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The economic context of climate change impacts and an evaluation of the impacts of the proposed adaptation measures in the South Moravian region of the Czech Republic

Abstract: *The problem of climate change was the subject of the project EEA-CZ02-OV-1-039-2015, which was carried out by partners from the Czech Republic and Norway. Cost-benefit analysis was applied for 36 cadastral units where co-investigators suggested adaptation measures on the impacts of drought, erosion, retention and torrential rains. Costs were investments for the creation measures, and loss of production from the area where the action was on the arable land. Benefits were based on reducing the negative impacts of climate change and ecosystem services. The results of the analysis clearly showed that the implementation of adaptation measures could bring societal benefits beyond the cost of the measures. Net social benefits at current value are estimated at nearly CZK 55 million for the 2017-2040 timeframe while maintaining the current situation and implementing measures. Finally, the project develops a comprehensive strategy to harmonise and link the partial conclusions into the linkages and ensuring the synergy effect of different types of instruments (e.g. economic, legislative, planning approach).*

Keywords: *cost-benefit analysis, cadastral units, societal benefits*

Introduction

The objective of the ÚZEI research team in the project EHP-CZ02-OV-1-039-2015 "Complex planning, monitoring, information and educational tools for adaptation of territory to the climate change impacts with the main emphasis on agriculture and forestry management in the landscape" (abbreviated AdapdaN) was to evaluate the economic impacts of proposed adaptation measures through cost-benefit analysis (CBA). The evaluated adaptation measures were focused on the mitigation of impacts of climate change in 36 cadastral units within the South Moravian region of the Czech Republic. The economic analysis builds on the data processed by other researchers in the AdaptaN project, including Brno University of Technology, EKOTOXA, s.r.o. and the T.G. Masaryk Water Research Institute. The proposed adaptation measures are from the group of close measures which eliminate mainly negative impacts of torrential rain, soil erosion and thereby topsoil runoff from lands and surroundings, and loss of nutrients in the soil. Other possible influences and impacts of the measures were considered which, however, were not addressed due to lack of time.

Methods

CBA works with a set of assumptions and limitations; in an ideal data environment the effort is made to express all costs and benefits in the monetary value. CBA in this case included the overall costs and benefits[1] for farmers, land owners, administrators as well as for other users of land and soil ecosystems. CBA works with indicators, where one of the key indicators is the "Net Present Value" (NPV). The indicator calculates only with the future cash flow. It says how much money will a given project actually bring or take within a selected lifetime. Thus, it is not focused on accounting items, such as revenue or costs or some future value of a company, but it solves only the cash flow which a given investment or generally any project/measure will bring. The NPV is more suitable for a short-term and medium-term period for the evaluation of tactic activities of a company.

In the case of the introduction of a new technology, which will be in operation for x years, the NPV will help to evaluate whether to opt for it or, if there are more variants, it advises which one to choose. In individual variants there is the expression of the NPV of social benefits until the year 2040[2]. In order to evaluate results, the method of net benefit of measures and the cost benefits ratio is most often used. The net benefit of measures is usually expressed in the absolute value by the NPV:

$$NPV = \sum_{t-1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \quad (1)$$

[1] Which were possible to be found out and transferred to financial flows = monetarised.

[2] In the case of this project it was 25 years.

where the NPV is the net present value, Bt are benefits in the year t, and r is the interest rate. To accept a measure, the NPV must be higher than zero. If more variants meet this condition, the one with the highest NPV is chosen.

Besides costs and benefits, which are quantified and expressed in the monetary value, there are also specific categories stated for every variant which are not expressed in the monetary value. Given that financial resources lose their value with time, costs as well as benefits are burdened by a discount coefficient, which adjusts financial values to a current value during the whole time of monitoring of costs and benefits. Thus, the results partially depend on a used discount rate.

Within the project AdaptaN, which included evaluation of very similar examples of impacts of climate change and adaptation measures in 36 cadastral units, sensitivity analysis (Macháč, 2016) was carried out and the discount rates of 1, 4 and 8 per cent were tested. It was shown here that the most suitable discount rate for this period of evaluation (24 years) was 4 per cent.

A discount factor is calculated per a formula:

$$\text{Discount factor} = \frac{1}{(1+r)^t} \tag{2}$$

where r is the discount rate and t is the project duration (maturity).

In this analysis, four basic variants were chosen, which were based on the realisation of measures and the state of climate change, and they are explained below. The process of work was as follows:

- The first task in this economic evaluation is dedicated to the identification and qualification of costs and benefits;
- Next, there follows a phase of quantification of costs and benefits from the measure in natural units from more resources;
- Discounting of costs and benefits was carried out according to a work document (or process) compiled by Slavíková (2016);
- The prepared materials subsequently enter into individual variants, for which there are evaluated costs and benefits shown below;

The economic evaluation by the CBA then leads to the conclusion, completion of qualitative costs and benefits;

- The basic criterion for the creation of variants is an optional condition, when a farmer considers an option, if he/she implements a measure or not. The second criterion is not dependent on the decision of the farmer; it works with the assumption whether a climate change will occur or not. The chosen variant of climate change is based on a median of contemplated variants of climate models (Trnka et al., 2015).

The four variants used were as follows:

- Variant 1: *without measures; without change of climate*. It does not consider the realisation of any measures, it counts with maintaining of the current situation, i.e. it ignores potential impacts of climate change, it includes only current risks;
- Variant 2: *without measures; with change of climat*e. It does not consider the realisation of any measures, it counts with impacts of climate change;
- Variant 3: *with measures; without change of climate*. Considers the realisation of measures proposed in 36 cadastral units and it counts on maintaining of the current situation, i.e. it ignores potential impact of climate change, it includes only current risks;
- Variant 4: *with measures; with change of climate*. It considers the realisation of adaptation measures proposed in 36 cadastral units and it counts with impacts of climate change.

Within the requirements of the project a comparison of overall costs and benefits expressed in the present value to 1 July 2016 was carried out with the time horizon until the year 2040. The condition of climate change could work only with selection of impacts in the calculation. More precisely, it meant that impacts were measured as changes in soil compaction, increase of proposed rainfall in the calculation of erosion and decrease of water retention in soil. The calculation of CBA used did not use directly model processing of climate change during the whole period, but it used data in the actual situation (2016) and after 25 years with or without the realisation of measures (2040). Subsequently, there was a decomposition of impacts of climate change linearly through individual years in order to avoid the necessity to determine the year when there will occur a step change from the current state to a state corresponding with impacts of climate change subjectively.

Results

The overview of impacts of erosion of agricultural land for chosen terriers provided data about erosion losses for variants of the current state (2016) and climate change (2040). In Table 1, differences of values are stated in tonnes per hectare per year which it retains due to the adaptation measures per the used model for the calculation of erosion – USLE. Impacts of measures were expressed in overall amounts per terrier and per pilot area. The overall pilot area was 34,434 ha of fertile ground, vineyards and orchards.

For the calculation of costs, it was necessary to quantify the proposed realisations of individual measures in individual cadastral units. In the monitored area, ten types of measures were evaluated within the economic analysis:

- Exclusion of erosion dangerous crops including maize, other crops without limitation (VENP);

- Exclusion of erosion dangerous crops, in the crop rotation there will be no maize, but other crops will be grown in contour lines and without ploughing until there is mulch after harvesting (VENP2);
- Maize grown to cover crops, other crops without limitation (AGT);
- Maize grown to cover crops, other crops will be grown in contour lines and without ploughing until there is mulch after harvesting (AGT2);
- Grassing;
- Afforestation;
- Stabilisation of pathway of concentrated runoff (PCR);
- Dam;
- Furrow;
- Retention area.

Data about areas of individual measures within the researched area are shown in Table 2. Based on these measures, three categories of relevant costs were identified. Besides the initial investment costs, operational costs as well as opportunity costs were included in the evaluation. This division of costs is commonly applied in the processing of CBA. The data resources were the realised measures with similar parameters, professional studies, catalogues of building works and market research in the form of non-binding inquiry. Opportunity costs of the concerned area caused by the realisation of measures on arable land (e.g. building of furrow or grassing) were calculated based on the contribution to cover fixed costs and profit from the concerned cultivation.

Within the AdaptaN project, there was the monetarisation of five types of benefits which occur in the case of the realisation of measures and they de facto decrease the negative impact caused by water erosion and low retention of water in soil. It included the additional benefits from:

- Cost savings from recovering of washed down topsoil back on land blocks;
- Cost saving from removal of topsoil washed down from water streams and reservoirs;
- Cost savings from lost soil;
- Replacement of nutrients;
- Savings from irrigation thanks to higher retention of water in the landscape.

The process of discounting included costs for solving erosion, benefits stemming from the realisation of measures in the form of reduced erosion activity and decrease of quantity of soil which is washed down, and thus to lower costs for solving erosion. In the case of water retention, it was cost of irrigation in the scope of water volume which will be retained by the realised adaptation measure. The amount of partial benefits per one effect in prices of the year 2015 is based on the ÚZEI methodology within the AdaptaN project (Table 3).

Table 1. Statistics of erosion in 36 cadastral units of the pilot area (quantity of soil runoff in tonnes per hectare per year)

Name of cadastral unit	variant 1	variant 2	variant 3	variant 4	difference 1 and 3	difference 2 and 4
		Climate change		*Climate change*		*Climate change*
Archlebov	22.3	47.2	2.8	5.7	19.5	41.5
Bohumilice	28.9	63.0	3.8	8.1	25.1	54.9
Boleradice	29.8	63.0	2.0	4.0	27.8	59.0
Bořetice u Hustopečí	15.4	31.1	2.6	4.9	12.8	26.2
Brumovice	16.5	34.6	2.6	5.2	13.9	29.4
Čejkovice	21.3	45.7	2.4	5.2	18.9	40.5
Dambořice	21.2	45.7	4.3	9.0	16.9	36.7
Dolní Bojanovice	6.9	13.2	2.4	4.2	4.5	9.0
Dubňany	1.7	2.8	1.0	1.7	0.7	1.1
Hodonín	1.0	1.6	0.6	1.0	0.4	0.6
Horní Bojanovice	35.2	76.2	1.9	4.2	33.3	72.0
Hrušky	1.4	2.3	1.0	1.7	0.4	0.6
Josefov u Hodonína	8.1	15.6	1.9	3.4	6.2	12.2
Kašnice	19.7	42	3	6.4	16.7	35.6
Klobouky u Brna	28.6	61.4	2.7	5.5	25.9	55.9
Křepice u Hustopečí	14.3	31.6	5.1	11.4	9.2	20.2
Ladná	1.3	2.3	0.7	1.2	0.6	1.1
Lovčice u Kyjova	24.4	51.3	3.0	6.2	21.4	45.1
Lužice u Hodonína	1.5	2.5	0.7	1.1	0.8	1.4
Mikulčice	1.5	2.6	0.9	1.6	0.6	1.0
Moravská Nová Ves	2.7	5.2	0.9	1.6	1.8	3.6
Moravský Žižkov	2.7	4.7	1.5	2.5	1.2	2.2
Morkůvky	26.0	54.2	3.6	7.2	22.4	47.0
Mutěnice	13.3	26.2	2.6	4.8	10.7	21.4
Nikolčice	10.9	23.4	2.8	5.8	8.1	17.6
Nový Poddvorov	12.6	22.8	3.2	5.5	9.4	17.3
Prušánky	6.3	10.5	1.6	2.7	4.7	7.8
Ratíškovice	1.9	3.1	0.5	0.9	1.4	2.2
Rohatec	1.1	1.8	0.7	1.2	0.4	0.6
Starý Poddvorov	17.3	31.5	3.2	5.8	14.1	25.7
Terezín u Čejče	11.8	23.4	1.9	3.7	9.9	19.7
Tvrdonice	2.5	5.0	0.8	1.4	1.7	3.6
Uhřice u Kyjova	24.2	50.7	4.2	8.6	20.0	42.1
Velké Hostěrádky	31.7	70.3	3.1	6.8	28.6	63.5
Vrbice u Vel. Pavlovic	23.0	44.6	3.5	6.9	19.5	37.7
Ždánice	22.1	47.1	2.2	4.4	19.9	42.7

Source: own data.

Table 2. Areas that are considered for partial measures in individual cadastral units (in ha)

Name of cadastral unit	VENP	VENP2	AGT	AGT2	Grassing	Afforestation	PCR	Dam	Furrow	Retention area
Archlebov	35.3	5.3	177.6	99.3	31.6	0.0	1.5	3.9	0.7	7.1
Bohumilice	8.9	69.4	38.8	44.8	38.0	0.0	1.1	0.5	0.0	9.9
Boleradice	0.0	0.0	29.8	112.0	76.3	0.0	6.8	0.5	0.0	2.7
Bořetice u Hust.	107.1	17.5	82.1	0.0	13.5	0.0	3.0	0.0	0.0	0.0
Brumovice	0.0	17.7	150.4	81.7	33.6	0.0	4.0	1.9	0.0	1.1
Čejkovice	114.8	127.0	151.4	630.4	13.9	0.0	16.8	2.6	1.2	48.1
Dambořice	0.0	0.0	49.8	434.8	37.4	0.0	7.8	6.1	1.0	11.8
Dolní Bojanovice	71.4	14.5	52.0	0.0	0.0	0.0	0.0	0.0	1.1	32.0
Dubňany	163.5	0.0	92.0	0.0	0.0	0.0	3.8	0.0	1.4	12.4
Hodonín	23.1	0.0	103.0	0.0	0.0	0.0	0.0	0.0	1.1	0.0
Horní Bojanovice	0.0	0.0	26.1	27.9	3.6	0.0	0.0	0.0	0.0	23.1
Hrušky	34.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	10.9
Josefov u Hod.	29.7	0.0	101.3	0.0	0.0	0.0	0.0	0.4	1.2	19.2
Kašnice	0.0	0.0	15.5	47.6	0.0	0.0	0.6	1.0	0.2	7.6
Klobouky u Brna	3.1	50.3	225.7	336.8	98.9	0.0	8.9	12.3	0.5	12.5
Křepice u Hust.	0.0	20.9	113.4	47.9	4.2	0.0	6.9	1.6	0.2	3.1
Ladná	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lovčice u Kyjova	0.0	0.0	115.0	234.0	22.6	0.0	3.6	2.2	0.1	4.1
Lužice u Hod.	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	0.0	0.0
Mikulčice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Moravská N. Ves	0.0	0.0	184.5	0.0	0.0	0.0	0.0	0.0	0.0	7.4
Moravský Žižkov	10.2	0.0	105.9	0.0	0.0	0.0	0.0	0.0	0.0	2.6
Morkůvky	0.0	75.5	28.6	167.6	6.1	0.0	3.6	0.5	1.1	1.8
Mutěnice	11.9	0.0	471.9	304.9	15.0	0.0	8.4	4.1	0.0	24.2
Nikolčice	9.7	14.6	226.9	73.4	22.3	0.0	6.6	2.6	0.1	2.8
Nový Poddvorov	38.0	20.6	111.5	14.3	0.0	0.0	1.6	0.0	0.0	1.0
Prušánky	197.8	44.8	16.7	23.8	0.0	0.0	3.4	0.0	0.0	9.2
Ratíškovice	76.2	0.0	6.0	0.0	0.0	0.0	0.9	0.3	2.0	5.6
Rohatec	11.7	0.0	86.5	0.0	0.0	0.0	0.0	0.0	0.0	2.3
Starý Poddvorov	5.1	78.5	67.0	28.9	0.0	0.0	3.2	0.3	0.0	3.3
Terezín u Čejče	12.7	0.0	152.0	7.0	26.7	0.0	2.4	0.0	0.0	11.3
Tvrdonice	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uhřice u Kyjova	0.0	0.0	91.7	274.0	3.6	0.0	5.5	7.3	0.7	2.3
V. Hostěrádky	0.0	18.5	19.9	70.9	25.2	0.0	1.0	1.1	0.3	13.1
Vrbice u Velkých Pavlovic	2.1	8.6	97.4	186.8	0.0	0.0	10.9	3.0	0.3	13.5
Ždánice	0.0	0.0	84.9	188.6	165.8	0.0	4.1	1.4	1.3	13.9
Total	967.0	583.7	3,275.2	3,437.3	638.3	10.0	116.1	53.3	14.4	319.8

For abbreviations see text.
Source: own data.

Table 3. Amount of partial benefits (costs) in prices of the year 2015

Benefit/costs connected with:	Amount
Restoration of washed down topsoil back on land blocks	CZK 204 per tonne
Removal of washed down topsoil from water streams and reservoirs	CZK 650 per tonne
Purchase of lost soil	CZK 205 per tonne
Replacement of nutrients	CZK 5,188 per tonne
Water retention in the landscape	CZK 7 per m^3

Source: Slavíková (2016).

The total current costs for the realisation of the ten measures in the researched area were CZK 4.45 billion (variants 3 and 4). Costs of the realisation of measures were significantly different between individual cadastral units depending on types of measures, area on which they were realised, the total size of a cadastral unit. Costs connected with erosion were in all cases included in costs within the CBA, in benefits there were saved costs, which occur thanks to the realisation of adaptation measures. Thus, benefits include the difference between costs for removal of erosion impacts in case of not implementing measures and in case of implementing measures. The calculation of present costs and benefits is summarised in Table 4, where values are expressed as the current value at 1 July 2016.

Table 4. Current value of benefits and costs of individual variants (million CZK)

	Variant 1		Variant 2		Variant 3		Variant 4	
B/C connected with:	C	B	C	B	C	B	C	B
Realisation of measures					4,447		4,447	
Restoration of washed down topsoil back on land blocks	1,066		1,542		177	889	248	1,294
Removal of washed down topsoil from water streams and reservoirs	1,011		1,464		163	848	229	1,235
Purchase of lost soil	319		462		51	267	72	390
Nutrient replacement	4,075		5,892		676	3,399	947	4,945
Water retention in the landscape	166		166			166		166

Source: Macháč (2016).

Based on the calculations of costs and benefits for individual variants, it was possible to express the net social benefit of individual variants as the difference between benefits and costs expressed in the present value. In case of variants 1 and 2, there were costs for measures and benefits from them equal to zero and it was so in case of maintaining the current state of erosion as well as in case of increase of the erosion activity due to climate change, where cli-

mate change deepened the social loss even more. On the contrary, variants 3 and 4 were socially beneficial measures, where benefits exceeded costs for the realisation of measures and costs of the remaining impacts of erosion, which has an impact on the area despite the realisation of measures (Table 5).

Table 5. Net social benefit of individual variants (thousand CZK)

Variant	Costs	Benefits	Net social benefit	Ratio B/C
1	6,636,870	0	-6,636,870	0
2	9,525,420	0	-9,525,420	0
3	5,514,434	5,569,200	54,766	1.01
4	5,941,924	8,030,260	2,088,335	1.35

Source: Macháč (2016).

Per the net economic benefit, it was shown that the most socially beneficial was the realisation of adaptation measures, which will have a net social benefit of CZK 2.09 billion even when climate change will be CZK 55 billion or it will not happen at all. Not realising the measures will, on the contrary, cause a loss of CZK 9.53 billion in case of climate change and with the assumption of maintaining the current erosion activity, a net social loss of CZK 6.64 billion was calculated.

The indicator of the ratio of benefits and costs in individual scenarios expresses the social benefit per unit of costs. A measure is usually accepted if this ratio is higher than one, and it also means that for CZK 1 of costs there should be a benefit of more than CZK 1. In case there will be no significant manifestations and impacts of climate change on erosion and therefore on the agricultural activity, the narrow B/C ratio was found, however, in the case of climate change over 25 years, the ratio increased to CZK 1.35 of benefits per CZK 1 of costs. Thus, this led to the social valorisation of costs by 35 per cent.

Besides the above stated monetarised benefits, there may be also considered other benefits which, however, were not monetarily evaluated due to financial and time requirements. In order to state other benefits, it is possible to start from the concept of ecosystem services, which determines anthropocentric benefits provided by ecosystems, or more precisely by services that these ecosystems create. Ecosystem services are most often divided into production, support, regulatory, ecological and cultural.

Conclusions

The study of economic impacts in the AdaptaN project compared costs and benefits of impacts of erosion activity and realisation of adaptation measures in four variants. These variants were different in two conditions, the first was related to the realisation or non-realisation of adaptation measures and the

second was related to the application or non-application of impacts of climate change. In costs, the potential realisation was calculated of measures according to the models, more specifically ten types of measures, with costs for removal of erosion activity and costs for irrigation. Benefits were expressed as cost savings from removal of erosion impacts and cost savings from irrigation. However, due to time limitations, it was not possible to quantify other possible benefits. Annually, the pilot area (34,434 ha) currently loses 436,783 tonnes of quality topsoil due to erosion. If climate change occurred and no measures were in place, the impacts without measures would be around double and thus representing a threat of 905,608 tonnes of topsoil. In case of implementation of measures, there would be significant decrease in washed down topsoil in the pilot area, currently it would be 72,015 tonnes a year and after climate change 141,386 tonnes.

Based on the comparison of net social benefit in the basic variant, it was shown that it is socially beneficial to realise the adaptation measures. This was valid for maintaining the current state of erosion activity as well as in the occurrence of negative impacts due to climate change. A significant role in quantification of costs and benefits was played by the discount rate and the rate of return of nutrients. However, this had no impact on the order of scenarios. In the case of maintaining of the current situation of climate and realization of measures (variant 3), the net social benefit in the present value would be almost CZK 55 million in the time horizon of 2016 to 2040. In the case of the modelled impacts of climate change and realisation of adaptation measures, the net social capital would be CZK 2.1 billion.

The analysis of costs and benefits implies that it is recommended to realise adaptation measures regardless of whether there will or will not be negative impacts of climate change. If social benefits are not achieved, there will at least be a minimisation of social losses.

References

Macháč, J., 2016. *Cost-benefit analýza opatření pro adaptaci území na dopady klimatické změny v Jihomoravském kraji, Výsledky a propočty CBA v rámci projektu AdaptaN* [Cost-benefit analysis of the adaptation area on the impacts of climate change in the Southern Region, and the results of calculations in the CBA project AdaptaN]. ÚZEI – Výstup z projektu AdaptaN.

Slavíková, L., 2016. *Podklady pro cost-benefit analýzu z výstupů projektu AdaptaN. Příprava „technické stránky" - systém propočtů, postavených na příslušných teoriích a návodech z literatury* [Data for cost-benefit analysis of the project outputs AdaptaN. Preparation of the "technical aspects" - a system of calculations, built on relevant theories and guidelines from the literature]. ÚZEI – Výstup z projektu AdaptaN.

Trnka., M. and others, 2015. *Matematické modelování klimatických, hydrologických a pedohydrologických dat pro účely řešení projektu číslo EHP-CZ02-OV-1-039-2015 s názvem „Komplexní plánovací, monitorovací, informační a vzdělávací nástroje pro adaptaci území na dopady klimatické změny s hlavním zřetelem na zemědělské a lesnické hospodaření v krajině", souhrnná výzkumná zpráva* [Mathematical modelling of climate, hydrological and pedohydrologických data for the project number of the EEA-CZ02 1-039-2015-OV-called "comprehensive planning, monitoring, information and educational tools to adapt to the impact area climate change, with the main emphasis on agriculture and forestry management in the country", the summary research report]. Centrum výzkumu globální změny AV ČR v.v.i. 2015.