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ECONOMIC BENEFITS OF EBA MEASURES TO ASSURE WATER SECURITY CASE STUDY: EBA SEDIMENT TRAP VERSUS DREDGING

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ABSTRACT. Ecosystem based adaptation (EbA) has emerged as a key instrument widely applicable to help people to adapt to the adverse effects of climate change. EbA, similar to green infrastructure, uses services that river ecosystems are already providing, addressing the crucial link between sustainable resource management for the benefit of human populations and biodiversity conservation. EbA relevant case studies and literature address a broad range of water security topics, however, they lack knowledge on technical-economic comparison between EbA and alternative measures. This presentation sheds light on the major threat of water scarcity in the Huai Sai Bat River Basin in Khon Kaen, Thailand, comparing Sediment Pool Installation (EbA measure) with Dredging (Engineering measure), both designed to counteract this major threat by increasing water storage capacity. The comparative analysis, based on current land use in the catchment, demonstrates that the EbA measure has an economic benefit over the engineering measure from the first year onwards, increasing over the years. The overall costs for water storage can be reduced by up to 65% by applying the EbA measure. In addition, the presentation also addresses the subject of integrating land use management and water management.

Keywords: *Ecosystem-based Adaptation; Cost Effectiveness; Economic Evaluation; Integrated Water Management*

Introduction

Ecosystem-based adaptation (EBA) is defined by the Convention on Biological Diversity (CBD) as an increase in the population's adaptation capacities through the sustainable use and protection of ecosystem.

Non-sustainable land use (deforestation, overgrazing, pollutant input, etc.), lack of land planning (e.g. uncontrolled settlement and encroachment of floodplains, or the drying out of wetlands for golf courses) and water resources lead to many ecosystems already being damaged, restricting their services. Providing, regulating and purifying functions of ecosystems are crucial to protect the population from the effects of extreme events such as floods and droughts, which, as a result of negative consequences of climate change, will occur more frequently.

Advantages of ecosystem-based adaptation measures in flood and drought prevention in comparison to traditional grey measures are usually lower costs and lower maintenance requirements. They can be implemented with locally available materials. Positive side effects are the protection of biodiversity. Although these functions require intact ecosystems, ecosystem-based adaptation does not concentrate on protecting the environment, but to use ecosystem functions as a service to increase the adaptation capacity of population to a changing climate.

When sensitive ecosystems, such as mangrove forests, mountain forests and swamps are protected, both, their resilience against weather extremes, as well as the resilience of the local population can be strengthened, sustaining living conditions and economic development possibilities.

Within ecosystems, the water cycle is connected with other system components such as soils and vegetation and is influenced by these in its functions. Both the quantity available and the quality of the water resources are determined by ecosystem services.

In addition, ecosystems as a habitat, the landscape and the spiritual / religious significance of natural phenomena have an important cultural function. Functioning ecosystems are not only threatened by climate change, but also present a significant unused potential for adaptation through their functions. This innovative approach is increasingly seen as an effective strategy to promote adaptation to climate change.

Case Study in Huai Sai Bat River Basin, Thailand

Huai Sai Bat River Basin, Thailand

The Huai Sai Bat River Basin comprises approximately 678 km^2. The highest point upstream has an elevation of about 550 masl. The elevation drops to about 150 masl within a distance of about 60km. Only the headwaters area is covered with forest, where the watercourses stretch over 10km with steep slopes generating high energy potential of water. The precipitation sums up to 1000mm/yr inducing an average discharge of 200mm/yr. Approximately 65000 people live in the river basin which results in 95 inhabitants per km2.

A prominent feature of the Huai Sai Bat river basin are the structures for water management including two reservoirs, weirs along Huai Sai Bat, some tributaries and countless small ponds scattered throughout the river basin and mainly used for livestock and irrigation.

Nong Yai Reservoir in the north is an important water resource for the local population and the agricultural sector. Sedimentation is a prominent issue in this area and leads to a considerable decrease of water storage volume as well as costs for extracting the sediment out of reservoirs. Furthermore the sediment is contaminated by agricultural runoff, which leads to further costs for purifying. . The picture below shows the Nong Yai Reservoir (blue error) right in the middle of intense agricultural land use.

Figure 1 (above): Nong Yai Reservoir after rainy season, Figure 2 (below): Nong Yai Reservoir before rainy season; Source (Lohr, 2016)

The catchment area of the Nong Yai Reservoir comprises 66 km², the surface of the Nong Yai Reservoir is about 600.000 m2, its average depth is about 5m, which corresponds with a water storage volume of 3 Mio m3. The reservoir is surrounded by agricultural land. The water is used for irrigating about 4.700 rai (=752 ha).

Nong Yai Reservoir in Huai Sai Bat River Basin: EbA Measure sediment trap versus business as usual dredging

Currently, sediment is reducing the storage by 1.25% from its original capacity or minimum 38.000 m3 yearly. (Lohr, 2016) (G. Meier, 2015) The business as usual scenario is dredging every 20 years, which means that the storage capacity is reduced by 1.25% every year over a time span of 20 years. The yearly loss of water storage leads to a reduced irrigation area of about 60 rai or 9.4 ha per year. Not having enough water reduces the yield of the farmers and therewith their income. Reducing the storage capacity by 38.000m3 every year means that 9.4 ha each year are lost for irrigation. Consequently, the yield will be lower in this area. What is the economic effect of the reduced water storage capacity?

For calculating the losses the team used rice as an example and based the calculation on the following prices and yields:

Table1: Source: FAO data Thailand 2014

Rice farmer				
Yield per ha	3.01	t/ha	481.6	kg/rai
Producer Price per ton	8,280	THB/t	240	US$/t
Total Irrigated Area	4,700	rai	752	ha
Area affected	58.75	rai	9.4	ha

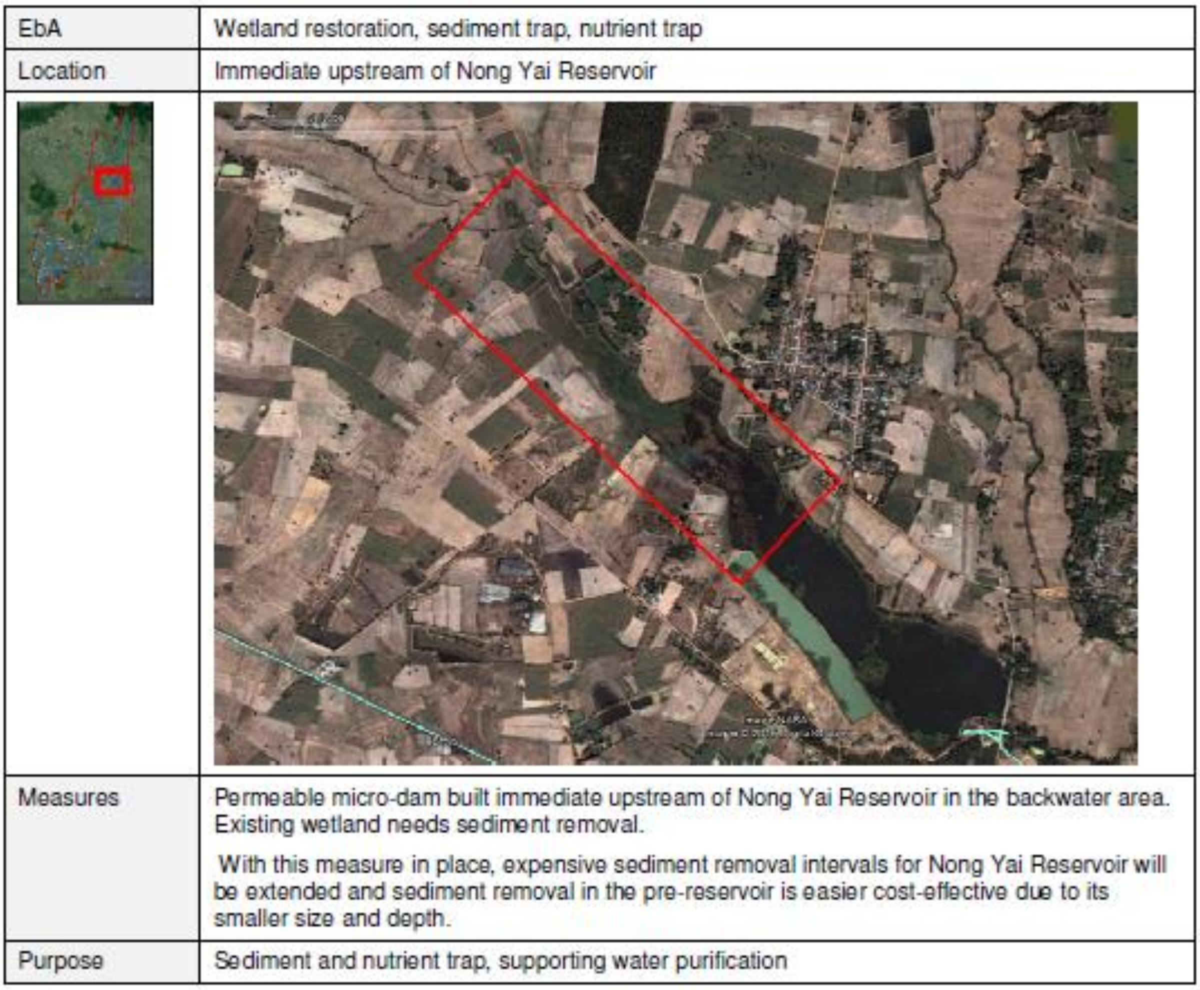
Assuming that the yield will be reduced by 10% the rice farmers will lose THB 23.430 (EUR 608) in the first year. After 5 years the losses will be already more than THB 160.000 (EUR 3.040) per year. Aggregated losses from year 1 to year 5 will be about THB 351.410 (EUR 9.130) and from year 1 to year 20 THB 4.9 Mio (EUR 127.790).

Simulating a reduced rice yield of 30% will triple the losses. Therefore the farmers would lose THB 70.280 (EUR 1.830) in the first year and after 5 years THB 351.410 (EUR 9.130) per year. These yearly losses would lead to an aggregated loss of THB 1.05 Mio (EUR 27.380) within 5 years and THB 14.8 Mio (EUR 383.360) after 20 years.

The Department for Water Resources (DWR) is managing the reservoir and addresses the sedimentation issues by dredging the reservoir every 20 years. This pattern is considered business as usual. After 20 years the storage capacity is reduced by 25% and the reservoir needs to be dredged. The current costs for dredging are THB 75 Mio (EUR 1.95 Mio).

DWR spends THB 75 Mio every 20 years for dredging. During the time from one to the next dredging intervention the farmers lose between THB 4.9 Mio and THB 14.8 Mio by the reduced water storage capacity caused by sedimentation. Hence, the private as well as the public sector are losing money without sustainably improving the situation. Overall, both sectors lose between THB 79.9 Mio (EUR 2.1 Mio) and THB 89.8 Mio (EUR 2.3 Mio) every 20 years.

As an alternative to the dredging, a wetland restoration as a sediment trap at a confluence upstream of the Nong Yai Reservoir is proposed as an EbA measure to reduce the sediment in the reservoir (Lohr, 2016). With such a measure the sediment can be reduced by 75%. Sensitivity analysis with the sediment reduction factor were carried out giving rise to similar results. Assuming the 75%, the yearly loss would be 9.500 m3 (compared to 38.000 m3). The proposed measure would costs THB 750.000 for construction with running costs for maintenance of THB 15.000 per year. (G. Meier, 2015)



EbA	Wetland restoration, sediment trap, nutrient trap
Location	Immediate upstream of Nong Yai Reservoir
Measures	Permeable micro-dam built immediate upstream of Nong Yai Reservoir in the backwater area. Existing wetland needs sediment removal. With this measure in place, expensive sediment removal intervals for Nong Yai Reservoir will be extended and sediment removal in the pre-reservoir is easier cost-effective due to its smaller size and depth.
Purpose	Sediment and nutrient trap, supporting water purification

Figure 3: proposed location of the EbA measure Sediment Trap; Source: (Lohr, 2016)

The construction of the sediment pool will lead to slightly higher costs at the beginning. Ideally the trap will be constructed when the reservoir is dredged. Consequently, the overall costs will be THB 75.75 Mio (EUR 1.97 Mio) (Dredging: THB 75 Mio, Sediment pool: THB 750.000). The yearly maintenance costs for the trap are THB 15.000 (EUR 390). Until the next dredging in 20 years the overall costs for the sediment trap will be THB 1.34 Mio (EUR 34.680). Therefore the overall costs for the sediment trap (dredging plus sediment poll plus maintenance) are THB 76.04 Mio, which is slightly higher than the dredging costs (THB 75 Mio). However, in 20 years the costs for the sediment trap will increase by the yearly maintenance rate of THB 15.000 (EUR 390), while without the trap further dredging is needed. The dredging costs again THB 75 Mio (EUR 1.95 Mio) neglecting inflation rate and price increases. After 21 years the overall costs of the sediment trap is significantly lower than the dredging costs – THB 76.05 Mio (EUR 1.98 Mio) vs. THB 150 Mio (EUR 3.9 Mio). The graph below shows the investments over 100 years. After 80 years the reservoir must be dredged even with the sediment trap measure being implemented, because the reservoir is filled with sediments. But until then, without the implementation the reservoir would have been needed to be dredged 4 times already.

Figure 4: Investments in THB (y-axis) over a period of 100 years (x-axis) for dredging and sediment pool

As mentioned above, the reduction of water storage capacity can be lowered by the installation of a sediment trap, because less sediment is flowing into the reservoir. The sediment trap can reduce the sediment inflow by 75% (Lohr, 2016). Hence, the storage capacity remains relatively high compared to the business as usual scenario (no sediment pool, but dredging every 20 years). While the water storage capacity is reduced by 25% within 20 years in the business as usual scenario, it needs 80 years to lose the same volume, when a sediment trap is installed (see graph below).

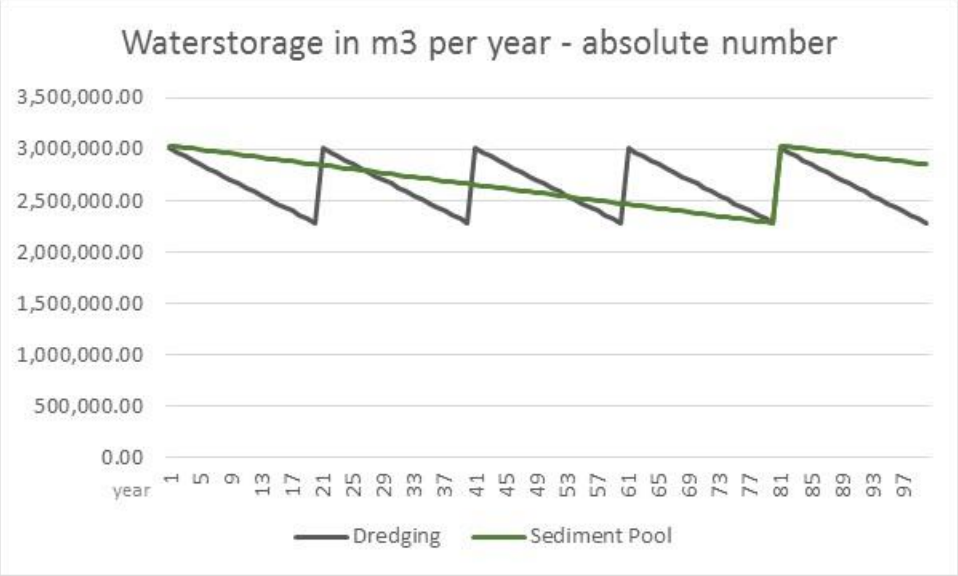


Figure 5: Water storage capacity in m3 (y-axis) over a period of 100 years (x-axis) for dredging and sediment trap

The absolute numbers (graph above) are indicating a higher storage volume when a sediment trap is installed. The average water storage volume per year should confirm this observation. For that the yearly water volume is calculated, added up and the aggregated numbers are divided by the years. With such a calculation the average water storage capacity of the business as usual scenario and the sediment trap installation can be compared (graph below).

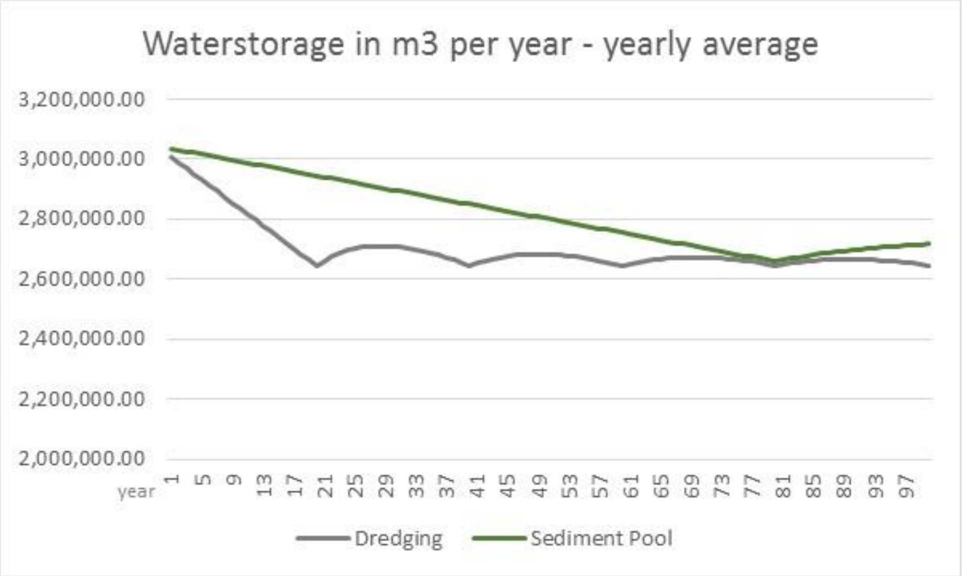
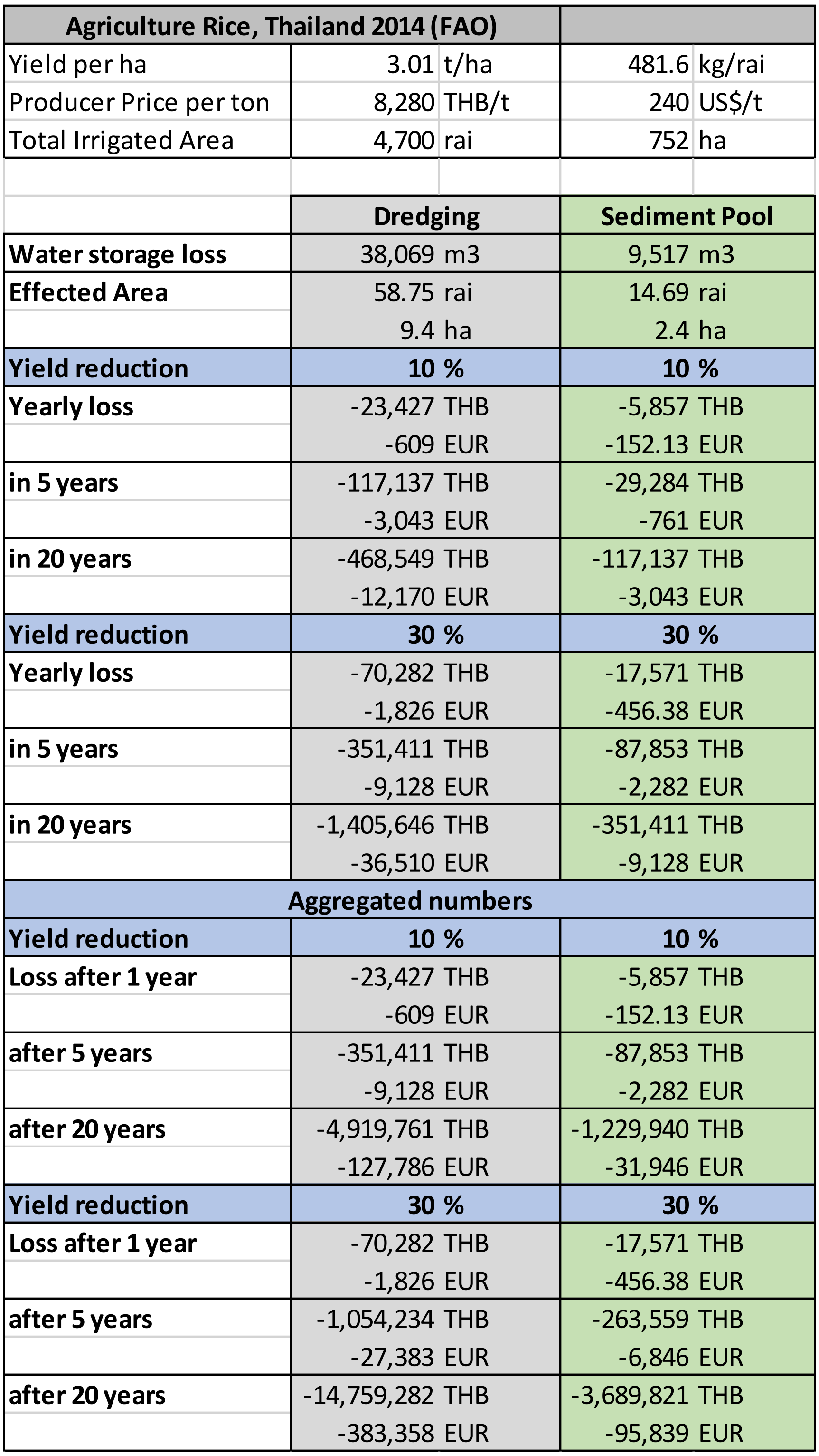


Figure 6: Average water storage capacity per year in m3 (y-axis) over a period of 100 years (x-axis) for dredging and sediment trap

The graph clearly shows that at any time the yearly average water storage capacity is higher when a sediment trap is installed. That means that more water is available, which further leads to higher economic output.
Calculating the impacts of the sediment trap installation on reduced water storage capacity and further on the lower yields of the farming as done above with the business as usual scenario (dredging every 20 years) demonstrates a remarkable advantage of the sediment trap.
Using the same input data and assumption as above (business as usual scenario), the overall economic losses are far lower despite a higher initial investment for dredging and installation of the sediment trap. While in the business as usual scenario 9.4 ha per year are affected by the lower water storage, the affected area can be reduced to 2.4 ha per year (-75%). Only 2.4 ha per year cannot be irrigated, which leads to much lower negative economic impacts. Assuming that the yield will be minus 10% the rice farmers lose THB 5.860 (EUR 152) per year, in 5 years THB 29.280 (EUR 760) and in 20 years THB 31.950 (EUR 3.040). On aggregate the losses will be THB 87.850 (EUR 2.280) after 5 years and THB 1.23 Mio (EUR 31.950) after 20 years. Again, assuming the yield will fall by 30% the negative economic impact will triple.
The table below compares the losses occurred by business as usual scenario (dredging) and by EbA scenario (sediment trap).

Table 2: Direct economic impacts of water losses on rice farmers



Agriculture Rice, Thailand 2014 (FAO)				
Yield per ha	3.01	t/ha	481.6	kg/rai
Producer Price per ton	8,280	THB/t	240	US$/t
Total Irrigated Area	4,700	rai	752	ha
	Dredging		**Sediment Pool**	
Water storage loss	38,069	m3	9,517	m3
Effected Area	58.75	rai	14.69	rai
	9.4	ha	2.4	ha
Yield reduction	**10**	**%**	**10**	**%**
Yearly loss	-23,427	THB	-5,857	THB
	-609	EUR	-152.13	EUR
in 5 years	-117,137	THB	-29,284	THB
	-3,043	EUR	-761	EUR
in 20 years	-468,549	THB	-117,137	THB
	-12,170	EUR	-3,043	EUR
Yield reduction	**30**	**%**	**30**	**%**
Yearly loss	-70,282	THB	-17,571	THB
	-1,826	EUR	-456.38	EUR
in 5 years	-351,411	THB	-87,853	THB
	-9,128	EUR	-2,282	EUR
in 20 years	-1,405,646	THB	-351,411	THB
	-36,510	EUR	-9,128	EUR
Aggregated numbers				
Yield reduction	**10**	**%**	**10**	**%**
Loss after 1 year	-23,427	THB	-5,857	THB
	-609	EUR	-152.13	EUR
after 5 years	-351,411	THB	-87,853	THB
	-9,128	EUR	-2,282	EUR
after 20 years	-4,919,761	THB	-1,229,940	THB
	-127,786	EUR	-31,946	EUR
Yield reduction	**30**	**%**	**30**	**%**
Loss after 1 year	-70,282	THB	-17,571	THB
	-1,826	EUR	-456.38	EUR
after 5 years	-1,054,234	THB	-263,559	THB
	-27,383	EUR	-6,846	EUR
after 20 years	-14,759,282	THB	-3,689,821	THB
	-383,358	EUR	-95,839	EUR

The benefits of the EbA measure compared to dredging increases over time, because the costs for dredging occur regularly and remain relatively high, while the overall costs for the sediment trap are rather low. The graph below compares the costs for 1 m3 of water between the EbA scenario (sediment trap) and the business as usual scenario (dredging) and shows the cost advantage per 1 m3 of water storage in %. In this case study the economic advantage of EbA measures increases in time and peaks at 75% in year 80, just before another dredging of the reservoir is needed despite the sediment trap. In other words the costs per m3 of water can be reduced by up to 75%, if a sediment trap as an EbA measure is installed.

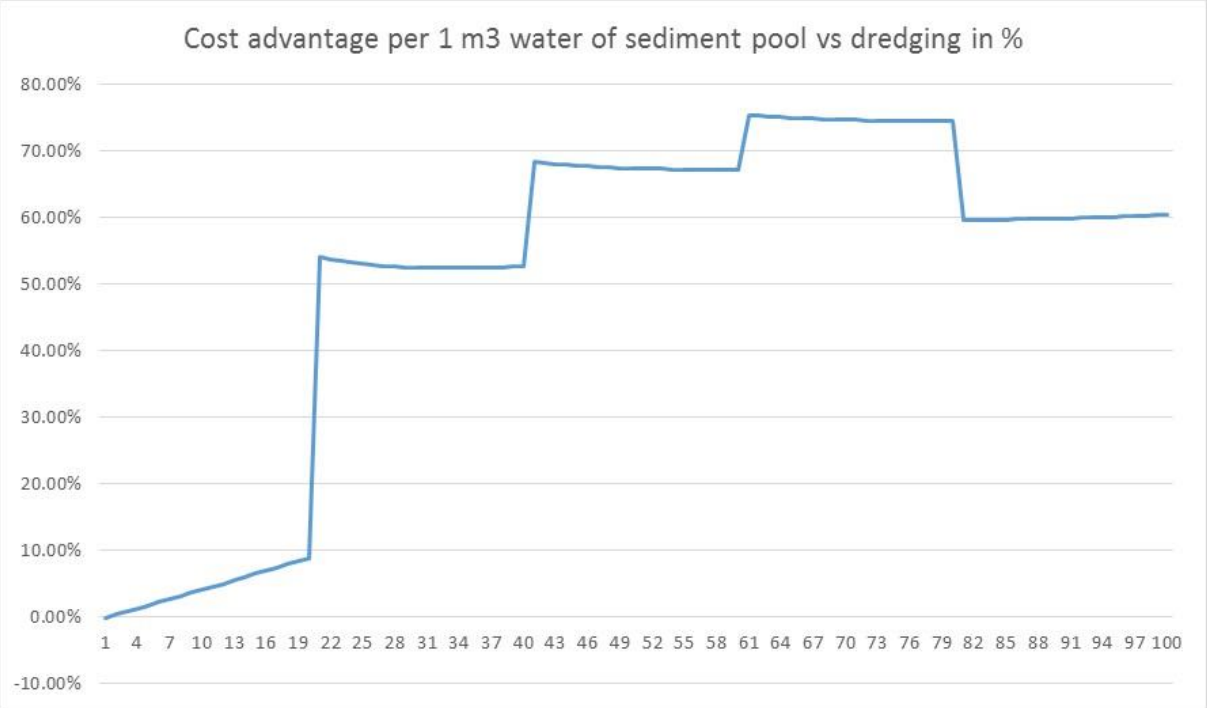


Figure 7: Cost advantage for 1 m3 of stored water compared between sediment trap and dredging in % (y-axis) over a period of 100 years (x-axis)

Over a time span of 100 years dredging costs THB 375 Mio. On average the water storage capacity is about 2.65 Mio m3 per year or 265 Mio m3 for the whole period. Hence, 1 m3 of water costs THB 1.42. With a sediment trap the overall costs can be reduced to THB 152 Mio, while the average water storage can be increased to 2.71 Mio m3. This corresponds with costs of THB 0.56 per m3.

Conclusion

The case study demonstrated that an EbA measure (wetland restoration as sediment trap) has a clear economic advantage to the grey measurement (dredging) even from year 1 on, although the initial investment is slightly higher. The higher installation costs are compensated by higher storage capacity, which leads to higher economic output of the farmers. Therefore the EbA measure has an immediate positive and economically direct benefit, which increases over years.

Beside the economic benefit it became clear that such a measure has also a favorable impact on drought and flood management. Obviously, more water storage capacity can reduce the negative impacts of drought. With the higher storage capacity the overflow of the reservoir can be delayed during heavy rain, which gives more time for preventive action downstream.

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