DANUBE FOODPLAIN PROJECT, WP 4.3:

HUNGARY: TISZA PILOT CBA

REKK

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1 INTRODUCTION

This document is part of 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). It contains the extended Cost-Benefit Analysis of the Hungarian partner, the Middle Tisza pilot case study, focusing on the dyke relocation project at Fokorú puszta on the river Tisza floodplain (KÖTIVIZIG, Middle-Tisza Case).

The document describes the main features of the dyke relocation project in chapter 2, necessary to acquire a good background to understand the analysis. The area's ecosystem services were collected and structured during the Work Package 4.2 phase of the project (The 23rd January 2019 stakeholder workshop in Szolnok, organized by KÖTIVIZIG, Szeged University and WWF Hungary, and further elaborated by CUEI). The summary of the findings that served as a starting point of the ESS-CBA analysis is in chapter 3. The subsequent chapters show the results of the ESS-CBA analysis integrated into the decision support structure and the use of the ESS-CBA Module.

This document applies the methodology to the extent made possible by data availability - ESS-CBA DECISION SUPPORT MODEL AND METHODOLOGY (2020) that was developed under the same work package. The CBA calculations of the Middle Tisza case are supported by an MS Excel based tool, The Danube Floodplain ESS extended Cost Benefit calculation and impact structure Module. Two version of the Module are supplied: 1) a blank file without case specific data and 2) a file with the Middle Tisza pilot case study data.

In our judgment the pilot site calculations proved the usefulness and the practical applicability of the methodology that follows a decision flow approach the extended CBA analysis is a part of. The sustainability analysis phase was conducted on a simpler dataset than what the methodology deemed suitable in order to grasp the most important dynamics of ecosystem service asset change. We are convinced that the right way ahead in this aspect is the improvement of the information supply, not the change of the methodology. The post CBA element of the decision flow, the structuring of the stakeholder group impact also proved a useful method to make the results understandable.

2 DESCRIPTION OF THE DYKE RELOCATION PROJECT

In the middle of Hungary, north of the city of Szolnok, a section of the current dyke will be relocated in order to give more space to the river and achieve multiple benefits as described in this document. Figure 1 below illustrates the project. The location is about 10 km upstream of the city of Szolnok, the biggest settlement in the area, which has the highest flood risk exposure along the Middle Tisza.

Figure 1 The modelling area including the dyke relocation project

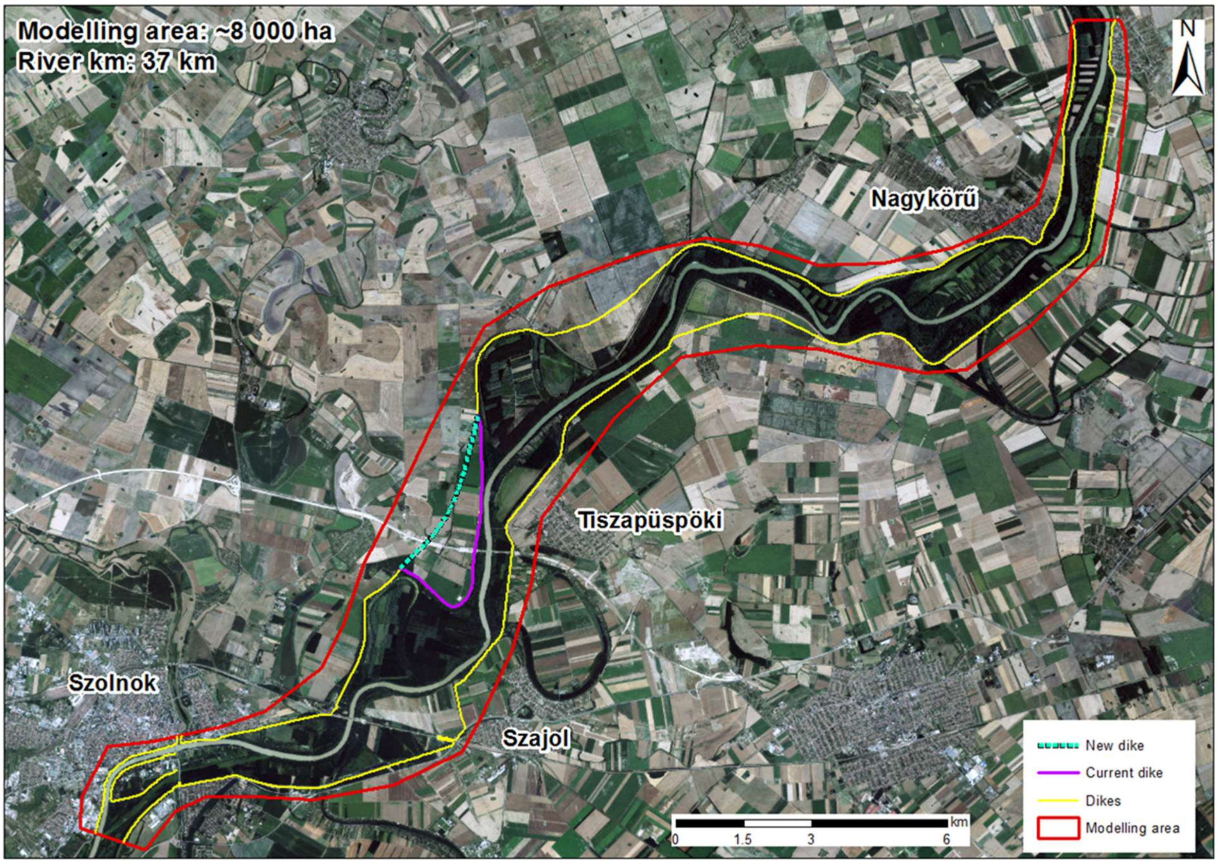
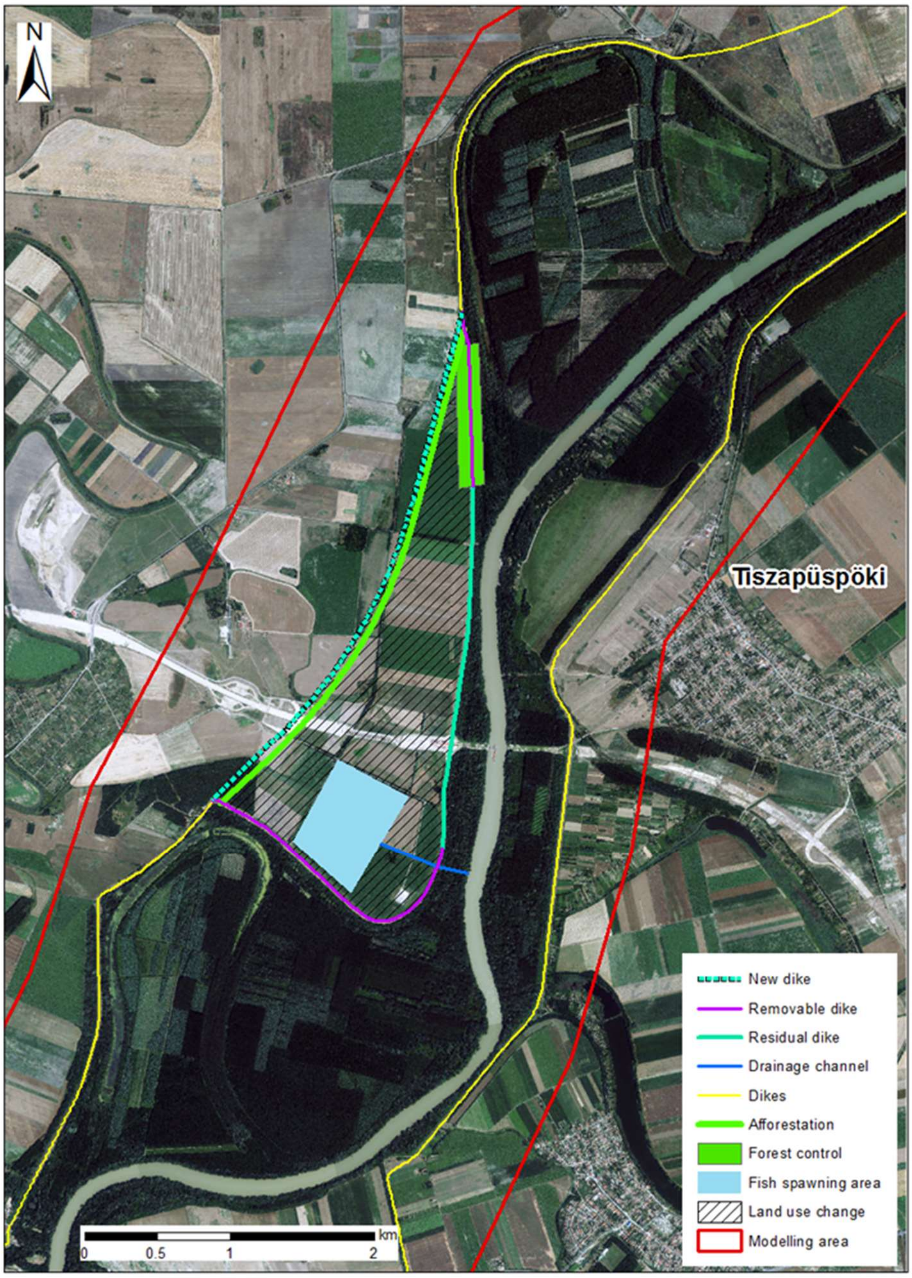


Figure 2 below provides more detail on the project. The shaded area is mainly cropland today. It is being purchased from its private owners and most of it will be turned into meadows, with a strip protective forest and a fish spawning area making up the rest of the purchased land. The fish spawning area will be connected to the river bed through a drainage channel. Part of the original dyke is removed, but the northern section is left in place, while a new dyke is erected west of the river, on its right bank. The total area that is added to the floodplain measures 325 hectares.

Figure 2 Key features of the dyke relocation project



The newly added floodplain is expected to be flooded about 10 percent of the time, although, as Figure 3 shows, there is a substantial interannual variability. We can also observe in Figure 4 that most of the flooding affecting the area takes place during the spring while the area essentially stays dry during the autumn.

Figure 3 Number of days when the newly annexed floodplain would have been flooded in given years

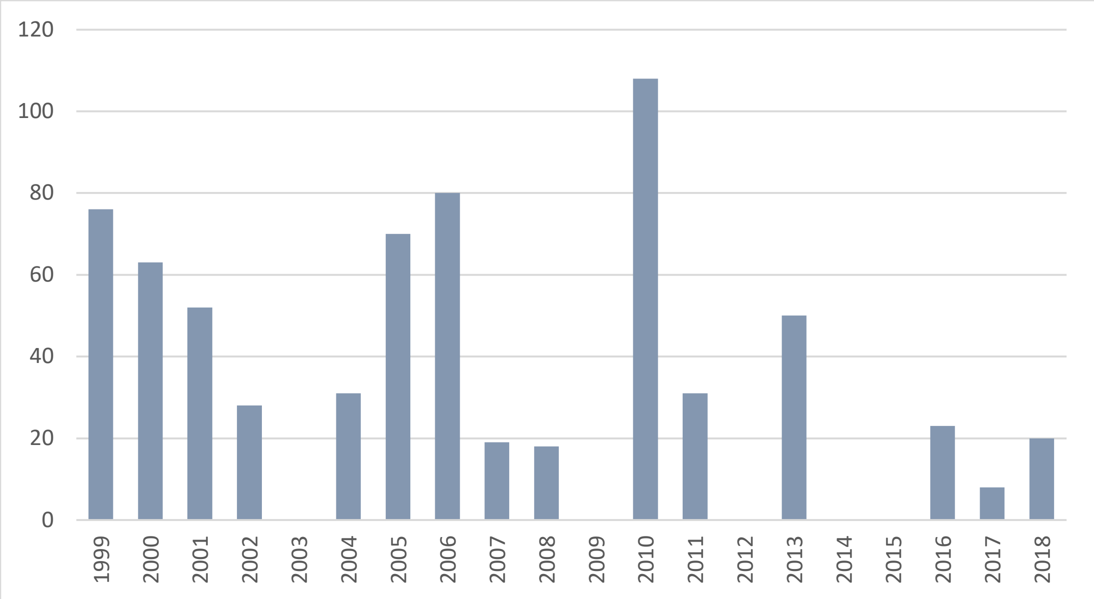
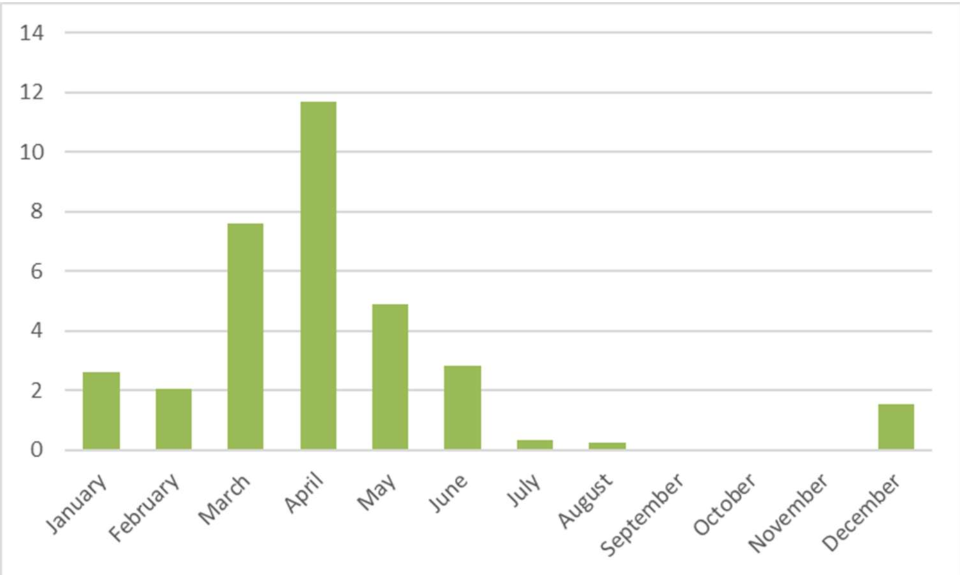


Figure 4 Average number of days in each month when the newly annexed floodplain would have been flooded between 1999 and 2018



3 RESULTS OF THE STAKEHOLDER WORKSHOP ON ECOSYSTEM SERVICES

On 23 January 2019 a stakeholder workshop took place in Szolnok, organised by KÖTIVIZIG, Szeged University and WWF Hungary, to assess the perceived changes resulting from the dyke relocation project. In this chapter we go through the main findings of this meeting and discuss how we handle specific ecosystem services and other land use related consequences within the study (Table 1). We supplemented the stakeholder consultations with a number of expert and stakeholder interviews to fine-tune our understanding of specific aspects of the dyke relocation: Lipták (2019), Katona (2019), Ficzere (2019), Právetz (2019), Horváth (2019), Lovas (2019), Vizi (2019), Járvás (2019), Tarkó (2019).

At the stakeholder workshop the assessment of ecosystem services took place in three groups, identified by colours: blue, green and red. The groups assessed the level of the ecosystem service in the pilot area before and after dyke relocation. A scale of 0 to 5 was applied, 5 indicating a high level of service. If a team could not agree on an actual score, they could still signal the direction of change, indicating it with an arrow. Additional comments are also included in Table 1, and we also indicated how / if we evaluate the given ecosystem service within the analysis.

Mainly based on Table 1, Figure 5 below reviews those ecosystem services that resulted in significant changes caused by the analyzed interventions the impact of which is compared between the scenarios (The significance of the changes were judged by REKK). Ecosystem services the value of which can be monetised, are described and evaluated in subsequent chapters. Ecosystem services that cannot be monetised within the current research due to lack of data, uncertainties or the feature of the service, are inspected in Chapter 11.

Figure 5 Ecosystem services significantly affected by the dyke relocation

Ecosystem service change that is monetised	**Ecosystem service change that is not monetised**
• Flood risk reduction (Chapter 7) • Greenhouse gas sequestration (Chapter 8) • Agricultural crop production (Chapter 9.1) • Fish spawning (Chapter 9.2) • Grass production on meadows (Chapter 9.3)	• Biodiversity • Habitat for various species, more robust fauna and flora • Lower pollution • Timber production • 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

Table 1 Assessment of ecosystem services at the stakeholder workshop and additional observations

		Blue Team		Green Team		Red Team		Comments from the workshop / **Handling of the service within the CBA**
		Before	After	Before	After	Before	After	
Provisioning Services	Agriculture			2	0	2-3	↑	crops not known, cover 80% of the area of the floodway channel on the protected side / **Cropland is turned into meadows and forest, agricultural production will decline. On the other hand, farmers receive a decent price for their land, enabling them to pursue other farming activities. This item is not assessed separately**
	Cereals					5	0	
	meat production			2	↑	?	2-3	Pastures (with livestock) / **There is a possibility for increasing meat production through grazing, but as we learned from KÖTIVIZIG, there is not much demand for the rental of grassland for grazing purposes**
	meadows (greenland)			2	↑	2-3	↑	**/ about 270 hectares of cropland replaced by meadows**
	gardens of weekendhouses, fruit orchards	2	-	2	-	2	↓	
	Vegetables	2	-	2	?	2	↓	
	timber/fire wood production			4	-	2	-	managed by NEFAG?, also for paper mill (wrapping paper), fire wood **/ Timber production from new afforestation has a life cycle of about 60 years, revenues from timber are not relevant in the near future**
	fish production (aquaculture + fishery)			5	↑	4	↑	commercial fishing forbidden, just selective fishing for ecological purposes, aquaculture, fishery **/ No change due to the project, no need to assess it. For angling and sport fishing see further below.**
	hunting			?	↑	3	↑	Game meat, dear meat, roe deer meat. Rabbit meat, pheasant meat **/ As the size of natural area increases, more wild animals are likely to be present. Due to lack of data, the value of this change is not estimated**
	hay, straw			2	?	4-5	0	grazing/pasturing increasing, hay harvesting consistent **/ More hay can be harvested but it is difficult to sell it at a cost-covering price. A rough estimate of costs and benefits is provided**
	Oil well			0	0			unused/not cultivated

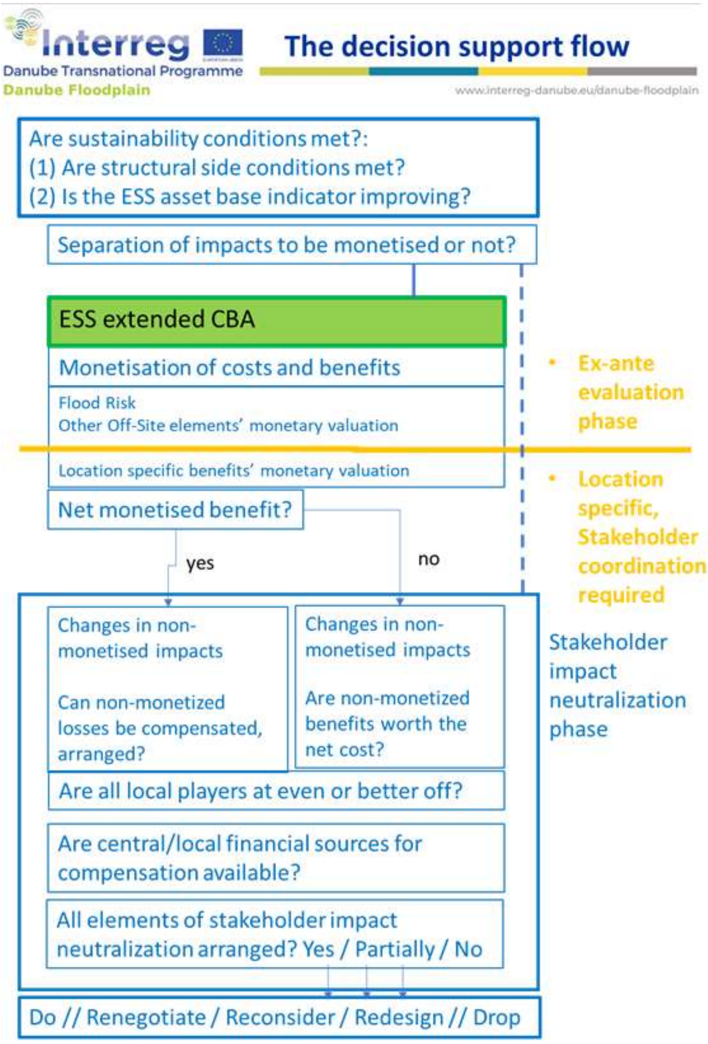
	Drinking water supply				5	-			supply for Szolnok **/ The project will not impact the drinking water supply, therefore this service is not assessed**
	water supply for industry				4	-	4	-	corn processing factory in Tiszapüspöki / **The project will not impact the industrial water supply, therefore this service is not assessed**
Regulating Services	(primal) forest and its regulating functions				3	↑	?	↑?	sinking CO_2, evaporation, regulating microclimate, cleaning the air **/ The shift in carbon balance and its value is estimated. Microclimate regulation is not, due to lack of data.**
	retention volumes				5	↑			draining floods **/ Flood risk change due to altered river morphology is estimated**
	Soil production						1-2	3	**/ Under meadow and forest management there should be an improvement or at least no deterioration**
	Sediment regulation in floodplains						4	-	
	waste water/nutrient retention	Tiszapüspöki	4	-	5	-	2	↑	all washed into the groundwater, biochemical detoxification/decomposition/mineralisation of pollutants in soil/water, biological filtration/sequestration/storage/accumulation of pollutants in soil **/ Due to land use change, less fertilisers will be applied which reduces nutrient transport volumes. The value of this change is not assessed as we do not have adequate information.**
		Dobapuszta			5	-			
		weekendhouses			2	-			
		M4 motorway construction			0	0			
		Fertilizers			2	0			
	provisioning of habitats for juvenile fish / spawning area				4	↑			in the Kovácsi Oxbow, increasing the fish stocks (carp, pike, perch, bream), better conditions on the right side than on the left **/ Due to the to be created fish spawning area, related costs of fish stock replenishment can be saved**
	Provisioning of habitats				4	↑	3	↑	especially fish, birds (nesting and migration), beaver **/ As over 300 hectares of cropland is converted into more natural land use, habitat will sustain an increased fauna and flora. The corresponding value is not analysed due to lack of data and methodological difficulties**
Cultural Services	recreational/sport fishing				5	-	4	↑	angling in oxbow **/ Not only can fish stock replenishment costs be saved, but an increased diversity of fish species will be available for sport fishers. This additional feature is not evaluated within the project.**
	aquatic sports		5	-	4	-	4-5	-	Beach at Tiszapüspöki **/ Unlikely to change due to the dyke relocation**

	recreation					3	↑	**/ More natural areas may entice more people to spend increasing recreational time in nature. However, due to lack of data this feature is not analysed**
	boats			3	-			**/ Unlikely to change due to the dyke relocation**
	cycling			2	↑	2-3	↑	no pavement on the dyke, in case in future -> tourism may grow, big potential **/ This is a future possibility which may or may not be fulfilled, therefore it is not assessed within the current study**
	hiking/jogging			2	↑	2-3	↑	**/ Unlikely to be affected, as the location is too far from the settlements**
	hunting			3	-	3?	↑	**/ As a result of an increasing number of wild animals due to more natural territory, the value associated with hunting may increase. Because of lack of data, we do not assess this service.**
	educational function			3	↑	3	↑	awareness-raising = IS **/ The project offers the option of educational activities. We do not evaluate this service**
	Excursion Ship Victor Hugo			2	-			periodically **/ Not related**
	cultural events			0	0			maybe PET Cup Waste Collection Action **/ Minimal relevance**
	weekendhouses	5	-	2	-	3-4	-	**/ Not allowed in the floodplain and the settlements are further away**
	bird watching			3	?			**/ More natural areas with more birds may entice more people to spend increasing time bird watching here. However, due to lack of data this feature is not analysed, and bird watching is not too widespread in rural Hungary**
	photographing	3	-	3	?	de?	3-4	**/ More natural area lends itself to more people taking photos, however, this feature will have minimal relevance here due to distance from settlements**
	mushrooms					1-2	↑	for private use **/ Possibly more mushroom picking than previously. Not evaluated due to lack of data.**

4 THE DECISION FLOW

The methodology document that was prepared parallel with this case elaboration developed the below the decision flow protocol. It is intended to support the realization of comprehensive, ecosystem service approach extended flood risk mitigation investments. In the subsequent chapters of this document the elements of this decision support analysis are elaborated for the Fokorú puszta dyke relocation case study. Chapter 5 examine the sustainability conditions, the extended CBA analysis cover the chapters from chapter 6 to chapter 9. Chapter 9.4 discuss the status of the non-monetized benefits. Chapter 11 summarizes the findings and calculations in a format that structures for the main stakeholder groups the financial and non-monetized impact of the intervention to prepare the scene for the necessary arrangements and highlight the potential conflicting points with the broad financial terms for reaching resolution. This last two chapters belongs to the phase, what the decision flow name as "Stakeholder impact neutralization". This process can set the scene for the development to step ahead.

Figure 6 The decision flow



5 ARE SUSTAINABILITY CONDITIONS MET?

Sustainability conditions are analyzed from two aspects: "Are structural site conditions met?" and "Is the ESS asset indicator improving?"

5.1 STRUCTURAL SITE CONDITIONS

In case of the structural site conditions the following four aspects are investigated:

- The continuity or connection of natural areas that make animal and plant species migration possible are not destroyed. Or, even better, new connections are developed.

The wider floodplain, the partial removal of the former, existing dyke, and the new spawning area (potential wetland) with no disturbance along the riparian lines are the elements that ensure that the condition is met.

- The size of open water surface area and the length of the shoreline doesn't decrease.

There will be newly created water surface, the river shoreline doesn't decrease. Besides the new spawning area, the relief of the meadow (the new area in the active floodplain) will maintain temporary water covers if the area is inundated during the floods.

- Heterogenity of the area's land use pattern is increased or stays constant.

Crop lands are transformed to meadows, forests and the spawning water body; moreover the use of the former dyke as savior hill for wild animals during flood. This pattern condition is also satisfied.

- The size of non-cultivated (natural) areas doesn't decrease and the area doesn't fragment

The size of the non-cultivated area increases, contiguous grassland area will be created with forest patches.

The changes meet all the requirements of the structural site condition.

5.2 IS THE ECOSYSTEM SERVICE ASSET BASE IMPROVING?

This sustainability condition consists of two aspects. The concept of the indicator is developed and described in the connecting methodology paper. This chapter shows the results and in the annex of the case study the application of the methodology is detailed, the available data sets are described reflecting to the possibilities and limits they provided.

- Compared to the water resource allocation efficiency of the baseline situation, REF(t0) to the change in allocation efficiency, REF(t1) what the floodplain intervention caused will describe the direction of change in the ecosystem service asset base. If the REF(t1) / REF(t0) ratio is higher than 1, there is a positive change in the Ecosystem Service Asset Base, the condition is met. If the ratio is below 1, there would be a decrease in the Ecosystem Service Asset Base, that requires the redesign of the details of the intervention.

The water resource allocation efficiency is the part of the indicator set that describes the cumulative functional ecosystem performance of the investigated area. The indicator reflects on how successfully the vegetation can transform the available water resources (on an annual basis) to transpiration beyond the readily available precipitation volumes.

The two figures below show the changes in the hydrological water balances of the case study area due to the dyke relocation and land use change.

Figure 7 Hydrological water balance of the initial status in the case study area

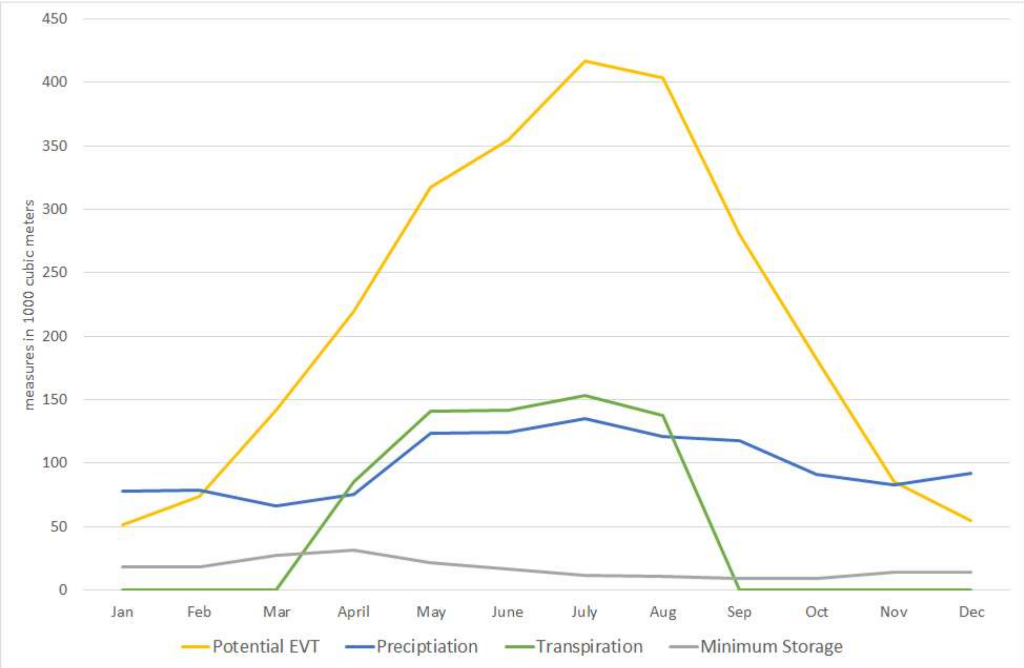
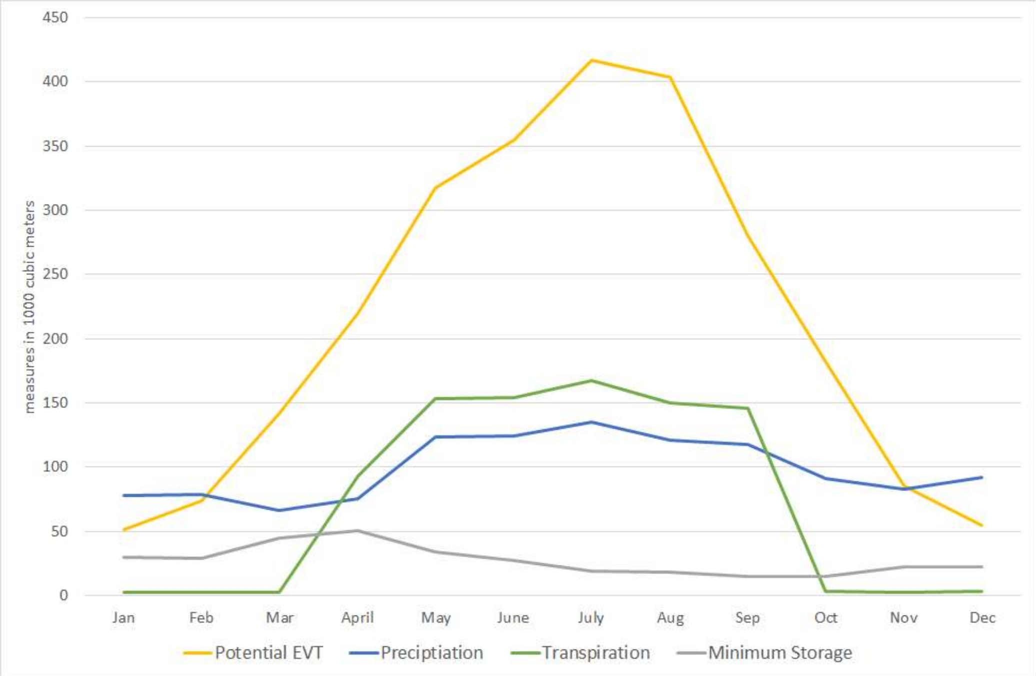


Figure 8 Hydrological water balance after the intervention in the case study area



Each figure represents the allocation efficiency status. The area between transpiration and the precipitation curves when the transpiration value is higher means the successfulness of water storage from the annually available quantity. In these two figures the available quantity is substituted for technical reasons (described in annex 14.1) with a storage quantity that shows a minimum estimation for the infiltration volumes. The difference in the two figures show that due to the interventions the infiltrated quantity and the transpired quantity also increased. In Figure 7 the vegetation period transpiration is 80 thousand m^3, while the minimum estimation for infiltration is 205 thousand m^3, thus the allocation ratio is 39%. In Figure 8 based on 166 thousand m^3 of vegetation period transpiration and a minimum of 329 thousand m^3 infiltration, a 50% ratio is calculated that shows a better status in itself, but for an equal basis comparison the rate of increase in excess transpiration is higher than the rate of increase in infiltration (2.08/1.61=1.28). This reveals a water allocation efficiency increase. The natural foundations of the ecosystem service asset base is considered as improving.

- Is soil loss prevented on the area? In case of natural, constant cover vegetation it obviously is. In case some kind of cultivated area covers (partly) the site, then it depends on the cultivation method, whether that disturbs the soil or not.

The crop land to grassland and forest transformations result in constant soil cover that feature in a flat terrain provide protection against soil loss. The long term land management practices will determine whether soil accumulation can take place. But with the land use transformation at a minimum the soil loss is prevented.

Sustainability from an ecosystem service asset base perspective is met.

6 MONETISED UP-FRONT COSTS

The dyke relocation project requires substantial up-front investments, as detailed by Table 2. Most of the costs are associated with construction activities, especially the demolition and reconstruction of dyke segments, the development of the fish spawning ditch in place of the mine used for the extraction of construction materials, and the reconstruction of a high voltage electricity transmission line. Purchase of land from private owners is also a sizeable expenditure, although not nearly as high as the construction related expenses.

Table 2 Upfront costs related to the dyke relocation

Measure	Upfront costs (million HUF)	Upfront costs EUR* (million)
Dyke construction	2,200	6.76
Demolition of the old dyke	400	1.23
Afforestation of protective forest	70	0.22
Recultivation of mine for construction materials, development of fish spawning ditch	750	2.31
Reconstruction of the high voltage line crossing the river	600	1.84
All other non-itemised initial cost	700	2.20
Acquisition of land from private owners, price paid for 325 hectares of land	540	1.66
Transaction costs related to the acquisition of land (Surveying, legal expertise, appraiser, dedicated manpower within KÖTIVIZIG)	21	0.06
Total	5,281	16.23

Source of information: Kötivizig (2019); * Using the 2019 average HUF/EUR rate (1€=325.30 HUF).

There is an additional cost item that is excluded from the above calculations. In case agricultural land is withdrawn from cultivation, a fee needs to be paid to the government. Part of this fee is returned when, after the investments are concluded, the land is classified as meadow or forest. Still, altogether, about HUF 100 million (=307.000 EUR) of net payment is expected. Since the project owner, KÖTIVIZIG, is a government authority, this transfer takes place within the government, and as such, we do not consider it to be a valid cost item.

7 MONETISED FLOOD RISK REDUCTION

The areas along the Hungarian section of the river Tisza (that belong to the river's morphological floodplain) are protected by dykes. Dykes alone, however, are not always sufficient to ensure protection for these areas. Large floods require additional (just in time, top of the dyke) defense operations, and a catastrophe may also occur in case a dyke fails or its height is not sufficient to hold the water, and the protected areas are flooded. These are the two main types of costs associated with large flood events from a flood defense perspective: 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 or 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, or reconnecting swathes of land of the morphological floodplain to the active floodplain for flow mitigation.

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 Fokorúpuszta dyke relocation project.

The core idea behind our analysis is that the changed river morphology 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 two scenarios: how the flood would move along the river under the original and the new, altered river morphology, when more space is available for the water. These scenarios are hydrologically simulated in HECRAS and the hydrological results are converted to become an input for the economic model. From this perspective any, above mentioned intervention that modifies the features of the flood-wave can be measured (or compared to each other) that how beneficial their impacts are on flood defense from an economic perspective.

Even relatively benign floods (with return periods of 2-5 years) 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[1]. 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 occurring. 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.

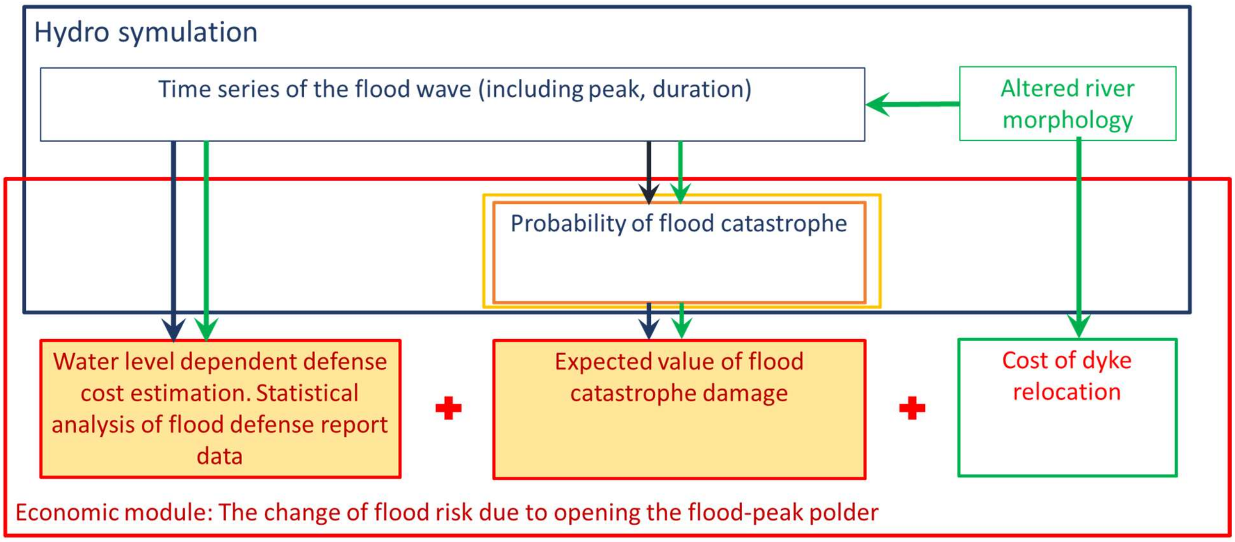
The economic model is a Monte Carlo simulation based probabilistic model. The main reason for applying the Monte Carlo approach in this case is that the dyke rupture and the resulting flood catastrophe is a small probability event, but one that comes with a huge economic loss. Simply looking at the average case – in which no catastrophe 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 connection between the hydrologic simulation and the economic model is depicted by Figure 9 below. The hydrologic simulation (blue rectangle) generates flood time series data for each river section. Using this data the economic model (red rectangle) determines if a dyke failure (=catastrophe) has taken place or not. In case of a catastrophe, the corresponding damage is calculated based on the flooded area and the land use / damage profile of that area. At the same time, the defense costs are also estimated using the flood data and the built-in statistical relationships. This model is run a large number of times, and the results will differ based on the risk of flood catastrophe.

The models need to be run for both the baseline scenario and the altered river morphology reflecting the relocation of the dyke. By comparing the expected total cost of the two scenarios it becomes possible to conclude if the dyke relocation has generated net benefits in terms of lower overall flood related costs.

[1] There are some disagreements between the case study project partners retroactively about the suitability of the risk assessment results of the ÁKK project to serve as a common ground of understanding of further strategy development, because they differently evaluate the appropriateness of the ÁKK project's public participation process and the spatial coverage of the risk maps. Maintaining their disagreement, they acknowledge that the data, the project acquired from the ÁKK database is the best available information and suitable for the purpose of the CBA analysis.

Figure 9 Illustration of the connection between the hydrologic simulation and the economic model



Note: in our analysis we refer to the damages from flooding as a type of cost, and defense operations and dyke relocations are also costs. Thus the expected value of damages are a part of the total 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 (including damage and defense) 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). If we wish to see the impact of the dyke relocation, then we have to repeat this exercise with the flood wave modified due to the new river morphology. This is exactly what we did to see the impact of the Fokorúpuszta dyke relocation on flood related costs. Our results are summarised in Table 3.

Table 3 The impact of the Fokorúpuszta dyke relocation on the annual expected cost of floods

		Cost of flood event, based on the economic model (million HUF)		Annual expected cost of flood event (million HUF)		
Range of return period (year to year)	Probability of flood	Current river regime	After dyke relocation	Current river regime	After dyke relocation	Difference
0-10	0.9000	0	0	0	0	0
10-30	0.0667	2,437	2,442	162	163	0
30-50	0.0133	25,749	23,461	343	313	-31
50-100	0.0100	69,710	62,917	697	629	-68
100 and more	0.0100	91,704	82,707	917	827	-90
All floods together	1.0000			2,120	1,932	-188

Note: Flood risk is frequently interpreted as the annual expected damage. In this analysis costs include more than just the damage, they also include the cost of defense operations, which are executed with the intention of avoidance (expected reduction) of the damage. The annual expected cost (2120 and 1932 million HUF) is therefore the flood risk adjusted with the expected flood defense cost.

For the return period a range has been provided. For example, in case of the 10-30 year return period both a 10-year and a 30-year flood has been simulated, and the average cost of the two floods were used for the analysis.

As the table shows, small floods, with return period of less than 10 years, do not generate costs. In case of floods with a return period between 10 and 30 years, the relocation of the dyke does not meaningfully alter the level of flood related costs. For all larger floods the dyke relocation reduces the cost of the flood. In terms of annual expected costs, the total benefit of dyke relocation is 188 million HUF. Most of this gain originates from the rare, but extreme flood events that happen less frequently than once in 50 years.

8 MONETISED GREENHOUSE GAS EMISSIONS AND REMOVALS

In this chapter we look at changes in greenhouse gas emissions (GHG) and carbon sequestration, as an ecosystem service generated by the project. We assess the GHG impacts of land use change, but disregard the emissions arising from construction activities during the dyke relocation due to the lack of available data on related resource use, such as fuel consumption.

8.1 CASE STUDY LAND USE CHANGE AND ITS ANNUAL GHG BALANCE

Due to the relocation of the dyke, 325 hectares of land is affected. The overwhelming majority of this land was cropland originally, with small fragments of forest, pasture, artificial land cover, or reeds (less than 1% in each category). For the purpose of our analysis we assume that all of the affected land was used for crop production. The new land use will consist of 270 hectares of grass land (meadow), 35 hectares of fish spawning area and 20 hectares of forest.

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. The fish spawning area is essentially a low lying and wet meadow with seasonal water coverage. Therefore we also employ the unit emission figure of the grassland in this case.

Concerning forests, 3141 kt of carbon-dioxide was sequestered in 2016 on 1,940,700 hectares, 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.

As summarised by Table 4, land use change will altogether improve the carbon balance of the pilot area substantially, as net emitting land use (cropland) is terminated, while the land use types that replace it have either a lower emission factor (grassland and fish spawning area) or they remove CO_2 from the air (forest).

Table 4 Net balance of CO_2e emission / removal due to land use change

Land use	Land use change (hectare)	CO_2e emisson / removal (ton/hectare/year)	Total CO_2e emission / removal (ton/year)
Cropland	-325	0.714	-232.1
Grassland	270	0.018	4.9
Forest	20	-1.618	-32.4
Fish spawning area	35	0.018	0.6
Net balance			-258.9

8.2 THE ECONOMIC VALUE OF CO2 EMISSIONS AND REMOVALS

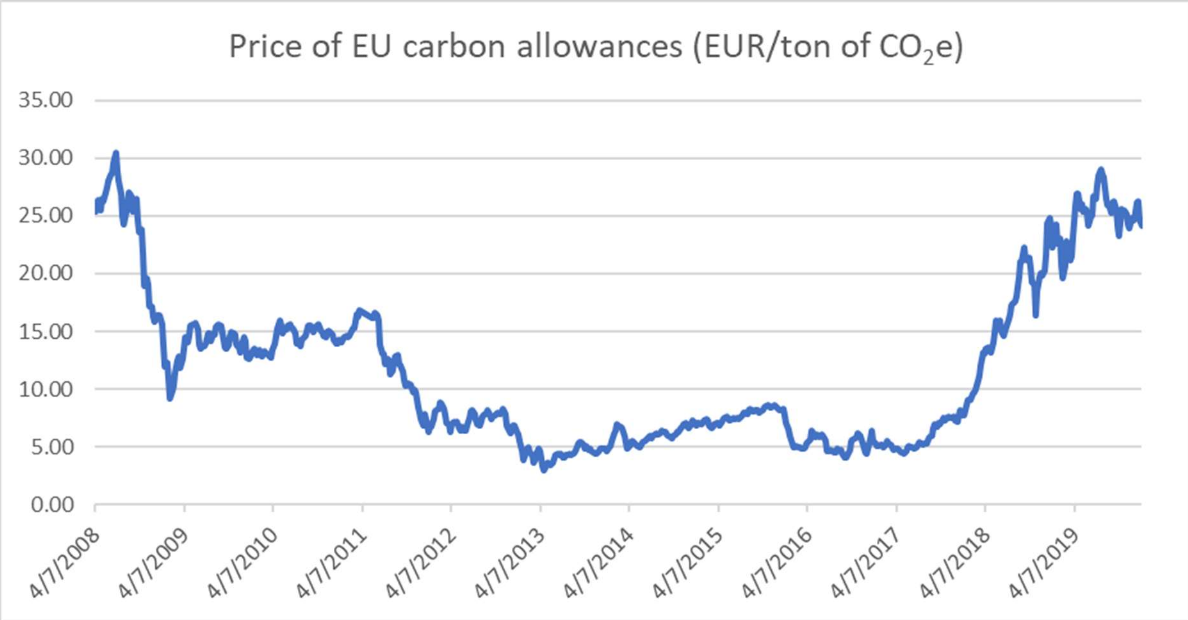
In calculating the economic value of CO2 emissions and removals, we follow the approach developed and applied by the EBRD, as we believe that this is a methodologically sound approach that well approximates the true cost of carbon emissions (and vice versa, the actual benefit of carbon sequestration).

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.

To be able to compare the shadow price and the actual market price of CO2, we should look at the EU ETS market, which is the the most relevant such market in European economies. Figure 10 unambiguously shows that the EU carbon allowance price is below the cost-reflecting shadow price of 40-80 USD/ton (36-72 EUR/ton at the current EUR/USD exchange rate). In addition, there is a large price variation and for years the price stayed below 10 EUR/ton due to overallocation of rights to emitters.

Figure 10 EU carbon allowance price in the EU ETS market



8.3 MONETISED IMPACT OF CHANGES IN LAND USE RELATED GHG EMISSIONS AND SEQUESTRATION

By multiplying the amount of CO_2 removed from the atmosphere and the year specific shadow price of CO_2, we arrive at the annual carbon related benefit of land use change, as depicted in Table 5.

Table 5 Monetised benefit of carbon removal due to land use change

Year	Net CO_2 removal	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	258.9	36.0	72.0	3.1	6.2
2021	258.9	36.9	73.8	3.2	6.3
2022	258.9	37.8	75.6	3.2	6.5
2023	258.9	38.7	77.4	3.3	6.6
2024	258.9	39.6	79.2	3.4	6.8
2025	258.9	40.5	81.0	3.5	6.9
2026	258.9	41.4	82.8	3.5	7.1
2027	258.9	42.3	84.6	3.6	7.2

2028	258.9	43.2	86.4	3.7	7.4
2029	258.9	44.1	88.2	3.8	7.5
2030	258.9	45.0	90.0	3.8	7.7
2031	258.9	46.1	92.3	3.9	7.9
2032	258.9	47.3	94.6	4.0	8.1
2033	258.9	48.5	96.9	4.1	8.3
2034	258.9	49.7	99.3	4.2	8.5
2035	258.9	50.9	101.8	4.4	8.7
2036	258.9	52.2	104.4	4.5	8.9
2037	258.9	53.5	107.0	4.6	9.1
2038	258.9	54.8	109.7	4.7	9.4
2039	258.9	56.2	112.4	4.8	9.6
2040	258.9	57.6	115.2	4.9	9.8
2041	258.9	59.0	118.1	5.0	10.1
2042	258.9	60.5	121.0	5.2	10.3
2043	258.9	62.0	124.1	5.3	10.6
2044	258.9	63.6	127.2	5.4	10.9
2045	258.9	65.2	130.3	5.6	11.1
2046	258.9	66.8	133.6	5.7	11.4
2047	258.9	68.5	136.9	5.9	11.7
2048	258.9	70.2	140.4	6.0	12.0
2049	258.9	71.9	143.9	6.1	12.3
2050	258.9	73.7	147.5	6.3	12.6

9 OTHER MONETISED BENEFITS AND COSTS

9.1 AGRICULTURAL CROP PRODUCTION

The approximately 325 hectares that becomes part of the active floodplain is mostly crop land. It is not a high quality crop production area, it was transformed from pasture to arable plot during the 1980's. The land quality is under the average of 18-20 AK (="aranykorona", or golden crown, the traditional indicator of land quality in Hungary). The average wheat yield here is 3.5-4 tons/hectare which is 60-70% of the national average of the years 2014-2016, FADN, 2018. Without the CAP subsidies the area is barely worth to cultivate. The profitability of the wheat is around break even without the subsidies, while the years when sunflower is cultivated (recently every fifth year, following four years of wheat production), generates extra revenue, but the five year longevity of the cycle is prone to weather and market turmoil that easily consumes this surplus. Due to the land property law most of the production takes place on rented land, that means that the impacts on the owners' position and the cultivators' position are different. The corresponding elements will be represented in the calculation module, here the main aspects of the approach are discussed. Calculations are based on interviews (Járvás, 2019, Tarkó, 2019, Katona, 2019) and the information derived from the Farm Accountancy Data Network.

The retransformation of the cropland to floodplain meadows and the expropriation/purchase of the land area has the following economic impacts:

1) Loss of income / livelihood production for the agricultural users that is compensated in the expropriation price.

> The value of land as a production input reflects the present value of future incomes the property could provide. Based on the 2014-16 years of the FADN (2018) report the post tax result of wheat/sunflower rotation is about 330 €/year (approximately 70% of that annual income is generated by the agricultural subsidy). The expropriation land price includes a 20% premium to enhance cooperation between the farmers and the state, also contributing to lower administration costs and presumably compensating for the inconvenience caused to farmers. The land price (not including the price premium) covers about 35 years of such net revenue, using a 4% discount rate. Concerning the lifespan of the revenue equivalent, one can argue that it covers all connected cost that can emerge from the crop production side.
>
> In Hungary agricultural production is heavily based on rented land. The expropriation or land purchase included an element that targeted the tenants for compensating the burden of adaptation in the business procedures that the termination of the rental agreement brings forth.

2) Decreasing demand for agricultural services of crop production due to the cease of operation on the plots. While from a plot based financial perspective the lack of agricultural production activities is a loss, it should not be categorized as such. The production needs financial resources (in our estimate it is a 50-60 million HUF annual financial requirement) and these resources are not destroyed by the transformation of the plots. Farmers - their firms or their families – will utilise the resources probably in a way to generate further income. Theoretically some temporary decrease of economic activity level can happen because decisions on new activities and transformation needs time, but it is beyond the scope of the analysis to track this phenomenon.

> The cost distribution of wheat production costs (FADN, 2018) shows that 30% of the costs are spent on fertilizers (19%) and pesticides (11%). The discontinuation of using these agro-chemicals is an environmental gain, pollution of ground water as well as surface water is reduced. As a result, notable external costs are avoided, the value of which, however, is methodologically complicated to estimate. The overall effect depends on exactly which activities the freed-up resources will finance.

3) Some overall productivity loss for the farmers will emerge from the shrinking farm size (ceteris paribus). Plots the productivity of which is close to the break even point (no financial gains on it) still have a useful contribution to the overall profitability of the farm as the operation and maintenance of expensive machinery needs scale to spread the costs. By shrinking the overall size of farms, this type of scale economy will be reduced. Moreover, farm level regulation requires set-aside areas to maintain. These are usually the lowest productivity plots within a farm. If such plots are purchased by the state due to the dyke relocation project, the farmers will need to sacrifice other, more productive areas to satisfy the set-aside requirement. These are negative impacts that farmers – as owners and/or renters of cropland - must absorb. At least there is one sizable farm enterprise that has a 1.5%, 6 hectare-cultivation-share in the area, the other plots are much smaller, the described

effect is not traceable. Nevertheless, in the case study this is a non-monetised burden for farmers.

4) The area according to the water directorate staff's experience is prone to waterlogging. However, there is no specific data on how frequently the excess water cover decreased or damaged the agricultural production. This suggests that the estimated value of non-realized agricultural production due to waterlogging events is relatively small, but there is no adequate information to specify its extent. Moreover, there are drainage channels across the area (4 km length). The land use change that the project initiates makes the maintenance of these infrastructure elements unnecessary. The annual maintenance cost (cc 450 thousand HUF) can be saved. However, there is no information whether the farmer community in whose interest the maintenance of the channels was, actually had spent resource for that goal.

Within the new floodplain there is a small track of land (5 hectares) currently registered as pasture, the animal husbandry here is not in contrast with the new land use requirements, mutually suitable arrangements can probably be formed.

9.2 FISH SPAWNING AREA

When the fish spawning area within the enlarged floodplain is flooded, which happens for at least a few days in about 80% of all years, then the fish that gets stranded there lays her eggs and fish reproduces. Later on when the water is released from the pond through a lock and a canal, the fish will migrate to the river and be available for angling. This is process resembles the traditional method of fish spawning, while in modern times the more widespread method is that juvenile fish is purchased from fish pond operators, transported to and released in the river („fish stock replenishment")

Compared to artificial replenishment, spawning-grounds offer some advantages:

- They can preserve and develop the biodiversity of the fish population (and therefore also of the related ecosystem) more effectively
- The cost of this type of reproduction method is notably lower (Bíró et al., 2006)

Newly built and managed spawning-grounds can substitute and/or supplement the yearly replenishment, which is the responsibility of the owner/maintainer of the territory. In the river Tisza, the control of fish-population (including its replenishment) generates significant costs to these organisations, usually angler associations, which could be reduced effectively by the proposed spawning-ground. Next we detail how we monetised the benefits that accrue due to avoided cost of fish stock replenishment.

The success and the productivity rate of a spawning-ground always depends on the characteristics of the territory, but Bíró et al. (2006) estimated that one hectare of spawning-ground ensures the natural population reproduction of ten hectares of river area. This rate is one of the cornerstones of our estimation method. With the use of the mentioned rate we estimate that the proposed spawning-ground with its 35 hectare size can substitute fish replenishment on 350 hectares of river area.

Unfortunately, data about the cost of fish replenishment/hectare/year is not available from the inspected region, however there is such data from one of the tributary rivers of the Tisza, the Körös. "Körösvidéki Horgász Egyesületek Szövetsége" (Association of Körös Region Angler Clubs, the maintainer of the mentioned territory) published its fish replenishment data. In 2019, the association populated 45.4 kg/hectare of carp in its river territories. (Körös Hírcentrum, 2019). A different source provides the net price of carp purchased from fish ponds with the goal of riverine replenishment, HUF 790 +VAT per kg of carp in 2018 (kozep-tisza.hu, 2018). In our calculations we applied the gross price of 1003.3 HUF/kg.

From the collected information and the estimation method, we predict that the proposed spawning-ground can reduce the maintenance cost by 16.0 million HUF/year. Besides this reduction, the organisation also needs to maintainer the constructed spawning-ground. Bíró et al (2006) estimated that the maintenance cost is about 60 thousand HUF/hectare for spawning-grounds. Inflating this figure to current prices using the consumer price index data published by the Central Statistical Office results in 88.4 thousand HUF/hectare, or 3.1 million HUF for all 35 hectares. Thus, the net annual saving ensured by the fish spawning area has been estimated at 12.9 million HUF.

We need to emphasize that the estimated value of cost savings is only applicable in those years, when the water level in the river is high enough to flood the spawn-ground for several days. This was true in the 80 percent of the last 20 years. Thus, in essence, the expected value of annual savings is lower: 16 mFt * 0.8 – 3.1 mFt = 9.7 million HUF/year. We assumed that the maintenance costs take place in all years.

In our estimation due to lack of data we did not calculate the replaced replenishment cost of other fish species besides carp. However we must underline that in spawning-grounds, many other species will also reproduce, generating additional, but non-monetised benefits for anglers as well as for the ecosystem. Thus our estimation on cost savings is rather a conservative valuation.

9.3 GRASS PRODUCTION ON MEADOWS

Once land use change has been completed, 270 hectares of grassland (meadow) will be under the management of KÖTIVIZIG. The meadows need to be maintained in order to ensure low surface roughness for the smooth flow of water in case of flooding. From the perspective of KÖTIVIZIG the easiest solution is rental of the area to agricultural enterprises that would use it for grazing and/or hay production. However, there is limited demand for such areas (Katona, 2019) and often only a symbolic rental fee, such as 1000 HUF/year/hectare can be collected. A specific rental agreement with the Hortobágy National Park has been under discussion, according to which the national park would be able to use the area to graze gray cattle on it, without a rental fee payment. Even despite the lack of revenue this could be an attractive arrangement for KÖTIVIZIG, as the obligation to take care of the meadow and cut the grass would be handed over to the national park. In addition, if shrubs appear in the floodplain, the cost of clearing the area could escalate compared to the cost of cutting grass. A rental agreement with clear clauses for responsibility could help to preclude such costs.

The other alternative is own management of the land and selling any harvested hay in the market. The hay market is not very liquid and the corresponding revenue is modest and not well predictable. The cost of meadow management, on the other hand, can be substantial.

External enterprises are hired at a cost of about 40 – 70 thousand HUF/hectare to harvest the grass, and ideally the grass should be cut twice a year, doubling the cost (Lipták, 2019). If the grass is cut with KÖTIVIZIG's own machine, the direct cost is only about 10 thousand HUF/hectare, but some of the corresponding costs of labour and depreciation is not included. In case KÖTIVIZIG takes care of the meadow, it is eligible to receive EU CAP subsidies, which – together with revenue from hay – substantially improves the economic position of meadow management. Since the dyke relocation project is supported from EU sources, for the first five years after the project has been implemented, KÖTIVIZIG is not allowed to generate revenue on it, also including the receipt of CAP subsidies.

Since there is very limited demand for land rented out to graze or mow because livestock management is hardly profitable, a market-based outsourcing of land management can't be calculated. We assume that KÖTIVIZIG hires an external enterprise or use their own equipment to take care of the meadow and the net annual cost of this task including two harvests and some revenue from selling the grass, is 80 thousand HUF/hectare/year. At the same time, 70 thousand HUF/hectare/year of EU subsidies are collected from year 6. These are the figures that we use within the CBA. In case of changing demand KÖTIVIZIG is able to conclude a rental agreement under which the area is grazed or taken care of in a different way, the annual net cost could drop to zero (and the EU CAP subsidy would be the revenue of the renter, not KÖTIVIZIG)

9.4 FOREST MANAGEMENT

The cost of afforestation - already accounted for under up-front-costs – is estimated at HUF 70 million. Regular maintenance costs of the forest will take place, in the beginning to ensure that weeds and shrubs do not restrict the growth of trees, later on thinning to help the most attractive trees to succeed. At the same time revenues will also be generated, minor revenues from thinning and increasing revenues later on from selective cutting. State support for forest maintenance will also be available. Experience shows that after initial afforestation maintenance costs and revenues from thinning can more or less balance each other if a long enough period is examined.

Concerning timber harvest two options are available: 1) Clear cutting at the end of the forest cycle, which would be 60 years here (Ficzere, 2019) and 2) Continuous selective cutting. Since this is a protective forest the main goal of which the protection of the dyke from the force of flooding, only selective cutting is feasible. This type of forest management, however, will require some timber harvest before the conventional cutting age. In our analysis we assumed an oak forest to grow and the selective cutting starts 30 years from now and will take place every 10 years from there on. As the forest grows, the amount of harvested timber will also increase with each 10 year period, but we assume that the process leaves 10 percent of the area intact with a final stabilized cut of a 90 year old segment every 10 years. Selective cutting ensures that the forest naturally regenerates, therefore no reforestation costs were assumed. The results of our analysis are summed in Table 6 below. During the first 50 years HUF 10.4 million worth of timber is harvested.

Table 6 The volume of timber stock, harvested timber and the value of the timber for all 20 hectares together

Year	Timber stock before harvest (m^3)	Timber harvest (m^3)	Timber stock after harvest (m^3)	Value of timber harvest (HUF)
10	0	0	0	0
20	1,040	0	1,040	0
30	1,540	154	1,386	2,464,000
40	1,944	216	1,728	3,456,000
50	2,344	280	2,064	4,480,000
60	2,666	344	2,322	5,504,000
70	2,886	402	2,484	6,432,000
80	3,034	456	2,578	7,296,000
90	3,114	504	2,610	8,064,000
100	3,144	548	2,596	8,768,000
110	3,128	586	2,542	9,376,000
120	3,080	504	2,576	8,064,000
130	3,108	504	2,604	8,064,000

Notes: The timber stock values are based on timber growth data for oak. 16,000 HUF/m^3 of timber revenue has been used for the calculations.

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10 NON-MONETISED BENEFITS AND COSTS

10.1 BEEKEEPING

More bee families can be released to the additional natural area. From the beekeepers' point of view it is an additional opportunity to let their bees collect pollen.. According to Ficzere (2019) the floodplain extension would make it possible for 2-3 small holder beekeepers to use the place. Monetizing the value of the additional potential however is problematic as beekeepers usually use the dikes as a launch base to let the bees reach specific agricultural fields like rapeseed and less frequently the forests and meadow in the floodplain. Meanwhile there are several licenses issued for beekeepers to place hives along the dike, at the moment it is not a constrained opportunity to ask for an additional permit (issued by the directorate with no fee attached). Therefore beekeeping, from the perspective of the available area, has been an underutilised opportunity recently, therefore the value that can be assigned to this activity as an option value for potential future use is rather uncertain. We do not make attempts to monetise it.

This approach doesn't mean that the area has no value from beekeeping point of view or improving the utilization of this ecosystem service potential of the area wouldn't be advisable. The analysis is focusing on the additional impacts. Based on the findings, the recent economic constraints of beekeeping in the area would be interesting to study.

10.2 HUNTING

As the size of natural area increases, more wild animals will be present. According to Ficzere (2019) water fowl is more likely to thrive than wild mammals. Altogether, the value of hunting may increase, but the extent if this change is difficult to predict.

Due to the land use change the area won't be prone to agricultural damages by wild animals. Based on the data of the National Game Management Database in Jász-Nagykun-Szolnok County the annual compensation payment for the reported damage of wild animals paid by the local game management organisations was 6.2 million HUF (for the entire county; the NUTS 3 level unit), equivalent to 19,000 EUR (5 year average 2014-2018). The proportional value for the case study area cc. 300 hectar is too small to include in the calculation.

10.3 RECREATIONAL, SPORT, HOBBY AND EDUCATIONAL ACTIVITIES

More natural areas may entice more people to spend increasing time in nature pursuing different activities. For jogging and leisure walking the location is too far from the settlements, we do not expect significant change, however, for biking and longer distance hiking it is more accessible. Participants of canoe and kayak tours on the river Tisza may wander into the area to enjoy the natural environment. The new floodplain can 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, such as nature trails and on-site biology and ecology classes, school trips and camps.

10.4 ECOSYSTEM IMPROVEMENT

As approximately 300 hectares of cropland is converted into more natural land use, the habitat will sustain an increased fauna and flora, it is supposed to exhibit increased biodiversity and more resilience to external disturbances.

The new water surface of the fish spawning area will increase the diversity of the habitat types. It will inadvertently serve as a feeding ground for different bird and mammal species. The multiple connected positive impacts of such additional water habitats are proven at other sites along the same river section. A balance in habitat resource management must be set between the bird habitat maintenance interests (maximizing the feedstock for valuable species) and the fish stock management interest (maximizing the volume and selection of the new breed that can be discharged into the river.)

10.5 INCREASING GROUNDWATER RECHARGE

Due to a larger surface area of the floodplain 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.

Even though there were no waterlogging channels on the incorporated area due to the arable type of cultivation, the area theoretically discharged to the otherwise disconnected regional drainage system, but its share by cover is miniscule and doesn't add to the regional waterlogging prevention costs.

11 SUM OF COSTS AND BENEFITS AND THEIR EVALUATION

11.1 NET BENEFITS

We created a spreadsheet tool to assist in the calculation of the balance of all costs and benefits (CBA Tisza pilot.xlsm). All the benefit and cost items described in the previous chapters are entered into this spreadsheet, indicating also the year in which given items occur. Non-monetised benefits are also entered in order to have everything in one structure, and stakeholders who bear the cost or enjoy the benefit also need to be supplied to help the structured discussion of distribution impacts and compensation mechanisms.

Within the tool the present value is calculated for all monetised costs and benefits through the application of a real discount rate (discount rate in excess of the rate of inflation) supplied by the user. For this exercise we used a 2% discount rate, and made sensitivity analysis with 1% and 3% values as well. Additional sensitivity analysis is in Chapter 11.2.

The detailed results of the analysis using 2% real discount rate and a 50 year time horizon (discounting all costs and benefits that register during the next 50 years) are in Table 7. There is a net monetised overall benefit of about HUF 1.16 billion. In case of a 1% real discount rate net benefits would increase to HUF 2.71 billion, while a 3% discount rate would reduce them to HUF 0.02 billion, still a positive result. Obviously, results are highly sensitive to the level of the real discount rate. A low interest rate will result in a higher present value for costs and benefits farther in the future, and since most of the costs are up-front investment type costs while most benefits take place in the future, lower interest rates will improve the cost benefit balance substantially.

A number of non-monetised items could further modify these results, but it is unlikely that they would represent such a high level of cost that would turn the current positive expectations around, especially since non-monetised benefits substantially outnumber non-monetised costs.

The main cost type is the up-front investment cost (altogether HUF 5.3 billion) paid by the state[2], while the main benefit is reduced flood risk (HUF 6 billion) enjoyed by and spread through society. From a different perspective this is also a state benefit, since it reduces other types of flood defense costs of the state. From the perspective of the state, the relocation of the dyke is a good investment, already justified by flood risk reduction alone.

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[2] By state cost we mean the central budget and KÖTIVIZIG together

Looking at other stakeholders, society (in its numerous manifestations) will reap a wide variety of benefits, only part of which was possible to monetise, to some extent balanced by one type of cost, due to ending crop production. We can safely assume that for society as a whole, the project is advantageous.

Part of the local population can benefit from enhanced opportunities for hunting, beekeeping, fishing and other activities, all in all, the changes are positive for them.

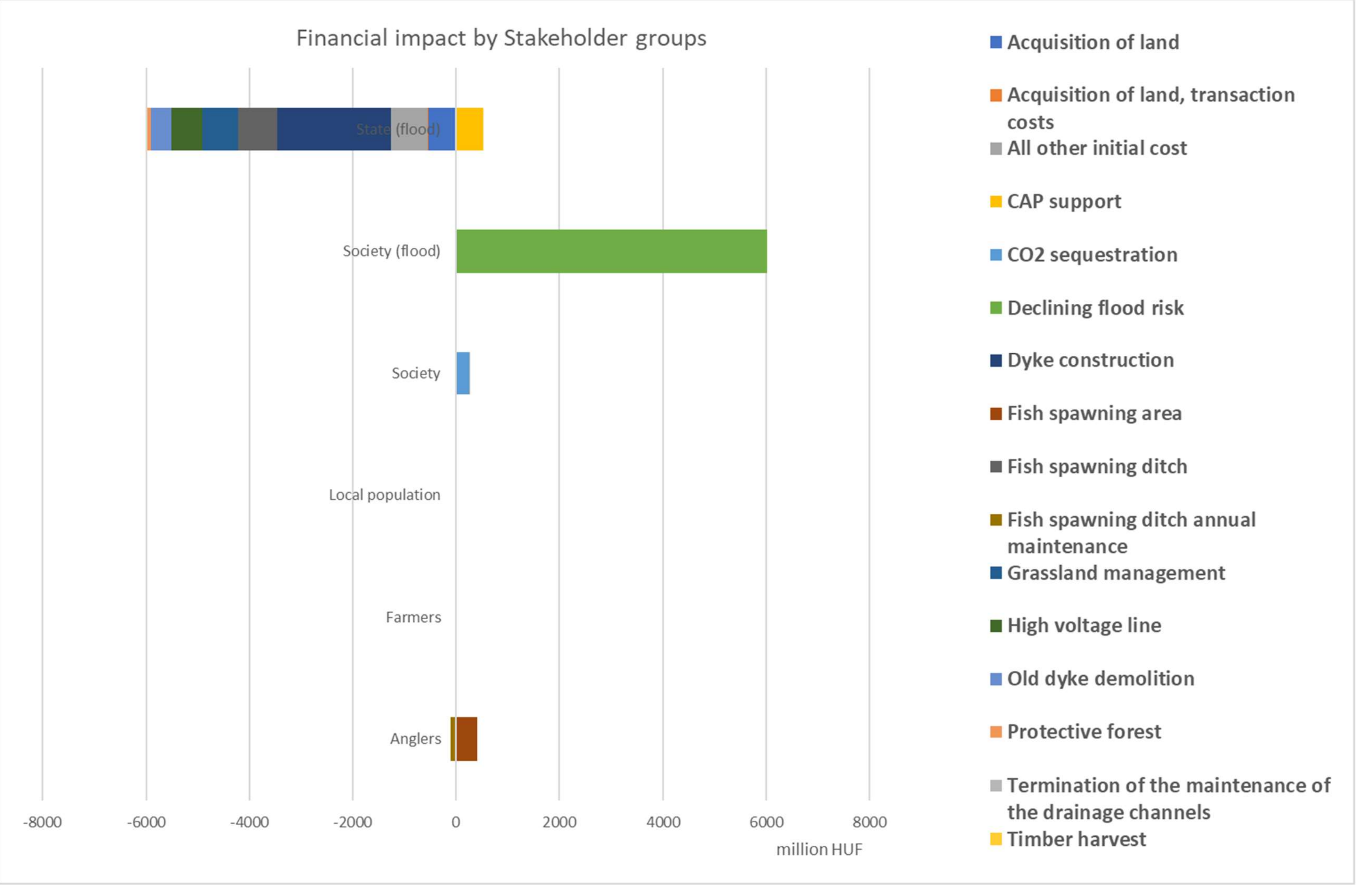
Anglers, through their associations, – if in charge of taking care of the spawning grounds – will face a new annual expenditure, but in exchange they can substantially reduce their fish stock replenishment expenditures, overall enjoying a sizeable financial benefit.

Table 7 Costs and benefits of dyke relocation, 2% real discount rate

Stakeholder	Costs / Benefits	Name	Description	Present value (million HUF)
State (flood)	Costs	Dyke construction	All the design, construction etc.	-2,200
State (flood)	Costs	Old dyke demolition		-400
State (flood)	Costs	Protective forest	Cost of afforestation.	-70
State (flood)	Costs	Fish spawning ditch	Recultivation of mine for construction materials, development of fish spawning ditch	-750
State (flood)	Costs	High voltage line	Reconstruction of high voltage line	-600
State (flood)	Costs	All other initial cost		-700
State (flood)	Costs	Acquisition of land	Price paid for acquired land	-540
State (flood)	Costs	Acquisition of land, transaction costs	Surveying, legal expertise, appraiser, dedicated manpower within KÖTIVIZIG	-21
State (flood)	Costs	Grassland management	Maintaining, cutting the grass	-692
State (flood)	Benefits	CAP support	CAP support to manage the meadow	515
State (flood)	Benefits	Timber harvest	Selective cutting from the protective forest	5
State (flood)	**Net monetised benefit (+) or cost (-)**			**-5,453**
Society (flood)	Benefits	Declining flood risk	Due to change in river morphology, there is a lower flood risk	6,026
Society (flood)	**Net monetised benefit (+) or cost (-)**			**6,026**
Society	Benefits	CO2 sequestration	Average value of captured CO2 for the first 10 years	47
Society	Benefits	CO2 sequestration	Average value of captured CO2 for years 11-30	101
Society	Benefits	CO2 sequestration	Average value of captured CO2 for years 31-50	111
Society	Benefits	Recreational, sport, hobby and educational activities	Hiking, running, photography, bird watching, education	Non-monetised
Society	Benefits	Ecosystem improvement	Enlarged habitats, enhanced biodiversity, more resilient ecosystem	Non-monetised

Society	Benefits	Lower use of agrochemicals	Reduced pollution of water bodies	Non-monetised
Society	Benefits	Increased ground water recharge	Due to a larger surface area of the floodplain	Non-monetised
Society	Benefits	Termination of the maintenance of the drainage channels	The area will not have to be drained due to the land use change	15
Society	**Net monetised benefit (+) or cost (-)**			**274**
Local population	Benefits	Bee keepers	Potential for more bee families	Non-monetised
Local population	Benefits	Hunters	More water fowl and potentially more game animals	Non-monetised
Local population	**Net monetised benefit (+) or cost (-)**			**0**
Farmers	Costs	Productivity loss	Productivity loss due to lower economies of scale and less opportunity for vertical integration	Non-monetised
Farmers	**Net monetised benefit (+) or cost (-)**			**0**
Anglers	Costs	Fish spawning ditch annual maintenance	Maintenance	-99
Anglers	Benefits	Fish spawning area	Reduced cost of fish stock replenishment in the river	410
Anglers	**Net monetised benefit (+) or cost (-)**			**311**
All stakeholders together	***Net monetised benefit (+) or cost (-)***			***1,157***

Figure 11 Financial impact by stakeholder groups



11.2 SENSITIVITY ANALYSIS OF NET BENEFITS

Our standard cost benefit analysis that Chapter 11.1 presented used a 50 year time horizon and a 2% real discount rate. With these parameters the net result of the calculation is 1,157 million HUF. We applied this combination because in case of public investments on long life-cycle infrastructure the 1%-3% interval of discount values could be considered as an acceptable range (Drupp et. al. 2015). In this range of discount rates the time horizon becomes crucial, if it is too long, it implies an unjustified bet on unchanging circumstances, while setting it too short keeps important segments of the impacts out of the analysis. Dyke developments are a long term public investment, it is safe to assume that at least a 50 year period of operation should be expected. As the results of the below table show, this timescale is sufficient to generate enough benefits that the project is worth executing.

To better understand the sensitivity of net benefits to both the time horizon and the discount rate, we inspected different combinations of time horizon (30 to 100 years, with 10 year intervals) and discount rate (0% to 10% with 1% intervals). The results are summarised in Table 8.

Table 8 Net benefits of dyke relocation under various combinations of real discount rate and time horizon (million HUF)

	Length of analysis (years)							
Discount rate	30	40	50	60	70	80	90	100
0%	699	2,774	4,849	6,926	9,003	11,082	13,161	15,241
1%	-100	1,373	2,706	3,914	5,008	5,998	6,895	7,708
2%	-753	296	1,157	1,864	2,444	2,920	3,311	3,631
3%	-1,291	-540	19	435	745	975	1,147	1,275
4%	-1,737	-1,197	-833	-586	-420	-307	-231	-180
5%	-2,109	-1,720	-1,481	-1,334	-1,244	-1,189	-1,155	-1,134
6%	-2,422	-2,140	-1,983	-1,895	-1,846	-1,818	-1,803	-1,794
7%	-2,686	-2,482	-2,378	-2,325	-2,298	-2,284	-2,277	-2,273
8%	-2,912	-2,762	-2,693	-2,661	-2,646	-2,639	-2,636	-2,635
9%	-3,105	-2,995	-2,949	-2,930	-2,921	-2,918	-2,916	-2,916
10%	-3,271	-3,191	-3,160	-3,148	-3,143	-3,141	-3,141	-3,141

As shown, in the 1%-3% discount rate range the project turns to net financial positive result if at least 40-50 years of operation was assumed. A real discount rate of 4% or higher would make the project a loss making one on any of the inspected time horizons, but these discount rate – time horizon combinations shouldn't be considered relevant for the evaluation of this project. The consideration of shorter than 40-50 years as a time horizon in case of flood risk mitigation investment doesn't comply with the public expectation of how long time the impacts pf such an investment should last. The utilization of 4% or higher discount rate in case of a long time horizon public investment project, doesn't comply with the public considerations regarding the weight with which the impacts on stakeholders in the future must be taken into account. The higher the interest rate the less importance is given to impacts in the future. Above the 3% discount rate there is a significant decrease in the weight of future impacts. For an illustration of how the time horizon and the discount rate together impact the present value of a given sum, please visit Annex 14.2.

12 CONCLUSIONS

The results of the complex, extended CBA based analysis of the Fokorú puszta dyke relocation project show that implementing the intervention would be a beneficial public investment both from financial and natural point of view. Based on the analysis one can assume that no stakeholder group would be left behind in terms of bearing the cost of others' benefit without having compensation.

While the biggest share from the benefits is associated with flood risk reduction, the calculations show that the proper, ecosystem service benefit oriented management of the transformed territory also has a key role to ensure the positive balance of the investment. From this point of view the proper management agreements with the angler associations about the operation of fish spawning area for rejuvenating and supplementing the native fish population has high importance.

Although CO2 sequestration represent a smaller benefit element it is worth noting that this benefit comes from a relatively small area (20 hectares), that is only 6% of the transformed territory. Because it is a forest patch with defense function that protect the dyke, our calculation expected a constant forest cover management approach. Our results also illustrate that constant cover forests can be considered as a viable land use alternative for publicly acquired land for flood protection.

It is also worth acknowledging that these "fringe" benefits are responsible for 50% of the positive balance of the investment. Especially the creation of forests with carbon storage purpose in mind is a financial surplus generating efficient additional service implementation, if land is already available for public reconsideration of use optimalization.

Like in the case of the above mentioned additional ecosystem service provisions, it can be decisive to reach agreement on the terms of a development, but it requires site specific information and stakeholder bargains to reach in order to include them in a real ex-ante decision support calculation in a credible way, otherwise it represents only a theoretical potential and not a realised benefit.

The applied methodology helped to structure the intervention as a bundle of development elements whose economic and natural benefits exceeded costs. Importantly, the analysis also shows that evaluating the cost and benefit components separately will highlight items where additional considerations, issues can be raised for further improving the balance. The excel based support tool had a good helping hand in that element.

Economic analysis with a positive balance is only a part of the necessary approval of a flood risk mitigation intervention. That is the reason why the methodology we tried to follow and test at the same time, introduced a decision flow approach with a (1) sustainability check, (2) extended CBA and (3) stakeholder negative-impact neutralization. So far aspect (2) and (3) were assessed. The sustainability check of the intervention takes two steps, from one part showed that the decisive conditions of the environmental quality that dispatch through the land use patterns of the area don't deteriorate due to the intervention (actually improves).

The criteria/condition list itself were judged appropriate and practically useable for the purpose by both partners who collaborated with Rekk in the case study elaboration (Kötivizig, WWF). The second step monitors the change of the functional capacity of the area, how it provides ecosystem services. Did the asset (on which the actual bundle of ecosystem services are based on) change? In the methodology we laid down a theoretical framework that connected this measurement of ecosystem service asset base to the inter-seasonal water budget allocation efficiency of the analyzed territory. Based on the available data we can state that the intervention improved this capacity of the area. Meanwhile we couldn't prepare the dataset what we consider the suitable one for such a judgement. This element needs further development in simulation capacity to improve the integrated use of discharge, infiltration and transpiration models whose resolution can cope with the land use changes considered along the analyzed intervention.

By our opinion the case study demonstrated the applicability of the methodology. The ecosystem asset base change indicator for the decision flow as a whole needs further elaboration in the future in order to be able to handle the full spectrum of the risks an intervention poses on the aspects of sustainability of the impacted territory, but even without it the methodology provides a sufficiently high level of certainty on evaluating complex, nature related flood risk mitigation interventions.

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14 ANNEXES

14.1 SUSTAINABILITY CALCULATIONS

The sustainability calculation focuses on an area close to Szolnok city that surrounds the river Tisza. This studied area spreads over 4100 hectares and divided into 52 separate regions based on their CORINE coverage characteristics. Information about the area in focus has been stored in vector spatial data provided by KÖTIVIZIG (2019).

Furthermore, spatial information about those area affected by the dyke relocation and by changing land use has been provided, KÖTIVIZIG (2019). Based on these data we could found – as it has been discussed earlier – that two regions were added to the analyzed floodplain that have been used as cropland before the relocation. These regions, with an area of 125,9 and 133,6 hectares each, are then divided into further sub-regions due to changing land-use type. As a result, 32,6 hectares of cropland are to be transferred to woodlands area and an additional 10,6 hectares fish spawning area is to be developed.

The two analyzed scenarios are based on these changes: the baseline and the alternative scenario with changes both from dyke relocation and changing land use are analyzed.

The process of the sustainability calculations is introduced in the following sub-chapters.

14.1.1 CALCULATING THE MONTHLY AVERAGE POTENTIAL EVAPOTRANSPIRATION

The regional potential evapotranspiration calculations are based on national monthly data by Vitkuki (2008). The monthly data – provided in millimeters measure – is applied for each analyzed region. Furthermore, the size of each studied region is calculated by using the area measure tool in QGIS software. Therefore, the total monthly average potential evapotranspiration (TMAPE) for the entire studied area is provided as the sum of the monthly average potential evapotranspiration of each region ($MAPE_r$), that is the product of the unit national monthly average potential evapotranspiration (NMAPE) and the size of the region ($AREA_r$). The monthly average potential evapotranspiration is measured cubic meters and can be formulated as:

$$TMAPE = \sum_{r=1}^{R} (MAPE_r) = \sum_{r=1}^{R} (NMAPE)\,(AREA_r)$$

where r denotes each specific region and R is the number of regions within the studied area.

14.1.2 CALCULATING THE MONTHLY AVERAGE PRECIPITATION

The monthly average precipitation is calculated based on monthly average precipitation spatial data by KÖTIVIZIG (2019). The monthly average spatial data are provided in raster layer format.

Using QGIS software, the monthly average precipitation is calculated for each studied region by the following steps:

1) The raster layers are converted into vector layers using the „polygonize (raster to vector)" tool.
2) The vector layer containing information about the studied regions is then intersected by the previously converted monthly average precipitation vector layers in order to calculate the size of the sub-regions with a given precipitation value for each region.
3) Finally, the area-size weighted average precipitation for each region is estimated.

The total monthly average precipitation (TMAP) for the entire studied area is given as the sum of the monthly average precipitation of all regions (MAP_r).

$$TMAP = \sum_{r=1}^{R} (MAP_r)$$

where r denotes each specific region and R is the number of regions within the studied area. The monthly average precipitation is measured in cubic meters.

The same method is applied in the case of the alternative scenario as the monthly average precipitation is recalculated for those affected areas by changing land use.

14.1.3 CALCULATING THE MONTHLY AVERAGE TRANSPIRATION

The monthly average transpiration is calculated as the product of the monthly average precipitation and the land-use based transpiration value. The former data is calculated as described in the previous sub-chapter, using the monthly average spatial data. The transpiration values for cropland, woodland and grassland are provided by Móricz, 2011. These measures have been distinguished between periods of high and low evapotranspiration seasons for each land use. The transpiration value indicates the transpiration from both precipitation and infiltration and measured as a percentage of precipitation.

The transpiration values can be assigned for each studies region based on their CORINE characteristics. Thus, the monthly average transpiration (MAT_r) for a region is calculated as the product of its transpiration value (TV_r) and the monthly average precipitation (MAP_r), while the total monthly average transpiration (TMAT) is the sum of the monthly average transpiration of all regions.

$$TMAT = \sum_{r=1}^{R} (MAT_r) = \sum_{r=1}^{R} (TV_r)\,(MAP_r)$$

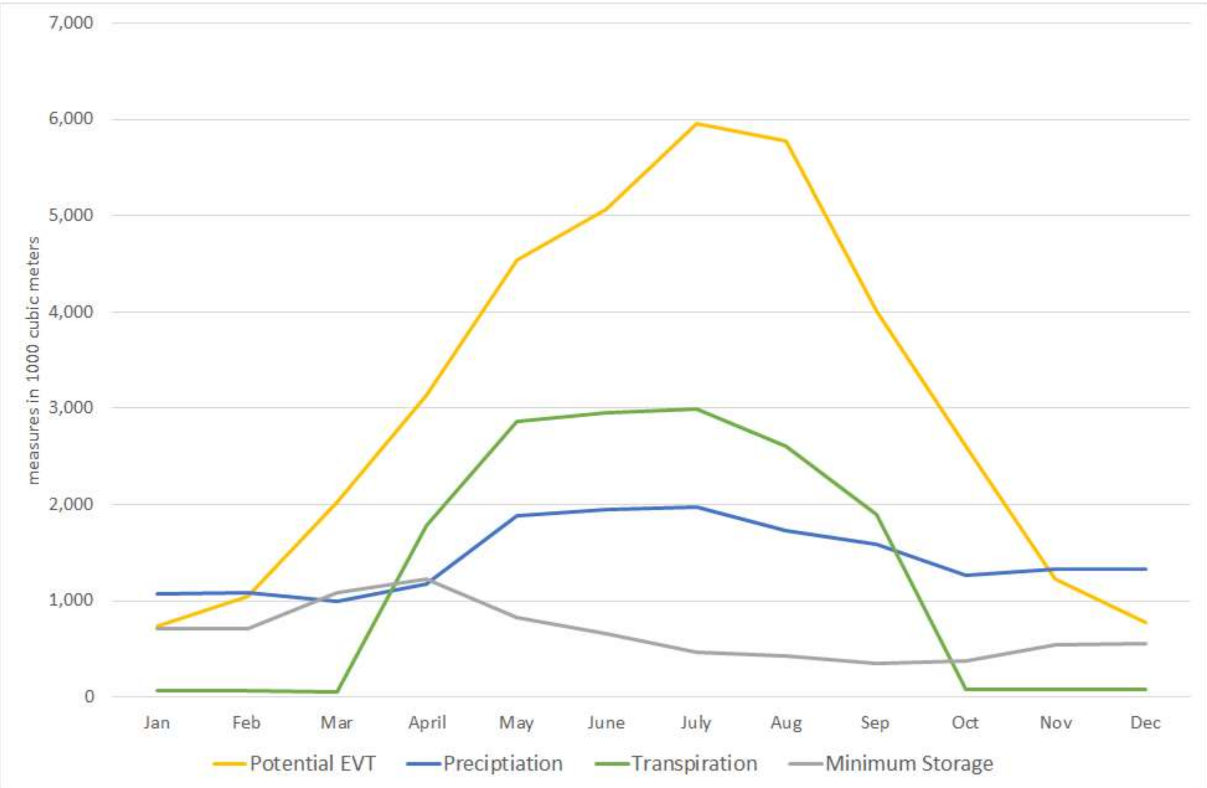
where r denotes each specific region and R is the number of regions within the studied area.

14.1.4 DEVELOPING INFORMATION FOR CALCULATING THE WATER RESOURCE ALLOCATING EFFICIENCY

The available data extorted some compromise on how the water resource allocation efficiency can be calculated that need further considerations to develop. One of the more important issues is the definition of the initial resource of water that originates from the surface flows and will add to the water supply of transformed floodplain. It is important to obtain to have an equal basis of water use comparison across scenarios. The current calculation this supply side information was replaced with the infiltration quantity as additional source of water with precipitation. The other issue was that calculating the indicator along the lines the methodology laid down a vegetation and water supply sensible data set would have been needed for calculating infiltration. Our effort with the available data sources didn't provide consistent results therefore coefficients based on Móricz, 2011 very detailed measurements on riparian forest and fallow were used. To solve this problem, for the calculations, a minimum estimation was created for the temporarily stored water quantity based on the Móricz (2011) site measurements that provided the share of transpiration from the groundwater budget and the overall change of the groundwater budget itself driven by the flow regime of the river. , .

The below figure shows the elements that were formulated for the calculation that reflects the hydrologic water balance of the extended case study territory from which the Fokorú puszta focus area was cut.

Figure 12 Hydrologic water balance of the simulation area



14.2 THE ROLE OF TIME HORIZON AND DISCOUNT RATE IN DISCOUNTING

To illustrate this issue of time preferences and choosing the discount rate, in **Hiba! A hivatkozási forrás nem található.** the power of discounting is represented. The table shows how much an original 100% value is considered in the net present value of a future cost or benefit using various discount rates on given time frames. The higher the interest rate and the longer the period, the less the discounted value. For example a cost or benefit value that will be expected to happen after 40 years will be considered only as 67%, 45%, 31% of the nominal value in the present value. It shows its declining weight in the calculation (and the decision support) with the increase of the discount rate. A discount rate in excess of 4% and a time horizon in excess of 50 years will reduce at least 95% of the future value. We think that these values are therefore not really appropriate for decision supporting analysis in a case where public investments are considered.

Table 9 Illustration: the results of discounting under various time frames and discount rates

	Length of analysis (years)							
Discount rate	30	40	50	60	70	80	90	100
0%	100%	100%	100%	100%	100%	100%	100%	100%
1%	74%	67%	61%	55%	50%	45%	41%	37%
2%	55%	45%	37%	30%	25%	21%	17%	14%
3%	41%	31%	23%	17%	13%	9%	7%	5%
4%	31%	21%	14%	10%	6%	4%	3%	2%
5%	23%	14%	9%	5%	3%	2%	1%	1%
6%	17%	10%	5%	3%	2%	1%	1%	0%
7%	13%	7%	3%	2%	1%	0%	0%	0%
8%	10%	5%	2%	1%	0%	0%	0%	0%
9%	8%	3%	1%	1%	0%	0%	0%	0%
10%	6%	2%	1%	0%	0%	0%	0%	0%