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SCENARIO ANALYSIS TO INVESTIGATE THE EFFECT OF IMPLEMENTING COMPENSATORY PAYMENTS FOR REDUCING WATER EROSION IN BULGARIA

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Abstract
Soil degradation due to water erosion presents a critical challenge with far-reaching economic and environmental implications. This article focuses on strategies to enhance the efficacy of agro-ecological interventions aimed at mitigating water erosion. The Strategic Plan for Agriculture and Rural Development in the Republic of Bulgaria for the 2023 – 2027 period outlines specific measures, including the "Eco Scheme for Preservation and Restoration of Soil Potential" and the "Eco Scheme for Ecological Maintenance of Permanent Plantations," to address this issue. For the purposes of this analysis, in addition to the size of compensatory payments, an indicator of the economic value of reduced water erosion is introduced. Three scenarios are simulated, each varying the size of agro-ecological payments. They are contingent upon specific outcomes achieved in reducing water erosion. The agri-environmental payments from the CAP 2023 – 2027 are tied to agricultural practices and are influenced by both the compensatory payment amount and the agricultural area. In the three scenarios considered, additional indicators include the economic value of reduced soil erosion and the extent of soil erosion reduction attributable to agro-ecological payments. For the purposes of this analysis, seven distinct crop farms located in the Blagoevgrad district were selected. The analysis revealed the necessity for differentiating compensatory payments based on the size of the farms and the specific outcomes achieved. Land degradation is a significant threat to sustainable development, particularly in Southern European countries (Barbayiannis et al., 2011). Farmers, primarily focused on their business operations and profit maximization, often lack awareness or concern for various environmental issues (Taguas and Gómez, 2015). Through their agricultural practices, farmers exert both positive and negative impacts on various processes that not only affect their own farms but also have broader implications for society and ecosystems. The adoption of effective management practices and investments in soil health protection plays a significant role in achieving balance in these processes. This approach leads to a reduction in soil erosion and degradation, enhances water retention, and helps prevent or mitigate the effects of natural disasters: landslides and floods etc. As a result of their activities, farmers have developed various protective systems in mountainous and semi-mountainous areas, where agricultural conditions are more challenging. The construction of stone walls, terracing, and other such elements by engaged farmers provides essential measures for reducing surface erosion and preventing landslides (Agnoletti et al., 2011). Soil erosion is a phenomenon, associated with a series of natural and/or anthropogenic processes of detachment and transfer of soil particles by wind, rain and irrigation waters (Rousseva, 2008).
Keywords: agriculture, agri-environmental payments, water erosion, scenario analysis
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1. Introduction

Agroecological measures are designed to support a range of conservation activities and to either promote or restrict certain agricultural practices. Examples include altering plowing regimes, utilizing cover crops, implementing various conservation techniques, etc. The European Union has introduced agro-environmental measures to mitigate the negative environmental impacts of conventional agriculture. The measures implemented under the CAP 2014 – 2020 have proven insufficient in generating significant environmental benefits, such as reducing soil erosion, etc. (Früh-Müller et al., 2019). By modeling various approaches and introducing new or improved tools to achieve specific environmental outcomes, the efficiency in the allocation of public funds can be enhanced. The analysis examines the introduction of compensatory payments based on simulated results from several farms of varying sizes located in the Blagoevgrad district. This region is notable for its favorable climatic conditions, which support the cultivation of cereals, vegetables, and perennial crops, including vines.

Soil loss resulting from water erosion is a significant environmental issue that incurs economic losses of approximately $20 billion annually in the EU (Panagos et al., 2015). This soil loss is unevenly distributed across regions, with 70% occurring in mountainous and hilly areas, which comprise only 10% of the EU's land area (Barbayiannis et al., 2011). This issue is also prevalent in Bulgaria, impacting a significant portion of the country's territory. Figure 1, titled “Actual Risk of Sheet Water Erosion of Soil,” presents data from the 2021 report by the Executive Environment Agency.

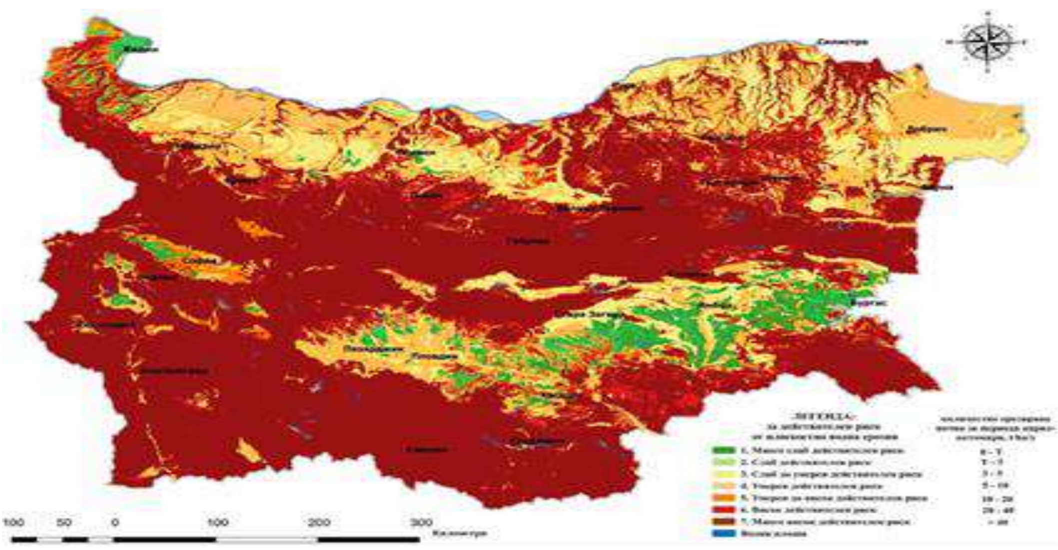

Figure 1. “Actual Risk of Sheet Water Erosion of Soil”

Source: IAES, Report for 2021

This research aims to enhance the effectiveness of agro-ecological measures by evaluating their impact on reducing water erosion. The current Strategic Plan for Agriculture and Rural Development of the Republic of Bulgaria for the 2023 – 2027 period incorporates agro-ecological measures based on agricultural practices implemented by farmers to mitigate water erosion. Three scenarios have been developed to analyze two eco-schemes from the Strategic Plan. In these scenarios, agro-ecological payments are determined by the amount of compensatory payments, the agricultural area involved, the economic value of reduced soil erosion, and the extent of soil erosion reduction due to the agro-ecological payments. In the first scenario, compensatory payments are set to match the indicative rate under the “Eco Scheme for Preservation and Restoration of Soil Potential” and the “Eco Scheme for Ecological Maintenance of Permanent Crops.” In the second and third scenarios, these compensatory payments are adjusted by increasing and decreasing them by 50%, respectively. The mathematical model incorporates both low and high indicators of the economic value of reduced soil erosion in all three scenarios. These scenarios facilitate the investigation of how compensatory payments for a given area correlate with indicators of the economic value of reduced soil erosion and the extent of soil erosion reduction achieved through agro-ecological payments. The three scenarios are tested across seven agricultural holdings in the Blagoevgrad region.

2. Methodology

This study employs scenario analysis and a mathematical model to determine the amount of agro-ecological payments. The model is based on the “CONSOLE” project, “Simulations and Implementation of New Contractual Solutions” work package (Olivieri et al., 2019). Water erosion affects the largest area in Bulgaria: about 65% of all arable land (Rousseva, 2008).

A mathematical model is utilized to simulate farmer behavior. This approach not only considers the size of the compensatory payment and the area of the farm declared under agro-ecological measures but also incorporates indicators of reduced soil erosion resulting from agro-ecological payments (δaes) and the low and high economic value of reduced soil erosion (V). The agro-ecological payment is calculated according to the following formula:

$$AESt = (P*K1) + (V * \delta aes) \quad (1)$$

where:

- $AESt$ is the total agro-ecological payment.
- P is the area of the holding declared under agro-ecology, in hectares (ha).
- $K1$ is the amount of compensatory payment, in BGN per hectare (BGN/ha).

- V is the economic value of reduced soil erosion, in BGN per ton per hectare per year (BGN/t/ha/year).
- δaes is the amount of reduced soil erosion due to the agro-ecological payment, in tons per hectare per year (t/ha/year).

The potential impact of agro-ecological measures and schemes will be assessed by comparing the contribution to erosion reduction between farms that have made commitments and those that do not participate in agro-ecological schemes. The reduced soil erosion due to agri-environmental payments is calculated using a general formula. It is the difference between:

$$\delta aes = Sp_1 - Sp_0 \qquad (2)$$

where:

- Sp_1 is the annual potential erosion of a farm that has committed to agro-ecological actions aimed at reducing soil erosion.
- Sp_0 the annual potential erosion of the farm without any environmental commitments.

This mathematical model enables the integration of compensatory payments per area with specific indicators for water erosion: V and δaes. Two schemes from the CAP 2023 – 2027 are incorporated: the “Eco Scheme for Preservation and Restoration of Soil Potential,” which promotes green fertilization, and the “Eco Scheme for Ecological Maintenance of Permanent Plantings,” which involves weeding the interrows. The indicative rates, according to the adopted Strategic Plan for the development of agriculture in Bulgaria, are BGN 223.33/ha for perennial crops and vineyards, and BGN 130.31/ha for annual crops. The following three scenarios are developed to determine the size of compensatory payments:

- **First scenario:** The compensatory payment amount is assumed to be identical to the indicative rate under the two applied eco-schemes, as outlined in the Strategic Plan for the Development of Agriculture in Bulgaria for 2023 – 2027.
- **Second scenario:** The compensatory payment amount is increased by 50%.
- **Third scenario:** The compensatory payment amount is reduced by 50%.

For each of the three scenarios, both low and high economic values of reduced soil erosion are tested.

The Report on the State of Soils for the Period 2005 – 2019 (IAES, 2021) determines various parameters for the average annual intensity of water erosion. For arable land where agro-ecological activities have been implemented, the erosion rate is 11 t/ha/year, compared to 21 t/ha/year for land without such activities. For the purposes of the study, the reduced soil erosion due to agro-ecological payments is assumed to be 10 t/ha annually.

In the Report on the Structure of Agricultural Holdings in Bulgaria (MZHG, 2021) for the 2019 campaign, the average farm size in the Blagoevgrad district is determined to be 14.37 ha. Additionally, based on the criteria used for defining the agricultural area and the structure of farms, they are categorized by size as follows:

- **Very small farms:** 1 to 5 ha
- **Small farms:** 5 to 30 ha
- **Medium farms:** 30 to 650 ha
- **Large farms:** 650 to 1500 ha
- **Very large farms:** Over 1500 ha

In the research, the selection and inclusion of the Blagoevgrad district were based on the following factors:

- Exposure, hydrogeological instability**,** rural farming practices, soil erosion issues:
- The area is intra-territorial, characterized by a very high actual risk of sheet water erosion, as indicated in the National Status Report on Environmental Protection in the Republic of Bulgaria for 2021.

For the purposes of this study, only very small, small, and medium-sized farms with a plant-growing specialization are considered. These farms primarily cultivate cereal crops, vegetables, perennials, and vineyards. They represent the majority of farms in the Blagoevgrad region. Data on these farms are summarized in Table 1, "Characteristics of the Studied Farms".

Table 1. "Characteristics of the Studied Farms"

Farm	Area under agroecological commitment, ha	Specialization	Size
1	1,80	perennial crop	Very small
2	35,0	cereals	Medium
3	2,30	vineyards	Very small
4	25,00	cereal grain	small
5	3,20	perennial crops	Very small
6	4,50	perennial crops	Very small
7	18,00	vegetables	small

Source: author's research

3. Scenario Analysis

To implement the three scenarios, simulations are conducted to calculate three different amounts of agro-environmental payments, using Formula 1. Two levels of economic value for reduced soil erosion are determined for this purpose. The scientific literature reports average soil erosion costs of approximately 50 – 60 €/t/year

(Panagos et al., 2015; Telles et al., 2011). However, there is significant variability, with estimates ranging from as low as 3 € to as high as 300 €/t/year (Panagos et al., 2015). In the developed scenarios based on the achieved results, two values for the unit benefit (V) are used for the study: a low value of 45 BGN/t/year and a high value of 90 BGN/t/year. The other key indicator considered is the reduction in soil erosion due to agro-ecological payments. For the purposes of the study, the reduction in soil erosion due to agro-ecological payments (δaes) is assumed to be 9.7 t/ha/year. Each of the three payment scenarios involves a different amount of compensatory agro-ecological payment (K).

3.1. First Scenario

In the first payment scenario, the indicative rates from the "Eco Scheme for Preservation and Restoration of Soil Potential," which promotes green fertilization, and the "Eco Scheme for Ecological Maintenance of Permanent Plantings," which involves weeding of the rows, are adopted for research purposes. According to the adopted Strategic Plan for the Development of Agriculture in Bulgaria 2023 – 2027, compensatory payments are set at BGN 223.33/ha for permanent plantations and vineyards, and BGN 130.31/ha for cereal crops and vegetables. Two indicators are introduced: low and high economic value of reduced soil erosion (V) and reduced soil erosion due to agro-ecological payments (δaes). Summary data are presented in Table 2, "Agro-Ecological Payments According to Indicative Compensatory Rates."

At a low economic value of reduced soil erosion, only Farm 1 shows a negative amount of agro-ecological payments. The compensatory payments fail to cover the established water erosion indicators, despite the various agricultural practices implemented. This outcome may lead to Farm 1 opting out of future participation in similar eco-schemes. As a small farm, it does not meet the introduced low value of reduced soil erosion. When considering a high economic value of reduced erosion, Farms 3 and 5, in addition to Farm 1, are also unable to meet the established indicators. All of these farms are very small and primarily cultivate perennials, including vineyards. The amount of their agro-ecological payments is negative. Although Farm 6 has a positive amount, it is minimal. Given this level of compensatory payments and the economic value of reduced soil erosion, participation in such an eco-scheme would not be economically viable for very small farms. These farms may implement agricultural practices, but they will not meet the established water erosion indicators. As a result, they will either receive no agri-environmental payments or their payments will be too small to cover the expenses incurred. In contrast, all other agricultural holdings, including small and medium-sized ones, will experience a positive impact from their participation in such an eco-scheme. The benchmarks to be achieved are uniform across all holdings, regardless of their varying sizes.

This scenario demonstrates that the amount of agro-ecological payments received by farmers decreases as the economic value of reduced soil erosion increases.

Table 2. "Agri-environmental Payments According to Indicative Compensatory Payment Rates"

Results-based agri-environment payments					
Farm	Specialization – Eco Scheme	Area under Agroecology (ha)	Compensatory Payment (BGN/ha)	Size of Agroecological Payments (BGN)	
				Low Economic Value of Reduced Erosion (BGN)	High Economic Value of Reduced Erosion (BGN)
1	Perennial crops – EPPSS	1.80	223.33	-48.01	–498.01
2	Cereal grain – ECPPC	35.00	130.31	4110.85	3660.85
3	Vineyards – EPPSS	2.30	223.33	63.66	–386.34
4	Cereal grain – ECPPC	25.00	130.31	2807.75	2357.75
5	Perennial crops – EPPSS	3.20	223.33	264.66	–185.34
6	Perennial crops – EPPSS	4.50	223.33	554.99	104.99
7	Vegetables – ECPPC	18.00	130.31	1895.58	1445.58

Source: author's research

3.2. Second Scenario

In the second scenario, compensatory payments are increased by 50%. For farms growing cereals and vegetables, the payment will be BGN 195.47 per hectare, while for those cultivating perennial crops and vineyards, it will be BGN 335.00 per hectare. Table 3, titled "Agri-Environmental Payments with 50% Increased Compensatory Payment," summarizes the data. No farmer receives a negative amount of agro-ecological payments when a low economic value of reduced erosion is applied. Only Farm 1 and Farm 3, the smallest holdings, show negative agro-ecological payments at the high level of economic value of reduced erosion. However, these farms have no issues applying agricultural practices to address the low levels of soil erosion. Here as well, a decrease in agro-ecological payments to individual farmers is observed as the value of reduced erosion increases. However, for larger farms, this percentage reduction is smaller.

Table 3. "Agri-environmental Payments with 50% Increased Compensatory Payment"

Results-based agri-environment payments					
Farm	Specialization – Eco Scheme	Area under Agroecology (ha)	Compensatory Payment (BGN/ha)	Size of Agroecological Payments (BGN)	
				Low Economic Value of Reduced Erosion (BGN)	High Economic Value of Reduced Erosion (BGN)
1	Perennial crops – EPPSS	1.80	335	152.99	–297.01
2	Cereal grain – ECPPC	35.00	195.47	6391.28	5941.28
3	Vineyards – EPPSS	2.30	335	320.49	–129.51
4	Cereal grain – ECPPC	25.00	195.47	4436.63	3986.63
5	Perennial crops – EPPSS	3.20	335	621.98	171.98
6	Perennial crops – EPPSS	4.50	335	1057.48	607.48
7	Vegetables – ECPPC	18.00	195.47	3068.37	2618.37

Source: author's research

3.3. Third Scenario

In the third payment scenario, a 50% reduction in compensatory payments is applied for the purposes of the study. The payment amount varies based on the type of cultivated crop. For farms growing cereal crops and vegetables, the payment will be BGN 65.16 per hectare, while for those cultivating perennial crops and vineyards, it will be BGN 111.67 per hectare. Table 4, titled "Agri-Environmental Payments with 50% Reduced Compensatory Payment," summarizes all the data. At a low economic value of reduced erosion, Farms 1, 3, and 5 show negative agri-environmental payments. Farm 6, which also grows perennials, will receive a small payment under the low value of reduced erosion, despite the activities performed. All of these farms are very small. With a high economic value of reduced soil erosion, Farm 6 will also fail to meet the criteria and will receive a negative amount of agri-environmental payments.

Table 4. Agri-environmental Payments with 50% Reduced Compensatory Payment

Agri-environmental Payments Based on Results					
Farm	Specialization – Eco Scheme	Area under Agroecology (ha)	Compensatory Payment (BGN/ha)	Size of Agri-environmental Payments (BGN)	
				Low Economic Value of Reduced Erosion (BGN)	High Economic Value of Reduced Erosion (BGN)
1	Perennial Crops – ESCP	1.80	111.67	–249	–699
2	Cereal Crops – ESVP	35.00	65.16	1830.43	1380.43
3	Vineyards – ESCP	2.30	111.67	–193.17	–643.17
4	Cereal Crops – ESVP	25.00	65.16	1178.88	728.88
5	Perennial Crops – ESCP	3.20	111.67	–92.67	–542.67
6	Perennial Crops – ESCP	4.50	111.67	52.49	–397.51
7	Vegetables – ESVP	18.00	65.16	722.79	272.79

Source: author's research

4. Conclusion

The three analyzed scenarios of agri-environmental payments are related to the implementation of eco-schemes aimed at protecting soil from water erosion. In the current Strategic Plan for the Development of Agriculture and Rural Areas in the Republic of Bulgaria for the period 2023 – 2027, these agroecological measures are based on the agricultural practices implemented by farmers. This approach is not sufficiently effective in terms of public fund allocation. A shift to a new model is necessary, one that associates practices to specific, measurable outcomes. For the purposes of this study, indicators such as the economic value of reduced soil erosion and the actual reduction in soil erosion due to agroecological payments are introduced. Three scenarios were developed to analyze the "Eco Scheme for Preservation and Restoration of Soil Potential" and the "Eco Scheme for Ecological Maintenance of Permanent Crops." In all three scenarios, farmers not only apply specific agricultural practices but also simulate certain outcomes. Agri-environmental payments depend on both the agricultural area and the size of the compensatory payment. The mathematical model also incorporates the economic value of reduced soil erosion and the actual reduction in soil erosion due to agroecological payments. Three scenarios were developed for size of the compensatory payment, including low and high economic value of reduced soil erosion. Between all these indicators, as a result of the analysis, certain dependencies were derived.

The introduction of agro-ecological payments, combined with indicators that measure the effectiveness of reducing soil erosion, requires careful examination and research. There is a need to diversify the compensatory payment amounts and the economic value of reduced soil erosion based on the size of the farm. For many small farms, it is crucial to either increase the amount of compensatory payments or lower the performance indicators. For medium-sized farms, it may be feasible to raise the water erosion reduction targets or reduce the compensatory payments. This approach will enhance the efficiency of agro-ecological payments, leading to tangible results in reducing water erosion, optimizing public expenditure, and delivering agroecological public goods. It is essential to minimize the risk for individual farmers of potentially failing to meet the indicators set, despite the application of prescribed agricultural practices.

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