into peak flood polders, ensuring smoother water flow in the river bed or giving more room to the river via the relocation of dykes.

To judge the cost effectiveness of investing into and operating peak flood polders, a hydrologic simulation based economic decision support model was developed within the “Coordinated peak-flood polder management on the river Tisza” project (Tisza Üzemirányítási projekt, 2017-19). While the original model was designed to assess the economic viability of peak flood polders, it was now amended to be able to inspect the economic benefits of the Cibakháza-Tiszaföldvár floodplain restoration idea.

The core idea behind our analysis is that the changed river regime (floodplain restoration through different solutions) will alter the behaviour of flood waves, thereby requiring a different level of defense operation and altering the risk of a catastrophe. The economic model is based on the relationship between water levels, defense costs and the probability of dyke failure. For any given flood wave we are comparing several scenarios: how the flood would move along the river under the original and the new, altered river regime, when more space is available for the water (through various engineering solutions). These scenarios are hydrologically simulated in HECRAS and the hydrological results are converted to an input for the economic model: hourly time series of water levels in various river sections.

Even relatively benign floods require some flood defense preparations, such as the daily inspection of the condition of the dykes, while higher floods tend to demand growing efforts, such as reinforcing the side of the dykes or piling sand bags on top of the embankment. Within the economic model the relationship between flood characteristics and defense operation costs along the dykes was derived from a regression analysis of historic flood defense data from the river Tisza and its tributaries between the 2000-2013 period. The input data of the cost estimation comprised the physical characteristics of the flood waves (peak water level of the flood, the number of days under stage three defense alert, the length of the defended dike section) and the flood defense activities taking place during the analyzed period officially characterized as “extreme level” defense. The resulting statistical relationship was reliable, with a relatively large standard deviation.

The economic model also depicts the connection between flood events and catastrophe damages. This relationship was to a large extent formulated based on the ÁKK (Árvíz Kockázat Kezelési projekt – Flood Risk Management project) database, created by the flood risk mapping project triggered by the EU Flood Directive. The ÁKK project surveyed all dykes to identify the most vulnerable dyke sections, which were called „rupture sections”. For all these sections the water level was determined at which static problems may start occuring. Within the economic model – based on consultations with the engineers of the ÁKK project – a water level based dyke failure probability function was generated for all rupture sections. Higher water levels thus translate into a higher probability of catastrophe. If high water levels stay for an extended period, then the value of this probability further increases. The ÁKK project also assessed the areas that would be flooded if the dyke at a given rupture section fails, and how much damage would register in this case. All of this information is incorporated into the economic model.

The economic model is a Monte Carlo simulation based probabilistic model. The main reason for applying the Monte Carlo approach in this case is that the dyke rupture and the resulting flood catastrophe is a small probability event, but one that comes with a huge economic loss. Simply looking at the average case – in which no catasrophe takes place – is misleading. A flood wave is better depicted by the expected value of the full event horizon, which also includes the probability of a catastrophe. The full event horizon can be rather complex. Even a short river stretch may contain multiple rupture sections, and once a section breaks the water level within the river bed drops, thus a second dyke rupture cannot happen. Moreover, a dyke breach may happen at different water levels (with increasing probability at higher levels), implying that the flooded area is also different, and so is the corresponding damage. To be sure that the majority of the event horizon is captured, each model scenario needs to be run at least 10,000 times.

The models need to be run for both the baseline scenario and the altered river regime reflecting the changes of the dyke section along the Cibakháza-Tiszaföldvár floodplain. By comparing the expected total cost of the two scenarios it becomes possible to conclude if the floodplain restoration has generated net benefits in terms of lower overall flood related costs.

The above process is applicable to a specific flood, and the results will show the flood related benefits of dyke relocation for that one specific flood event. However, the dyke relocation is supposed to generate benefits not only for a single flood event, but for an extended time horizon. Therefore it makes sense to look at a long time horizon (e.g. 100 years) and consider all the possible floods that can take place during the period. Alternatively, we can look at the annual probability that specific floods will occur. Floods are defined by their "return period", which is the estimated average time between events. A 10 year flood, for example, is a flood with a peak water level that has a 1/10=10% chance of being exceeded in any given year. In a similar vein, a 50 year flood has a 1/50=2% chance of being exceeded in any given year.

We can compute the annual expected cost of floods if we simulate floods with different return periods, compute the cost associated with each flood, calculate the annual expected value of each flood by multiplying its cost and the probability that the flood would occur in any given year, and finally sum all of the annual expected values to arrive at the cost of the full event horizon (all possible floods).