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EROSION AND THE ECONOMIC EVALUATION OF THE CONSERVATION GRASSLAND AS AN EXISTING EFFECTIVE TOOL TO REDUCE EROSION

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Abstract

Problem with soil erosion has not yet been satisfactorily solved with a holistic approach through a precisely targeted and duly explained strategic plan in the Czech Republic. Even though there are effective means to undertake needed measures, conservation grassland being one of them. The research aims to contribute to the debate that concerns battling soil erosion in Czech conditions. The idea of conservation grassland as an effective tool to battle soil erosion is well-known by the experts and farmers alike. Although there has been a discussion on what should be the extent of conservation grassland on a country-level in Czech conditions, there still has not been enough vigour to push the idea forth. We set two research questions. Firstly, what should be the total volume of agricultural land that should undergo the conservation grassland. Secondly, how to adjust subsidy scheme for making the conservation grassland as erosion protection economically viable for the farmers. We provide answers with holistic analysis of all Land Parcel Blocks (LPB) in 2016–2021 period where the erosion events were analysed, and the Erosion Hazard Classes (TEO) were considered too. We concluded that if we take into the account a five-year project according to 2023–2027 Common Agricultural Policy scheme, more than CZK 3.4 billion worth of soil could be saved if 103,428.4 hectares were grassed. For a conventional farmer, additional subsidy scheme would have to be presented to compensate farmer's expenses for implementing the conservation grassland that secures an anti-erosion ecosystem service and other ecosystem services as well.

Keywords: erosion, economic evaluation, conservation grassland, ecosystem services

INTRODUCTION

Erosion as a Complex Socio-economic and Environmental Problem

Soil erosion is a major problem in today's worsening climatic conditions along with the loss of biodiversity in the Czech landscape. It was estimated by the Ministry of Agriculture (Soil, 2021) that, annually, erosion causes a damage of a total of CZK 4.3 billion; this is based on the damage caused purely to the soil, not considering ecosystem services that contribute significantly to human well-being and the functioning of the entire ecosystem (Horák and Marada, 2022). It is fairly common in the Czech Republic to find large land parcel blocks which could be in most cases a decisive factor whether an erosion event takes place or not (Gebhart, Dumbrovský *et al.*, 2023). Farmers are important actors in suppressing or enabling erosion, albeit unintentionally. There are many ways of dealing with erosion. One of them is a sustainable agricultural management of the landscape which goes hand in hand with appropriate financial incentives based on national and supranational policies.

However, Prasuhn (2020) and Herweg *et al.* (2010) pointed out that financial incentives alone are not enough: there is also a need for a follow-up education for farmers, meaning also raising their awareness about erosion, cooperation with colleagues, field monitoring and cooperation between academic and non-academic sectors because, according to the two authors mentioned above, erosion is a complex socio-environmental problem. Farmers should be given some incentives and further education to undertake needed direction for the sustainable land management (Gebhart, Dumbrovský *et al.*, 2023). Prasuhn (2020) reported that over the period of conservation-agriculture-style management monitoring, erosion incidence decreased significantly, with 12% of the monitored fields being erosion-free in the first monitoring period and 42% being erosion-free in the second monitoring period, during which conservation agriculture practices were introduced.

Prasuhn (2020) further stated that under this style of sustainable farming, where 85 % of the land was converted to conservation agriculture, the average incidence of erosion in each field was reduced from 3.2 to 1.3, a very significant result. Arable land farmed in the conservation agriculture style was estimated to be between 11 % and 14 % of the global total by Borrelli *et al.* (2020); in absolute terms, it amounts to about 1.42 billion hectares, according to FAOSTAT (2019). Huber *et al.* (2022) stated that conservation agriculture should be targeted at regional rather than just individual farm-level sites to ensure the coherence, continuity and effectiveness of the measures. This is confirmed by the fact that the value of ecosystem services increased by significant amounts (45 %) when targeted at the regional level. Huber *et al.* (2022) put this finding in the context of grassland farming in particular, where erosion is significantly suppressed.

Borrelli *et al.* (2020) outlined scenarios based on the representative conservation pathway (RCP) concept, namely, the 2.6, 4.5 and 8.5 scenarios, in which the hydrological cycle could increase global erosion by 30 % to 66 % with the baseline model being based on a 2015 study that predicts a global erosion rate of 43 billion tonnes per year (already assuming a possible mitigation of 5 % just using conservation agriculture). According to Borrelli *et al.* (2020), the RCP 2.6 scenario, which calls for zero emissions by 2100, is assumed to reduce water-induced soil erosion by 6 % to 10 %, whereas scenarios 4.5 and 8.5, which are much less stringent and do not entail the necessary radical changes in the behaviour of world society, rather assume a worsening of water erosion by 2 % and 10 %, respectively, by 2070.

Given the very slow pace of change, it is necessary to consider other effective ways to prevent erosion. This means acting locally on the selected fields. Farmers must play a pivotal role in preparing the soil against water and wind erosion with government's help which must do everything possible to set optimal conditions. In order to assess holistically the causes of erosion and the combinations of causes behind the development of soil erosion itself, it is necessary to examine, first and foremost, the characteristics of the land on which the undesirable process of erosion takes place. Historically, the fight against erosion was known as early as 1910, when pea rotations were incorporated into crop rotations, successfully reducing erosion rates on given plots of land (Granatstein, 1992; in Maaz *et al.,* 2018).

Xie *et al.* (2019) further reported that an increase in soil loss correlates with an increase in the amount of land cultivated with a single crop in a higher slope area. Wuepper *et al.* (2020) demonstrated on the collection of global data that the effect of the state on erosion rates is real. The Czech Republic performs worse compared to Germany, Slovakia or Poland, whereas the Czech Republic is more successful in combating erosion compared to Austria (Wuepper *et al.*, 2020, p. 4). Foley (2011) and Mueller (2012) agreed that it will become increasingly difficult to meet global demand to feed the population with agricultural production (direct effect) and to provide ecosystem services (indirect effect) (in: Wuepper *et al.*, 2020).

Causes of Erosion

A concise and precise definition of erosion and its process was described by Pimentel and Burgess (2013), who postulated that *'erosion occurs when soil is exposed unprotected to rain or wind'.* One could only partially agree with this if we look at the concept of soil loss due to crop harvest (SLCH), when Ruysschaert *et al.* (2007) reported that: "*...large amounts of soil are lost from the field during the harvest of crops such as sugar beet (Beta vulgaris L.), potato (Solanum tuberosum L.), chicory roots (Cichorium intybus L.), cassava (Manihot spp.) and sweet potato (Ipomoea batatas (L.) Lam)*". At harvest, soil adhering to the crop, loose soil or soil clods and rock fragments shall be removed from the field together with these crops. Crop erosion occurs mainly in arable crops and root vegetables, which were grown on a minimum area of 1.1 million km^2 in 2019, or about 8.4 % of arable land globally, according to Kuhwald *et al.* (2022). Thus, the choice of crop present on the land is also an important variable in agricultural management.

Furthermore, Pimentel and Burgess (2013) cited research by Troe (1999), who stated that 1,000 mms of rainfall falling per hectare per year on New York State represents energy equivalent to 60,000 kcal. Thus, from these data, it can be inferred that the force exerted on the soil by raindrops is not negligible at all. Pimentel and Burgess (2013) also cited Oldeman (1998) and Troe (2004) who found that with such high rainfall, a slope of only 2% is sufficient to trigger sheet erosion (dominant type). By analogy, as the slope increases, the impact of erosion becomes more noticeable. In addition, wind erosion can have a noticeable impact on agricultural land too, as Pimentel and Burgess (2013) demonstrated on the example of a winter in Kansas in which 65 t/ha were eroded by wind erosion alone in 1995 and 1996.

Erosion is an inherently natural phenomenon, and it is important to realise that it cannot be eliminated completely, only reduced significantly. According to Ruysschaert *et al.* (2007), the definition of a tolerable erosion rate is: *"...any actual rate of soil erosion in which one or more soil functions are not impaired or lost and such erosion is conceptualized as the total amount of soil lost by all recognized types of erosion."* Thus, if any soil loss due to erosion of any type is taken into account, according to Ruysschaert *et al.* (2007), the upper permissible limit of loss without major impacts is 1.4 t/ha/year, if European conditions are taken into account. However, globally, this loss limit is exceeded 3 up to 40 times. These findings are alarming, even more so given the fact that these findings are from 2007.

Calculation of Soil Loss Due to Erosion

Kanito and Feyissa (2021) described different ways of calculating soil loss due to erosion but referring to Renard *et al.* (1994 and 1997), they postulated that the RUSLE equation is most appropriate for the purpose of calculating soil loss from agricultural areas due to erosion because it does not focus on naturally forested areas. Renard (1997) described a new equation that was revised from the original USLE equation and differs primarily in that the letter R takes into account rainfall and runoff; then denotes K = soil erodibility, LS = slope length and steepness, C = crop management; and finally, P = supporting agronomic and other practices. However, for the purpose of data processing in the Czech Republic, the method in Wischmeier and Smith (1978) is used and the "R" is applied as well. The use of the previously mentioned USLE equation is visible in the Czech application "Anti-Erosion Calculator" (Vopravil, 2014; Vopravil, 2006; Janeček, 1992) where it is possible to compute the potential threat that your LPB might have and to set up a plan of measures to reduce the erosion risk of agricultural land.

Grassland as an Effective Tool Against Erosion

Grasslands are present, according to Huber *et al.* (2022), on most of the world's cultivated agricultural land and are logically essential for global food security. Grassland ecosystems contribute to human well-being (Braat and De Groot, 2012) by providing a wide range of ecosystem services such as carbon sequestration, pollination or ecosystem maintenance for various species (Bengtsson *et al.,* 2019: in Huber *et al.,* 2022) and, of course, ecosystem services in the form of erosion control (Horák and Marada, 2022). Grassland management is critical to the sustainability of agriculture globally, but even here there must be trade-offs, as Manning *et al.* (2019) and Deng *et al.* (2018) (in Huber *et al.*, 2022) argued: farmers choose between intensively managing these grasslands or leaving them fallow, thereby enhancing the value of ecosystem services.

The most significant occurrence of erosion events by agricultural crop was, expectedly, on standard cropland (R), where out of 1,452,723 observations, an erosion event was recorded in 2,580 observations as we can see in the Tab. I. The cropland grass culture on arable land was the factor of most interest to the authors because of the highest possible protection against erosion. In terms of comparing the relative values of R and G, grassland can be seen as an effective erosion control, as the incidence of erosion is three times lower than on standard arable land. For this reason, the authors concluded that grassland on arable land in the form of protective grassland as a recommended measure is a suitable tool to suppress erosion on agricultural land.

According to the Tab. II, the use of conservation grassland presents a decreased potential of erosion risk expressed in monetary terms. Particularly the calculated mean value of potential damage that erosion can cause on grassed land is nearly CZK 3,800.ha^{-1}, while on non-grassed land it is more than CZK 8,500.ha^{-1}. Thus, the potential erosion damage on other forms of farmed land is more than double. We thus consider the conservation grassland as a very effective tool to battle severe soil erosion.

I: *Erosion Events by Agricultural Culture*

Total	2,665	0.16 %	1,649,135	99.84 %	1,651,800
Codes and explanations	Erosion event: Yes		Erosion event: No		Total
	Quantity	%	Quantity	%	
D – SRC*	3	0.03 %	8,717	99.97 %	8,720
G – Grassland	**61**	**0.06 %**	96,591	99.94 %	96,652
J – Another permanent culture	8	0.02 %	36,061	99.98 %	36,069
L – Forested land	3	0.01 %	32,461	99.99 %	32,464
R – Standard arable land	**2,580**	**0.18 %**	1,450,143	99.82 %	1,452,723
U – Fallow	10	0.04 %	25,162	99.96 %	25,172
Total no. of observations 2016–2021	2,665	0.16 %	1,649,135	99.84 %	1,651,800

Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021. * Short rotation coppice (SRC)

MATERIALS AND METHODS

Data on Land Parcel Blocks

Six datasets for the years 2016 to 2021 were prepared for statistical processing, for which it was possible to obtain complete source data. The basis of the database consisted of data of land parcel blocks (LPB) from the Land Parcel Identification System (LPIS), always referring to 30th June of the given year. An LPB is a basic spatial unit of the LPIS database and is a clearly delineable area of agricultural land farmed by one specific user: the farmer. The basic division of agricultural crops can be arable land, permanent grassland or permanent crops. An LPB is a continuous area of agriculturally managed land with a minimum area of 0.01 ha (100 m^2), the boundaries of which can be identified in the field, on which a natural or legal person carries out agricultural activity on his/her own behalf and under his/her own responsibility, and on which one type of agricultural crop is cultivated (as determined in accordance with Government Regulation No. 307/2014 Coll. on determining the details of the registration of land use according to user relationships) or where an ecologically significant feature is located (FAQ, State Agricultural Intervention Fund, 2018).

Data on Erosion

There is a range of characteristics that can influence or cause soil erosion; however, for the purposes of this research, available data provided by the Ministry of Agriculture for the six-year period 2016–2021 were requested. The basic unit under investigation was the LPB to which the individual characteristics provided by the LPIS database were assigned. According to Wuepper *et al.* (2020), the effect of the state in which the erosion takes place is also an important characteristic because the amount of erosion changes on average 1.4 tons/ha/year just by crossing the border, which is appropriate to take into account when investigating the causes of erosion. Wuepper explains this precisely by the agricultural characteristics and practices that are peculiar to the country. LPIS also records information on various subsidy measures, which are used to control and disburse these subsidies. For the purposes of this research, data were analysed to find out whether a given LPB has been included in the 'Grassing of Arable Land' measure. Information on this measure was appended to the main dataset using LPB identification codes, and its existence on the LPB was distinguished as YES/NO in the table. In addition, the area on which the measure was declared by the farmer, if any, was indicated.

Data on Erosion Hazard (Risk) Classes

A major newly added dataset was information on the acreage of erosion hazard classes within each LPB. The data source here was the raster layer TEO which is processed for the Ministry of Agriculture by the Research Institute for Soil and Water Conservation in an annual update on the scale of the whole Czech Republic. The layer contains the differentiation of agricultural land into ten erosion hazard classes, which reflect the long-term average soil loss in tons per hectare due to water erosion (Brázda, Kapička and Novotný; Research Institute for Soil and Water Conservation – henceforth VUMOP, 2021) (see Tab. III). The raster was converted into a vector layer in QGIS using the 'Convert to Polygons' tool, and then the overlap of each class with each LPB was calculated using the 'Union' tool. The result was converted into tabular form, and only the overlap data were retained in the table: the parts of the original grid without overlap with LPB were removed. The cleaned data was then summed up using a contingency table so that each LPB represented one row of the table, with the area divided into erosion hazard classes. The acreage for each erosion hazard class was then converted to soil loss per year in tonnes using the mean of each interval (see Fig. 1). The total soil loss from the LPB in tonnes per year was then added to the T_SUM attribute, and an estimate of the price of the lost soil in CZK per year was made in the T_PRICE attribute. Here, an estimated price of 205 CZK/t was used, which was derived from the claims made by the Ministry of Agriculture: *'Currently, the maximum soil loss in the Czech Republic is estimated at approximately 21 million tonnes of topsoil per year, which can be expressed as a loss of at least CZK 4.3 billion per year.'* (Ministry of Agriculture, Soil, 2021).

The vector data of erosion events were also subjected to an overlay with the LPB layer in geoinformation systems, and the following information was attached to each LPB according to the result: - the total number of erosion events that have occurred at the LPB location since the start of recording erosion events; - the number of erosion events at the given LPB in a specific year; - the area of the overlay with the largest erosion event in

II: *Grassland and the Risk of Erosion in Monetary Terms (CZK) – potential damage*

Factor	5%	25%	50%	75%	95%	Mean	S.D.
Grassed land							
Yes	3.3	268.1	1,221.9	3,245.4	14,908.4	3,767.7	11,037.7
No	3.1	300.6	1,316.1	4,886.6	42,164.1	8,520.9	25,856.7

Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021

III: *Erosion Hazard Classes – Potential volume of eroded topsoil*

Erosion Hazard Class TEO	Interval $t.ha^{-1}.y^{-1}$	Used medium value for calculation $t.ha^{-1}.y^{-1}$
1	1.0 and less	0.5
2	–2.0	1.5
3	2.1–3.0	2.5
4	3.1–4.0	3.5
5	4.1–8.0	6
6	8.1–10.0	9
7	10.1–12	11
8	12.1–20.	16
9	20.1–30.0	25
10	30.1 and more	40
NO DATA	X	4

Source: Categories of Erosion Hazard Classes (VUMOP, 2021)

a given year; - and the code and date of the erosion event. Lastly, all individual processed data sources were linked by the 'Join' function via the ID_ LPB (identification code) attribute into one common summary table for each year.

Data were analysed using frequencies (absolute and relative frequency), descriptive statistics (mean, standard deviation, median, upper and lower quantile, other quantiles) and column plot. TIBCO STATISTICA 13 software was used. We set two models to be calculated according to CAP Strategic plan 2023–2027 (2022, pp. 472–473): a) Normal (conventional) grassing mix and b) Regional grassing mix. The first option provides subsidy support of EUR 312/ha with grassing with conventional mix, and the second option provides subsidy support of EUR 1,114/ha in the first year and EUR 237/ha in the following years. Furthermore, the question of how to identify land that would be most suitable for conservation grassland had to be answered. We found the answer in the Situation and Outlook Report of the Ministry of Agriculture (2021, p. 26), where their hectares, proportion and recommended protection measures were expressed in each erosion hazard category. We decided to combine the first two categories of erosion risk and to take a position on the recommended protective measure, i.e., protective grassing. The factor $C_p.P_p$ expresses the required protective effect of vegetation and erosion control measures in relation to the permissible average annual soil loss. It is, therefore, the product of the maximum permissible value of the vegetation protection factor and the erosion control factor. This means that there are almost 102,000 hectares of land that should be grassed over from our point of view, see Tab. IV.

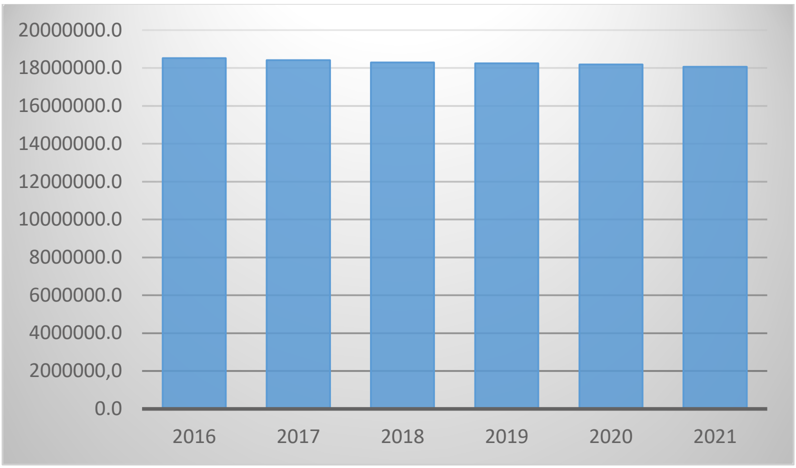
Aim of the Research

We set two research questions to be answered: 1) What should be the total volume of agricultural land that should undergo the conservation grassland? (and) 2) How to adjust subsidy scheme for making the conservation grassland as erosion protection economically viable for the farmers? We always bear in mind possible ecosystem services that are present after implementation of any conservation strategy, in our case, conservation grassland. We chose the anti-erosion ecosystem service that is, according to available expert knowledge in Czech and foreign conditions, quantifiable in terms of potentially eroded soil that we could save from degrading (Janeček *et al.*, 2012). The loss of production from conventionally managed arable land which the farmer would have realised under otherwise equal circumstances (*ceteris paribus*) is naturally considered as an opportunity cost (Konečná, Pražan *et al.*, 2014). We did not consider the acquisition of new mechanisation, as it is assumed that the basic mechanisation will be available to the farmer in view of his continuous agricultural activity. In calculating the loss of production on arable land and the establishment of grassland, the authors relied on the methodology described by Konečná, Pražan (*et al.*, 2014).

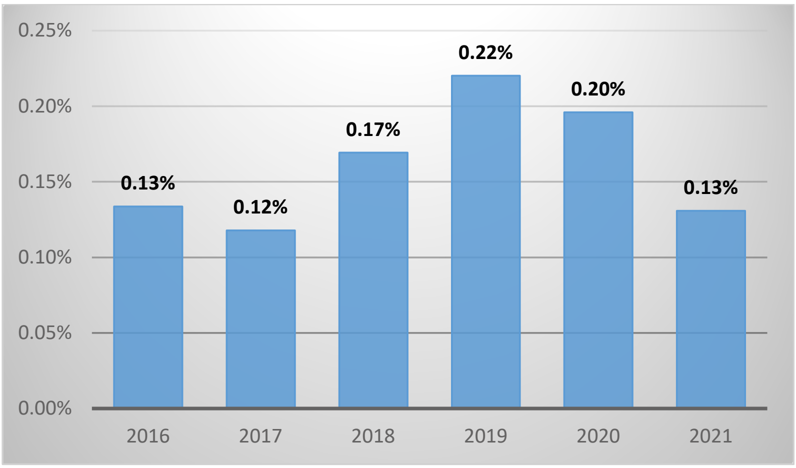
RESULTS AND DISCUSSION

The issue of conservation grassland as an effective tool in the fight against erosion is significantly reflected in the objectives and instruments of the new Common Agricultural Policy for the period 2023–2027, where much more emphasis is placed on sustainable rural development, rural life and, accordingly, the care of natural capital, i.e., agricultural land. The main motivation was to point out that an effective tool in the fight against erosion exists, and by linking the analysis of the state of Czech agricultural land published in the Situation and Outlook Report of the Ministry of Agriculture (2021) dealing with the state of Czech soil with the methodology for the protection of agricultural land against erosion (Konečná, Pražan *et al.*, 2014).

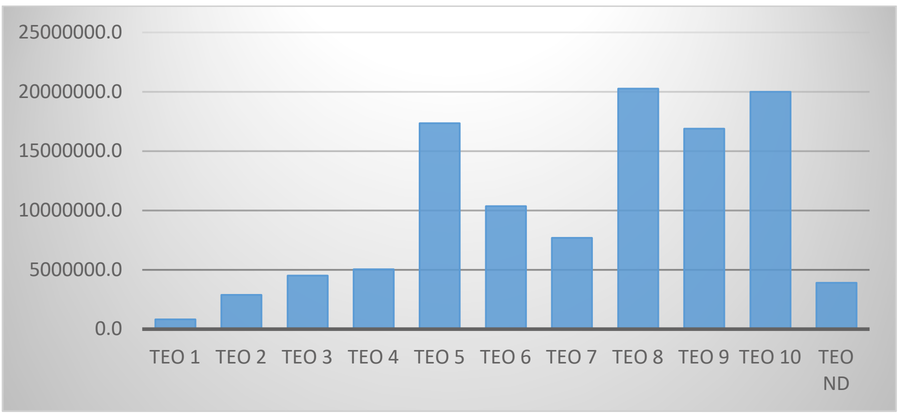
Fig. 1 shows that the potential volumes of eroded topsoil in tons is almost identical in each year for the period studied; however, comparing Fig. 1 and Fig. 2, the occurrence of erosion events relative to the base variable, LPB, is different in each year. This may have many causes, but one of the major limitations is that not all erosion events that occurred in a given year are recorded and entered into the database. The reasons for this may vary. Either it is a small-scale erosion event that does not manifest itself in any way, e.g., by washed-away soil on transport infrastructure or floods in the village, or it happens within the block on which the farmer farms, and many individuals do not themselves



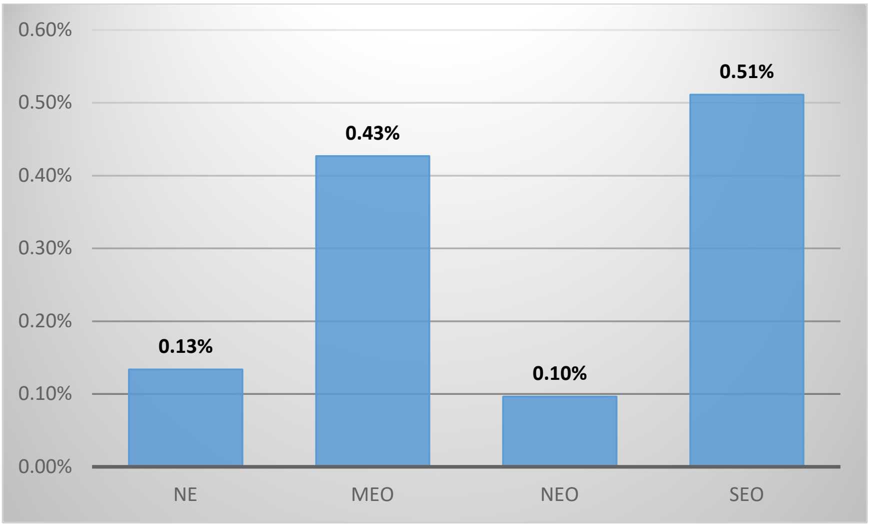
1: *Potential volume of eroded topsoil by Year in tonnes (t)*
Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021



2: *Occurrence of Erosion Events in Individual Years*
Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021. Occurrence regarding the whole number of observations



3: *Potential volume of eroded topsoil by TEO classes in tonnes (t)*
Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021



4: *Occurrence of erosion events according to erosion hazard*
Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021. The rest of observations lies within the scope where there was no erosion event recorded.

IV: *Range of the Subject Erosion Hazard Category*

Erosion Hazard Category $C_p.P_p$	Size (ha)	Share of Total ZPF (%)	Recommended Measures	Cost of Establishing 1 ha CZK	Total Set-up Costs for the Category (CZK million)
0.000–0.020	**101,830.01**	2.46	Conservation Grassland	24,747	2,520

Source: Situation and Outlook Report – Soil. 2021. Ministry of Agriculture

report that an erosion event has occurred on their farmed land. Another significant factor is, of course, the impact of rainfall, the intensity, volume, or timing of which can and does vary from year to year.

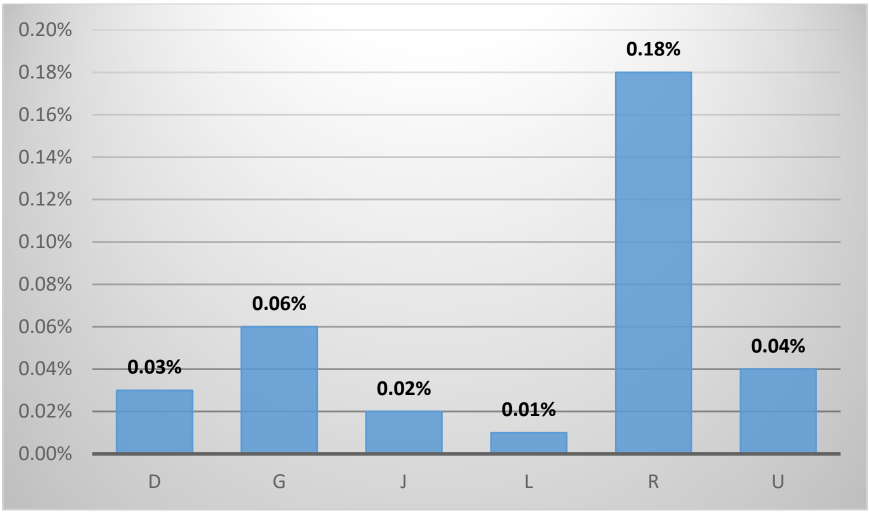
According to Fig. 3, the potential volume of eroded topsoil is most acute in the TEO 8 to TEO 10 categories, where an analysis of a six-year period shows that the potential volume of eroded topsoil was more than 57 million tonnes of topsoil in total. This finding largely correlates with the Fig. 4 where the largest proportion of observations within the 'severely erosion-prone' soil (SEO) had an erosion event, i.e., 110 erosion events were observed out of a total of 21,528 measurements in the SEO based on Tab. IV. II. It is also noteworthy that the moderate erosion-prone (MEO) class also has a significant proportion of erosion events within the total number of observations. Out of a total of 266,252 observations over the six-year period, 1,136 observations had erosion events. Again, given that not all erosion events are monitored, captured and recorded, data providers from the Ministry of Agriculture report that only 10 % of erosion events that occur in a given year are seized and put into the statistics. This is a limitation of this research but given the overall threat to agricultural land in the Czech Republic and the acute need to address the issue, these population-wide data are sufficiently credible.

However, data provided by the Ministry of Agriculture indicating the erosion hazard, shows that TEO 10 has the highest erosion hazard in terms of the potential volume of eroded topsoil. For the period of 2016–2021 there was a potential volume of eroded topsoil of 20,000,000 tonnes. The potential damage that could have been caused to this category

V: *Range of Erosion Hazard Class*

Class	Size (ha)
TEO 1	2,509,104.1
TEO 2	319,070.0
TEO 3	363,526.1
TEO 4	316,822.5
TEO 5	243,127.5
TEO 6	548,432.0
TEO 7	156,144.3
TEO 8	113,583.2
TEO 9	235,291.9
TEO 10	**103,428.4**
TEO no data	84,812.6

Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021



5: *Erosion Events by Agricultural Culture*
Source: Authors' analysis based on the data from the Ministry of Agriculture, dataset 2016–2021

alone is therefore CZK 4,1 billion over this six-year period, if we base this on the price per tonne of CZK 205 used by the Ministry of Agriculture. If we weigh the values of TEO 10 with the values of the erosion hazard category $C_p.P_p$ 0.000–0.020, we suggest that a minimum of 103,428.4 hectares (see Tab. IV and Tab. V) within the Czech Republic need to be grassed in order to reduce the erosion threat to such a level over the next five-year period that the allowable soil loss is such that it *'allows soil fertility to be maintained in a sustainable and economically affordable manner'* (Janeček *et al.*, 2012). If we accept that if we grass 103,428.4 hectares of topsoil, the maximum loss will be only 8 $tons.ha^{-1}.year^{-1}$ instead of the potential 40 $tons.ha^{-1}.year^{-1}$, considering the mean value of TEO 10. Analogically, we can say that after the grassing, the potential damage for the topsoil in the case of an erosion event is CZK 0,84 billion, instead of CZK 4,24 billion. Thus, for the first research question to be answered, we believe that at least 103,428.4 hectares of severely erosion-prone agricultural land should be grassed to effectively battle soil erosion.

We conducted a cost–benefit analysis to evaluate the creation of conservation grassing of erosion-prone soils throughout the Czech Republic. For the purpose of calculations, the method was used that had been applied to a case study of a landscaping orchard in the previous research (Horák and Marada, 2022, p. 297). Sensitivity analysis was carried out with reference to the European Commission (2008) methodology, where the basic discount rate is 5 % p.a. The procedure here was slightly different, as the authors considered only a five-year project grassed in two variants, namely, grassed with a normal mix and a regional mix. We considered the Czech Strategic Plan for the Common Agricultural Policy 2023–2027 (2022) that has been approved by the European Commission. In the first year of the project for grassed land at risk, a hectare of newly grassed land would not provide the expected ecosystem services; therefore, ecosystem service benefits were only considered for the next four years of the project. The five-year limitation is logically determined by the period 2023–2027 to which the CAP applies. As mentioned above, two options were considered. We created two model cases where an intensive farmer decides whether to fertilise a hectare of erosion-prone land with a conventional mix or a regional mix.

The difference is generally in the prices of the mixtures. While the conventional blend is generally less costly and so inexpensive to procure, the regional blend is naturally more costly due to its demanding production; therefore, there is a significantly higher subsidy in the first year of the project than when using the conventional option. However, we did not have an opportunity to seize a price offer for sowage of both variants, thus we calculated with same cost for establishment of grassland, its maintenance and renewal sowage.

From the farmer's perspective, it is not economically viable to undertake normal grassing mixture to set up a conservation grassland for two reasons. Firstly, it is generally quite difficult for a farmer to sell out produced hay and have a direct financial profit from selling it, unless that farmer has also his/her own cattle production which would allow an internal consumption within the corporation. Furthermore, there are some legal obstacles too as far as production of haylage for sale is concerned. Thus, it would not be just to calculate the possible benefit from the selling the hay. Secondly, farmer would not get any additional subsidy for the ecosystem service of 'protecting the erosion-prone land' even though the measure of conservation grassland is effective, either from the state or private sector.

VI: *Economic balance for Farmer - Grassing Variant 'Normal Mix'*

COSTS (CZK) 1 ha	1 year	2 years	3 years	4 years	5 years
Loss from arable land production	15,814	15,814	15,814	15,814	15,814
Establishment of grassland on arable land	8,933	-	-	-	-
Maintenance	-	3,000	3,000	3,000	3,000
Renewal Sowage	-	447	447	447	447
Total initial cost	24,747	-	-	-	-
Recurring costs	-	19,261	19,261	19,261	19,261
BENEFITS (CZK) 1 ha					
*Income from grass production**	*0*	*4,685*	*4,685*	*4,685*	*4,685*
Annual subsidies	7,486	7,486	7,486	7,486	7,486
Annual classical subsidy per area	5,431	5,431	5,431	5,431	5,431
Ecosystem service *anti-erosion***	*0*	*6,560*	*6,560*	*6,560*	*6,560*
Total benefits	12,917	24,162	24,162	24,162	24,162
Total	**-11,830**	**4,901**	**4,901**	**4,901**	**4,901**
Additional subsidy needed while not taking into account income from grass production and anti-erosion ecosystem service***	*11,830*	*6344*	*6344*	*6344*	*6344*

Source: Author, own processing, the ESVD database from 2020 (De Groot *et al.*, 2020); CAP Strategic Plan 2023–2027 CNB exchange rate as of 16. 1. 2023 1 EUR = 23.995 CZK.
* calculated according to Konečná, Pražan *et al.*, 2014.
** the value of anti-erosion ecosystem service was calculated according to calculation of total volume of arable land that would undergo conservation grassland (TEO 10) and the difference between the two maximums of potential topsoil loss in CZK without and with conservation grassland. TEO 10 class (40 t/ha/year – 8 t/ha/year after grassing = 32 t/ha/year at least saved => 32 × CZK 205 = CZK 6,560 worth of soil saved every year)

VII: *Net Present Values in 5 Years – "Normal Mix" Grassing Mixture*

Variants	$NPV_{3\,\%}$	$NPV_{5\,\%}$	$NPV_{7\,\%}$
Erosion ecosystem service + income from grass production + subsidies	6,387.5	5,548.70	4,770.72
Erosion ecosystem service + subsidies	-11,027.11	-11,064.07	-11,098.36
Only subsidies included	-35,411.27	-34,325.51	-33,318.47

Source: Authors' own elaboration, NPV% = net present value without values of ecosystem services – and the discount rate %

Therefore, it is necessary to look at these aspects as well, because the farmer is, first and foremost, also an entrepreneur, and if he has a negative result in his farming, even if potentially only on a small part of his capital – the land – other unfavourable circumstances of the farming business may discourage him from following this model. Moreover, the farmer could help the landscape, and the state would get an implicit benefit of another CZK 119,774 per hectare in the value of other ecosystem services beside anti-erosion ecosystem service. The state should look at this as an opportunity that could remedy the dismal state of the Czech agricultural landscape in terms of not only erosion but also other ecosystem services. If the value of ecosystem services is not taken into account, the net present value is always negative, and the project is, therefore, not interesting for a conventional farmer. Therefore, it is again necessary to encourage representatives of the state, local governments, and farmers themselves to place greater emphasis on education about ecosystem services, hand in hand with increasing support for the establishment of grasslands on erosion-prone land. Government would have to spend additional CZK 3.85 billion in a five-year project to subsidise farmers to at least equalize their expenses and opportunity costs if we were to grass 103,428.4 hectares, that would mean an increase in additional subsidy in the first year of project by CZK 11,830 per hectare and then by CZK 6,344 per hectare every year in four upcoming years.

As we have seen in "normal mix" model, the "regional mix" model is only a little bit better off, however, nearly the same applies. Without additional subsidy of at least CZK 6,290 $ha^{-1}.year^{-1}$ provided by the state, farmer would then very unlikely undertake the measure of conservation grassland on his field. The arguments for him to

VIII: *Economic balance for Farmer - Grassing Variant 'Regional Mix'*

COSTS (CZK) 1 ha	1 year	2 years	3 years	4 years	5 years
Loss from arable land production	15,814	15,814	15,814	15,814	15,814
Establishment of grassland on arable land	8,933	-	-	-	-
Maintenance	-	3,000	3,000	3,000	3,000
Renewal Sowage	-	447	447	447	447
Total initial cost	24,747	-	-	-	-
Recurring costs	-	19,261	19,261	19,261	19,261
BENEFITS (CZK) 1 ha					
Income from grass production*	*0*	*4,685*	*4,685*	*4,685*	*4,685*
Annual subsidies	26,730	5,687	5,687	5,687	5,687
Annual classical subsidy per area	5,431	5,431	5,431	5,431	5,431
Ecosystem service *anti-erosion***	*0*	*6,560*	*6,560*	*6,560*	*6,560*
Total benefits	32,161	22,363	22,363	22,363	22,363
Total	**7,414**	**3,102**	**3,102**	**3,102**	**3,102**
Additional subsidy needed while not taking into account income from grass production* and anti-erosion ecosystem service**	Not needed	6290	6290	6290	6290

Source: Author, own processing. CAP Strategic Plan 2023–2027. CNB exchange rate as of 16. 1. 2023 1 EUR = 23.995 CZK.
* Calculated according to Konečná, Pražan *et al.*, 2014.
** the value of anti-erosion ecosystem service was calculated according to calculation of total volume of arable land that would undergo conservation grassland (TEO 10) and the difference between the two maximums of potential topsoil loss in CZK without and with conservation grassland. TEO 10 class (40 t/ha/year – 8 t/ha/year after grassing = 32 t/ha/year saved => 32 × CZK 205 = CZK 6,560 worth of soil saved every year)

IX: *Net Present Values in 5 Years – Regional Grassing Mixture*

Variants	$NPV_{3\,\%}$	$NPV_{5\,\%}$	$NPV_{7\,\%}$
Erosion ecosystem service + income from grass production + subsidies	29,948.66	28,569.72	27,290.76
Erosion ecosystem service + subsidies	12,534.06	11,956.95	11,421.68
Only subsidies included	-23,378.69	-22,302.26	-21,303.87

Source: Authors' own elaboration, NPV% = net present value without values of ecosystem services – and the discount rate %

stick with conventional agriculture are constantly very strong, mainly because of the economic imbalance that the state is not willing to equilibrate. Alongside anti-erosion ecosystem service, there are of course other ecosystem services such as water retention, climate regulation and biodiversity according to ESVD, see Tab. X.

Thus, under given circumstances, to answer research question 2), it is not economically viable for the intensively farming farmer to undertake a measure of conservation grassland unless the state secures a better subsidy scheme of at least CZK 6,290 per hectare in case of regional mix variant, respectively CZK 6,344 per hectare for normal mix variant. This additional subsidy scheme would at least compensate farmer for having secured a vitally important anti-erosion ecosystem service which makes CZK 6,560 per hectare of TEO 10 of erosion hazard class.

Furthermore, implementation of the measure of conservation grassland means that other ecosystem services (Tab. X) will be present too. Taking into consideration the values from the

X: *Value of Selected Ecosystem Services "Cultivated Grassland"*

Other Ecosystem Services	$CZK.ha^{-1}.year^{-1}$
– water	15,155
– climate regulation	29,682
– biological control	15,869
– fertility	736
– waste treatment	50
– air quality	22,235
– cultural/aesthetic	5,066
– pollination	30,981
Other Ecosystem Services' Value	**119,774**

Source: Author, own processing, the ESVD database from 2020 (De Groot *et al.*, 2020); exchange rate 1 USD = 21.65 CZK.

Ecosystem Services Valuation Databese from 2020, the value of these ecosystem services would make additional CZK 119,774 $ha^{-1}.year^{-1}$ benefit. However, a limitation of both models is that the commitment period is only five years. Considering that the commitment period is only five years, the question is what would happen after the commitment period. It is quite possible that the farmer would decide to abandon the grassland practice and the land would become erosion-prone again, without appropriate protection. This would mean returning to the starting point unless the farmer realised the importance and necessity of conservation grassland and continued to manage grassland on arable land after the five-year commitment. If the land did return to the starting point, it could even be argued that the public funds had been spent inappropriately, as their impact would have mostly vanished after five years. The integration of conservation grassland into the farmer's cropping plan would naturally involve adapting the farmer's farming model, from the provision of equipment for managing conservation grassland, through haylage, to the management of the sale and general marketing of haylage, which may not be easy in years when there is a surplus of grass. Farmer without appropriate mechanisation would have to systematically order the cultivation of grassed land from other farmers who have the necessary mechanisation and technology.

Therefore, we conclude that conservation grassland is an appropriate tool. The question is what role the introduction of a conservation grassland would play, what impact it would have on the environment or, conversely, whether the harvested hay would be effectively sold and the farmer would make an explicit profit from it. A limiting factor in this research is primarily that it is not possible to say with certainty whether the value of other ecosystem services would be higher in a regional mix, or by how much, than in a normal mix because many external factors play a role here as well, beyond the scope of the research being conducted. The value of ecosystem services must inherently be part of any consideration that stakeholders have when farming agricultural land, even more so on land that is severely erosion-prone.

We would like to point out that one must always take into account the benefit of anti-erosion ecosystem service because the value of the potential damage is objectively quantifiable. Thus, by implementing a conservation grassland, we can effectively prevent the soil from degradation. However, there is another limitation to grassing only the areas that are in TEO 10 class. The areas that lie in TEO 10 class very often, nearly always, coincide with other TEO classes and it is generally very difficult to determine what should be grassed and what should not because the areas of different TEO classes are closely intertwined. For this reason, it is not always possible to grass only the area of TEO 10, however, we must be working with real situation in real agricultural area and let the experts decide what should be the total volume of grassed land in a particular area to have an effective protection against erosion.

CONCLUSION

It is regrettable that authors of the new Common Agricultural Policy for the new current period did not take into account the value of ecosystem services, particularly anti-erosion service, in their considerations and did not take into account the full opportunity cost to a farmer of grassing his production area. If the state's priority is to suppress erosion effectively in the Czech Republic, it is necessary to create conditions for farmers that will encourage them to decide to grass erosion-prone areas of their cultivated land, to cultivate them in a long-term sustainable way and, at the same time, to adapt their business model to the production of non-conventional crops that will reduce erosion to the required value as conservation grassland, besides completing also other measures. A limiting factor of this research is mainly the fact that it is not possible to link the crops grown with exact certainty to the area where conservation grassland would be needed, as these habitats naturally change with each year, new cropping plan or even new arrangement of land block parcels. Other contexts, such as fluctuations in production with respect to climatological conditions or the longer-term effects of intensive farming without grassing and soil damage due to erosion, are beyond the scope of this paper. A key finding of this research is that, if areas classified as erosion hazard class TEO 10 are not grassed, there is a potential damage to the agricultural land fund of almost CZK 4,24 billion; if they are grassed, this damage could be, at most, CZK 0.84 billion over a five-year period because erosion could never be fully suppressed. It should, therefore, be a top priority for the state and local governments to emphasise the importance of the ecosystem services that conservation grassland can provide and to make this option more attractive to conventional farmers. Hand in hand with this incentive instrument, legislation tightening and penalties, both financial and criminal, should also be applicable for poor land management that has clearly caused or is likely to cause an erosion event.

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