Analysis of investments on agricultural householding related to climate change resilience in Slovenia

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Abstract

This article explores climate-related investments co-financed under Measure 4 of Slovenia's Rural Development Programme (RDP) 2014–2022, with a focus on enhancing the resilience of agriculture to climate-related risks. The analysis is based on administrative data comprising 20,645 approved investments, of which 3,664 (29%) were identified as contributing—directly or indirectly—to climate resilience. Using a thematic classification method, the study reveals distinct patterns of investment orientation. Two main groups emerged: (1) frequent, lower-cost operational investments such as slurry tanks, fertilizer and manure spreaders, anti-hail nets, and private irrigation systems; and (2) less frequent, capital-intensive infrastructure investments, including the new construction of cattle housing and protected structures (greenhouses). Additionally, investments in water reservoirs have improved water self-sufficiency and increasing the resilience of farms to weather variability. In total, 96 investments worth EUR 954,512 were approved for the construction or renovation of reservoirs. Also 97 investments worth a total of EUR 901,510 were approved for the arrangement of existing irrigation systems, including modernizations and expansions that enable more efficient and responsive use of water resources. These are strategically important investments for managing weather-related risks such as drought and hail, contributing both to the day to day response capacity of farms and to the long-term structural resilience of agricultural production. The findings highlight the importance of evidence-based targeting of public support towards investments with the greatest potential to reduce climate vulnerability and ensure the sustainable transformation of agriculture in increasingly variable conditions.

INTRODUCTION

Climate change is already having a significant impact on many extreme weather and climate events in all regions of the world (IPCC, 2022). Europe is warming faster than the rest of the world, with the average global surface temperature rising by around 1.2°C between 2018 and 2022 compared to the previous period (1850–1900), while in Europe this difference was around 2.2°C (EEA, 2024). Agriculture in the European Union is increasingly facing the impacts of climate change, with more frequent droughts, floods and other extreme weather events threatening farm productivity and stability. According to the European Commission, weather and climate events cause average annual losses exceeding EUR 28 billion in the EU agricultural sector, with droughts accounting for more than half of the damage (European Commission, 2024). Despite these risks, insurance coverage remains low, underscoring the need for proactive adaptation measures. The EU's Common Agricultural Policy (CAP), notably its Rural Development Programme (RDP), supports investments on farms aimed at strengthening climate resilience. Measure 4 of the RDP, which focuses on physical investments, co-finances infrastructure and equipment that help reduce the vulnerability of farms to climate risks and improve resource management—including irrigation systems, livestock manure storage facilities and protective structures (European Commission, 2018). Investments of this type are increasingly recognised as key to improving adaptive capacity and ensuring the stability of production in changing weather conditions.

Recent OECD findings highlight the crucial role of scaling up such investments to achieve adaptation goals, especially in sectors such as agriculture, where infrastructure directly reduces exposure to extreme weather events (OECD, 2024). Despite their importance, systematic evaluations of these investments—especially in terms of their contribution to climate change adaptation—are still limited. Most studies focus on economic or environmental impacts, while fewer studies examine whether and how these investments contribute to long-term resilience (Loboguerrero et al., 2019). Furthermore, knowledge about the typology and distribution of climate-relevant investments is limited, especially based on comprehensive administrative datasets. To address this gap, our study analyses all approved investment applications under Slovenia's RDP 2014–2022, covering the period from 2014 to December 2023. We apply a thematic classification method based on the stated purpose of each investment, identifying those that contribute directly or indirectly to climate adaptation.

This article analyses investments made in agricultural holdings in Slovenia, co-financed under the RDP 2014–2022, which contribute to the adaptation of agriculture to climate change. Based on data on the number of approved investments and the amount of allocated funds, it identifies key investment groups and their focus on strengthening climate resilience. The aim is to shed light on national investment patterns that support agricultural resilience and inform future policy design.

Material and methods

In the research, we analysed the administrative database from the Ministry of Agriculture, Forestry and Food of all approved investments within the framework of the Rural Development Programme of the Republic of Slovenia 2014–2022 [analysed years from 2014 to December 2023]. The collection includes data on individual applications, such as the name of the investment, the name of the cost, the classification of costs, quantity, unit of measure, approved value and administrative codes.

Based on the substantive descriptions of the investments, we created thematic categories that reflect the main purpose of the individual investment. We further classified them into subcategories, using manual keyword analysis for the most accurate typification possible.

Thematic categories include:

- Agricultural machinery and equipment for fertilisation
- Agricultural machinery and soil cultivation equipment
- Hail protection nets,
- Construction of livestock housing
- Livestock manure storage facilities
- Private irrigation systems and related equipment
- Renewable energy generation on farms
- Protected structures and associated equipment
- Renovation and maintenance of livestock housing
- Establishment of permanent crops with protective measures
- Geothermal energy systems
- Protective film against fruit cracking and sunburn
- Construction of composting platforms
- Construction of small biological wastewater treatment plants (up to 50 PE)

The purpose of the analysis was to identify and evaluate only investments that contribute to the adaptation of agriculture to climate change – either by reducing exposure to weather and climate risks or by improving the management of natural resources, especially water and soil. We included both investments with a direct adaptation effect (e.g. hail protection nets, private irrigation systems, water reservoirs), as well as investments that are primarily intended to mitigate climate change, but also indirectly contribute to adaptation. The latter include, for example, investments in equipment for handling livestock excreta (tanks, spreaders, storage facilities), which enable timely and efficient fertilization even in adverse weather conditions. Such equipment strengthens the resilience of agricultural production to weather extremes and thus significantly contributes to adaptation, which is why we included it in the analysis.
Spatial and energy solutions, such as greenhouses, new housing construction and equipment for heating or energy self-sufficiency, which enable more stable and less weather-dependent production, were also included. Soil tillage machinery and seeders also play an important role in operational adaptation, contributing to better resource use, soil protection and greater adaptability of production.

For data analysis, we used descriptive statistical methods to calculate the number of approved investments and the total approved value by individual categories and subcategories. We also presented the results graphically, with an emphasis on the types of investments that were the most common or received the most financial resources. We paid special attention to the subcategories in terms of their occurrence and financial scope, as they best illustrate the orientations of Slovenian agriculture in adapting to climate change.

Results and discussion

By the end of December 2023, 2,543 applications or 20,645 investments had been approved within the framework of the Rural Development Programme 2014–2022, of which 1,613 applications or 3,664 investments were intended to strengthen the resilience of agriculture to climate change. The total value of approved investment funds for the entire period amounted to 177.6 million EUR, of which 29% or 51.5 million EUR was allocated to strengthening climate resilience. Further analysis focuses on this 29% investments.

The analysis was carried out at the level of approved investments and not at the level of approved applications, as a beneficiary can apply for multiple investments with one application (the average number of investments per application during this period was 2.3). Figure 1 shows the distribution of approved funds among the 10 main investment categories. Four minor categories (geothermal energy systems, protective film against fruit cracking and sunburn, construction of composting platforms, construction of small biological wastewater treatment plants - up to 50 PE) have been excluded due to their marginal financial share, as they together account for only 1% of the total approved investment funds. The most frequently supported investments, in terms of number, were technically simple and financially more accessible. The category agricultural mechanization and machinery intended for fertilization dominated, with 1,252 investments and a total approved value of EUR 10.2 million, which represents one third of the investments considered. These investments are particularly suitable for small and medium-sized farms, enabling operational adaptation to changed production conditions. Other commonly supported categories included private

irrigation systems and associated irrigation equipment (468 investments), anti-hail nets (447 investments), livestock manure storage facilities (498 investments) and soil cultivation machinery (367 investments). Together, these four categories comprised 1,780 investments or 48.58% of all investments analysed, indicating their central role in the daily response of farms to climate risks such as drought, hail and water pollution.

In terms of the total amount of approved funds, more capital-intensive investments stand out (Figure 1). The highest total value was achieved by the category construction of livestock housing (16.2 million EUR or 31.5% of all investments). This is followed by the agricultural machinery and equipment intended for fertilization (10.2 million EUR), followed by private irrigation systems (5.0 million EUR), protected spaces and associated equipment (4.3 million EUR), agricultural machinery for soil cultivation (3.9 million EUR), livestock manure storage facilities (3.6 million EUR) and anti-hail nets (3.2 million EUR). This distribution of investments confirms the presence of two complementary approaches, namely high-frequency, operational and accessible investments and low-frequency, infrastructure and capital-intensive investments. Both groups play a key role in increasing the resilience of the agricultural sector.

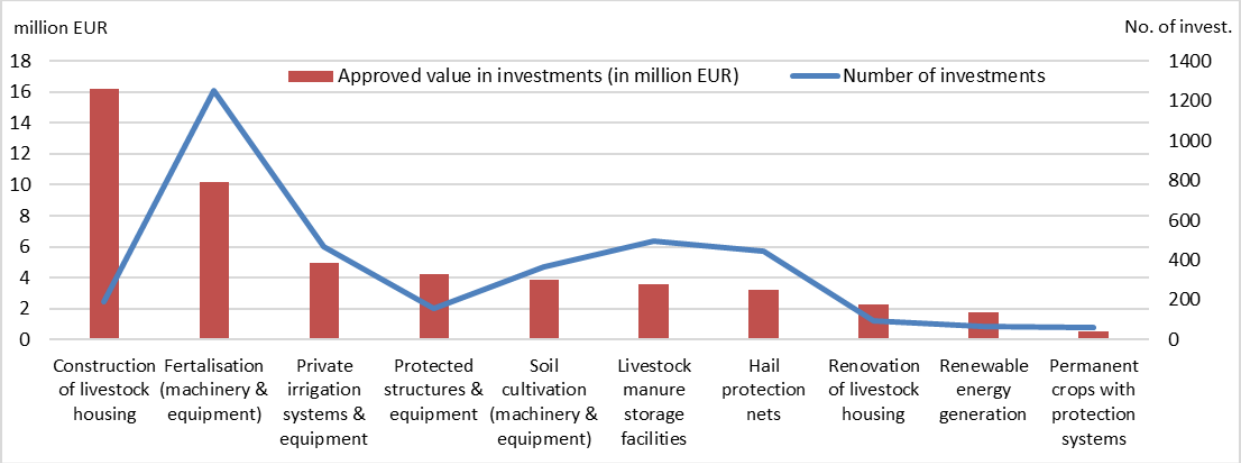

Figure 1: Distribution of investments by categories

Source: Ministry of Agriculture, Forestry and Food of the Republic of Slovenia; Agricultural institute of Slovenia calculations

The results of the subcategories we identified within the above-mentioned categories are presented below. We identified 65 subcategories, but for the main part of the analysis we focus on the first twenty subcategories (top 20) with the highest total value of approved funds, as they represent approximately 87% of the total value of the investments analysed (Table 1).

In first place is New construction of cattle housing with 115 investments and 10.7 million EUR in total approved funds (93,332 EUR per investment), which indicates a highly capital-intensive investment. High average values per investment were also recorded for greenhouses (52,475 EUR), poultry (166,518 EUR) and pig housing (74,325 EUR), which means that these investments are generally accessible to larger and specialized farms.
On the other hand, measures that were common but financially less extensive (EUR/investment) stand out. The most prominent example is slurry tanks (353 investments, 3.2 million EUR), which together with distribution pipes with trailed coulters and trailed pipes represent a comprehensive system for low-emission and targeted application of organic matter and represent 10.5% of all approved funds. It is one of the most important sets of technological adaptation, as it enables responsive nutrient management in the face of changing precipitation and temperature conditions. The installation of anti-hail nets also has a special position (397 investments, 3.0 million EUR), with a relatively high frequency and an average value of 7,434 EUR. Almost 5.7% of all approved funds represent investments in the installation of anti-hail nets. These nets represent one of the key measures for reducing exposure to direct weather risks and preventing crop losses due to increasingly frequent hail.

A total of 468 investments worth almost EUR 5 million were approved under the category Private irrigation systems and irrigation equipment. Of this, the majority (199 investments, 1.3 million EUR) were for the purchase of equipment such as pipes, pumps and drip irrigation systems, which indicates a widespread need for technological modernization of basic irrigation functions on farms. A significant part of the funds for private irrigation systems was also allocated for the arrangement of basic infrastructure such as water connections, pressure stations and supply channels (40 investments, 1.3 million EUR). In addition, 97 investments worth a total of 0.9 million EUR were approved for the arrangement of existing irrigation systems, including modernizations and expansions that enable more efficient and responsive use of water resources. Investments in water reservoirs, which are intended to retain rainwater or other water sources for use during dry periods, also play an important role in this group. In total, 96 investments worth 1 million EUR were approved for the construction or renovation of reservoirs, confirming their role in improving water self-sufficiency and increasing the resilience of farms to weather variability. These are measures that are strategically important for managing weather risks such as drought and hail.

Also important are numerous improvements in the management of livestock excreta, especially through the use of manure spreaders (242 investments, EUR 2,480,965) and fertilizers (276 investments, EUR 1,417,295),which enable daily operational adaptation with smaller resources.

Table 1. Distribution of investments by subcategory

	Approved value (EUR)	Approved value (%)	Number of investments	Average investment value (EUR)
Cattle housing - construction of livestock housing	10,733,189	20.8	115	93,332
Greenhouses	3,673,275	7.1	70	52,475
Pig housing - construction of livestock housing	3,418,956	6.6	46	74,325
Slurry tanks	3,222,989	6.3	353	9,130
Hail protection nets	2,951,212	5.7	397	7,434
Seeders for dense or row sowing	2,733,478	5.3	136	20,099
Manure spreaders	2,480,965	4.8	242	10,252
Trailing hose applicators for slurry tanks	2,166,224	4.2	166	13,050
Poultry housing - construction of livestock housing	1,998,223	3.9	12	166,519
Pig housing - renovation of livestock housing	1,448,123	2.8	48	30,169
Fertiliser spreaders - machinery and equipment	1,417,295	2.8	276	5,135
Development of irrigation infrastructure	1,294,235	2.5	40	32,356
Construction of slurry pits with drive-over slab	1,280,329	2.5	67	19,109
Irrigation equipment (private irrigation systems)	1,254,737	2.4	199	6,305
Slurry pit equipment (manure removal systems)	985,978	1.9	233	4,232
Water reservoirs	954,512	1.9	96	9,943
Irrigation system improvements	901,510	1.8	97	9,294
Biomass boilers	753,600	1.5	22	34,255
Seeders (attached units for dense sowing - width 3m)	606,711	1.2	64	9,480
Energy prod. from renewable sources (facilities, equipment)	590,534	1.1	25	23,621
Top 20	44,866,075	87.1	2,704	
Other investments for climate resilience	6,634,992	12.9	960	
TOTAL	51,501,067	100.0		

Source: Ministry of Agriculture, Forestry and Food of the Republic of Slovenia; Agricultural institute of Slovenia calculations

The remaining 13% of investments, which are not separately mentioned in Table 1, do not stand out financially, but they play an important role within the framework of strategies to increase the resilience of agriculture to climate change. For example, this include innovative energy investments such as geothermal energy (1 investment, EUR 387,300), and environmentally-oriented micro-investments, such as the new construction of small biological wastewater treatment plants (up to 50 PE) (17 investments, EUR 16,564) and films to protect fruits from cracking and sunburn (9 investments, EUR 91,676). In the fruit sector, there are sprinkler and anti-salt systems (36 investments, EUR 563,759) and the installation of plantation devices simultaneously with anti-hail nets (57 investments, EUR 556,168), which are a response to increasingly frequent weather extremes.

The analysis highlights the diverse and complex strategies used by agricultural holdings to reduce climate vulnerability. These investments range from simple, short-term investments to capital-intensive infrastructure investments, all contributing to greater resilience (Pret et al., 2025). Broader adoption of such investments, supported by coherent policy and adequate funding, will be essential to ensure the long-term stability and sustainability of Slovenian agriculture.

Conclusions

The analysis of investments related to the adaptation of agriculture to climate change showed significant differences between the types of investments in terms of their frequency, financial scope and accessibility. By category, the most frequently made investments were in fertilization machinery, mainly in slurry tanks, which were the subject of 353 approved investments. Together with distribution trailed pipes and trailed coulters, these investments represented a comprehensive technological package for targeted, low-emission application of nutrients, which contributed to reducing environmental losses and increasing soil resistance to drought and leaching. Their prevalence and relatively low average value per investment indicate the wide availability and operational applicability of these solutions in practice. In terms of total approved value, investments in new housing construction stand out (190 investments, EUR 16.2 million), among which the subcategory of new housing construction for cattle breeding stood out, where the total approved value was 10.7 EUR million which indicates the important role of infrastructure investments for the long-term adaptation of livestock systems. Investments in new housing construction in poultry farming were

also among the highest average values per investment, where it amounted to 166,819 EUR per investment, which indicates a concentration of funds in more technologically demanding industries. On the other hand, the most common investments were hail nets (397), fertilizer spreaders (276), manure spreaders (242), slurry pit and slurry equipment (233), private irrigation systems - equipment (199), where the average values per investment ranged from EUR 4,232 to EUR 10,252, which demonstrates the importance of smaller but numerically widespread investments in increasing the resilience of farms to weather risks.

The analysis confirms that both operational investments enabling rapid response to weather extremes and long-term infrastructure measures are essential for strengthening agricultural resilience. Funding should prioritise measures with the greatest impact on the long-term resilience of agro-ecosystems. Strategic and targeted investments are needed to effectively manage climate risks and support sustainable adaptation (Ortiz-Bobea et al., 2024). As the analysis covers only co-financed investments under the Rural Development Programme 2014–2022, it does not reflect privately funded or policy unsupported actions. Nevertheless, it provides valuable insight into public support priorities for climate resilience in Slovenian agriculture.

Based on the findings, several recommendations for decision-makers are proposed. First, small-scale operational investments—such as slurry tanks, trailing hose applicators for slurry tanks, manure spreaders and anti-hail nets should remain a funding priority, as they enable rapid adaptation and are widely adopted by farms. Second, infrastructure investments such as livestock housing, irrigation systems and greenhouses play a strategic role in long-term resilience and should be supported in a more targeted manner, particularly in regions and sectors most exposed to climate-related risks such as drought and hail. Third, to ensure that public support achieves its intended adaptation outcomes, clear criteria should be developed for assessing the climate resilience potential of proposed projects. Finally, the diversity and technical complexity of the investments suggests a need for stronger advisory services and knowledge transfer mechanisms to support the effective implementation of climate-resilient technologies on farms.

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