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Legislating for Soil Conservation: A 20-Year Review and the New Approach of the CAP in Spain

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Over the past two decades, soil conservation measures in the Rural Development Programmes (RDPs) of the Common Agricultural Policy (CAP) have played a crucial role in soil conservation in Spain. Despite detailed regional data, a comprehensive evaluation of executed public spending allocation and its drivers was lacking. This study aimed to (i) analyze direct and indirect soil conservation measures in RDPs over the last 20 years and (ii) explore the relationship between public spending, soil condition, and other drivers to evaluate if public spending was reasonably distributed. Moreover, the study reflects on the approach toward soil conservation within the new CAP. Our methodological approach included data mining and inventory creation of agri-environmental and agroforestry measures, spatial and temporal analysis, and statistical evaluation of correlations between these measures and factors such as land use, soil condition, socio-economic environment, and political influences. Results indicated an increase in executed public spending for soil conservation alongside a rising environmental perspective over three programming periods, with regional variations. A significant relationship between public investment, land use, and soil condition (including soil erosion) indicated a moderately reasonable distribution of public spending on measures for soil conservation in the last two decades within the RDPs. Political changes had minimal impact on soil conservation measures, highlighting that the CAP's main environmental goals remain mostly apolitical. Moving forward, from 2023 onwards, all new rural development actions were incorporated into national CAP strategic plans aligned with the European Green Deal. Soil conservation measures have been largely incorporated into the CAP's first pillar and, in some cases, it has become compulsory for farmers in order to receive subsidies, sparking conflicts in many regions. This new phase highlights the ongoing challenges in balancing soil conservation with agricultural practices amidst evolving social and environmental conditions.

Keywords: common agricultural policy, soil management, soil strategy, rural development programmes, green deal

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INTRODUCTION

Soil degradation driven by unsustainable land use remains a major environmental threat across Mediterranean Europe (United Nations, 1994; Lavado Contador et al., 2009). Soil erosion, which has been frequently used as a proxy for soil degradation, is widely extended throughout Spain, where 23% of the land is affected by erosion rates higher than the tolerable levels (Ministerio para la Transición Ecológica y el Reto Demográfico, 2022); Spain also has a mean soil loss of 12.3 t^{-1} ha^{-1} yr^{-1} compared

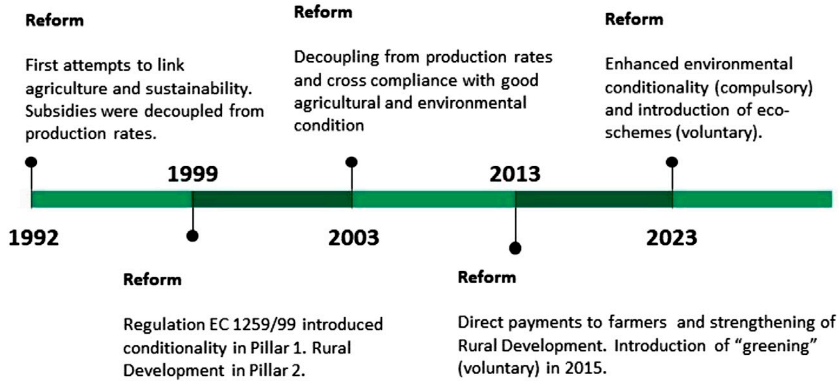

FIGURE 1 | CAP reforms since 1992 and their impact on environmental policy.

to Europe's 3.07 3 t^{-1} ha^{-1} yr^{-1} (Panagos et al., 2021). Loss of topsoil by erosion significantly impacts its fertility by reducing the organic matter and other nutrients, as well as reducing porosity and water retention capacity, degrading structure, and increasing runoff (Boix Fayos et al., 2005; Martínez-Mena et al., 2020). The literature has shown that many characteristically eroded landscapes could be traced back to the expansion of grain agriculture and nomadic livestock ranching (Van Leeuwen et al., 2019) with other drivers such as deforestation, expansion and intensification of agriculture, and, more recently, land abandonment (Eekhout et al., 2021; Fernández Carrillo, 2015; García-Ruiz, 2010) contributing to soil degradation over the years.

Human activities can worsen soil degradation, decreasing the system's capacity for recovery (Ibáñez et al., 2016). The European Common Agricultural Policy (CAP), from 1992 onwards, started shifting toward more sustainable practices and away from production-based subsidies. In this sense, its second pillar, Rural Development, served as an instrument to structure environmental policies of member-states within the CAP framework. As the environmental aspects gained importance influenced by international awareness, Rural Development Programmes (RDPs) established specific measures, quantified spending, and tracked results.

This paper had two objectives: (i) to analyze the spatial and temporal distribution of the RDPs' Soil Conservation Measures (SCM) over two decades in Spain; and (ii) to explore the relation between SCM public spending, actual soil condition, and other possible drivers. This paper intends to answer the hypothesis H_1, namely that soil conservation measures in Spain are positively correlated with soil condition, showing the importance of European legislation and RDPs to enable access to funds for soil-conscious development.

Soil Conservation Legal Framework: The CAP and Rural Development Programmes

The CAP has the biggest budget of all EU expenditure and rests on two pillars: agriculture and rural development. The latter was the focus of this study, as it demonstrated a consistent financing framework for measures that were broadly similar across different programming periods. This contrasts with measures in pillar 1, where compulsory environmental conditions had changed substantially with the different CAP reforms and the incorporation of voluntary elements such as greening, or the more recent eco-schemes, could not be compared between periods. All in all, the environmental perspective became progressively important within the CAP from 1992, when subsidies were decoupled from production rates (**Figure 1**).

The CAP established the RDPs as a means to structure and co-finance measures to guarantee the future of European rural areas (European Commission, 1997), promoting

- Accompanying measures introduced in 1992 (early retirement, agri-environment and climate measures [AECM], and agroforestry).
- Diversification measures for farms (subsidies for the transformation and commerce of agricultural products, vocational training, promotion of agriculture, and conversion).
- Structural adaptation of the farms and settlement of the young population.

Following those guidelines, EU member states developed a national RDP that could then be further divided by regions. In the case of Spain, in addition to a national RDP specifying horizontal measures, 17 RDPs were implemented for each of its regional administrations. The RDPs were adapted to the specific needs of the regions where they were implemented, depending on a previous analysis of the situation in each region (Fernández Carrillo, 2015). RDPs had to be previously approved by the European Commission, and their implementation had to be evaluated and audited throughout their development (inter-annual evaluations and a final *expost* evaluation). On a national scale, once the 17 RDPs were written and approved, they were activated through specific legislation, although throughout the entirety of their execution period they could be (and often were) subjected to changes. As a consequence of these changes, some measures may appear unused, due to possible changes in the prioritization of the RDP in question. Other measures, meanwhile, might have been incorporated into the RDP anew (Fernández Carrillo, 2015). To date, there have been three separate RDP programming periods, corresponding to the 2000–2006, 2007–2013, and 2014–2020 periods. Within these programs, soil conservation was listed in measures, sub-measures, or lines of action.

Interaction of Rural Development Programmes With Other Strategies

While the RDPs were being applied, Spain was also implementing strategies born out of commitments taken during the United Nations Convention to Combat Desertification (UNCCD) in 1994. Many of these strategies were designed to work in conjunction with RDPs and use their funds towards their successful execution. The 2002 National Plan of Priority Actions for Hydrological and Forestry Restoration, Erosion control and Defence Against Desertification (PNAP), established 19% of the 3.5 M.ha as high priority and planned the reforestation and afforestation of agricultural lands, the establishment of meadows and grasslands, soil conservation practices, and riverbank restorations. These actions were partly funded through the RDPs agri-environmental and forestry measures.

The 2008 National Action Program against Desertification (PAND) (Ministerio de Medio Ambiente y Medio Rural y Marino, 2008) aimed to promote sustainable development in desertification-prone areas of Spain by preventing land degradation and restoring degraded lands. It included a series of non-binding commitments and objectives. The PAND conducted situation diagnoses, risk mapping, and strategies for agriculture, forestry, and water management, after which it proposed a series of measures that could be funded through RDPs, among other instruments. Some of the PAND measures were

- Measure 1.3. on soil conservation and forestry activities → may be funded by RDPs forestry measures.
- Measure 1.4. on soil conservation, agricultural activities, and the management of pastures and meadows → may be funded by RDPs AECM.
- Measure 2. on protection against forest fires → may be funded by RDPs forestry measures.

The PAND was updated by the National Strategy against Desertification of 2022, recently updated in 2025 (MITECO, 2025).

Present and Future Framework: The European Green Deal

The European Green Deal (EGD) re-established the European Commission's commitment to address the challenges related to the environment and climate. It is necessary to understand how some aspects of RDPs were previously applied in Spain and how certain measures contributed to achieve environmental goals with farmers as the main conservation agent. This helps to understand the evolution and application of the CAP framework in the EGD stage. The EGD adopted several key land-management strategies to enhance the implementation of environmental commitments (Cuadros-Casanova et al., 2022). In particular, the Farm to Fork (F2F), Biodiversity (BS), and Soil (SS) Strategies place sustainable agriculture as a common objective to reach sustainability goals (Boix-Fayos and de Vente, 2023).

The latest 2023–2030 reform addresses its environmental commitments by use of three instruments: (i) enhanced conditionality (mandatory) with increased commitments called the "*Good Agricultural Environmental Conditions*" (GAEC) (European Commission, 2018); (ii) "*Agri-Environmental and Climate Measures*" (AECM), which are voluntary for farmers but mandatory for member states to include in their National Strategic Plans; and (iii) *eco-schemes,* which are also mandatory for member states but voluntary for farmers. Some environmental measures previously included in RDPs, such as measures to combat erosion, have been incorporated into pillar 1. Still, the effectiveness of environmental legislation, specifically AECM and eco-schemes, has been questioned in some studies (Cuadros-Casanova et al., 2022; Díaz et al., 2021; Nadeu et al., 2023).

Within this legal framework and social unrest, we lacked perspective and understanding on the evolution and distribution of executed public spending for soil conservation, how it was distributed at the regional level, and whether it correlated with soil condition.

METHODS

Data Mining

Executed Public Spending on SCM

To identify SCM in Spain's RDPs, 17 RDP documents were reviewed, as well as the national RDP for each programming period (2000–2006, 2007–2013, and 2014–2020), totaling 54 documents examined. SCM were extracted out of the RDP's *ex-ante* and *ex-post evaluations*, published by the Spanish Ministry of Agriculture for each region (Ministerio de Agricultura, Pesca y Alimentación, 2023b) during the years 2000–2022. Data on total executed public spending on RDPs and SCM were extracted from financial tables published in *ex-post evaluations* (**Figure 2**). The latest available data, as of December 2022, are presented in **Table 1**. The reliability of publicly available data was not assessed in this study.

Soil conservation measures can be found within the AECM (Ministerio de Agricultura, Pesca y Alimentación, 2023a; Petito et al., 2022; Samela et al., 2022). As AECM sub-measures varied widely, only those linked to soil conservation were chosen (**Table 1**). Afforestation measures were also selected as representative of indirect measures for soil conservation, as it is considered to mitigate land degradation if properly managed (Cerdá et al., 2017; Muñoz Rojas et al., 2011; Zethof et al., 2018). Forestry measures directed at erosion control or land restoration after wildfires were also considered. Finally, measures subsidizing ecological agriculture, separated from

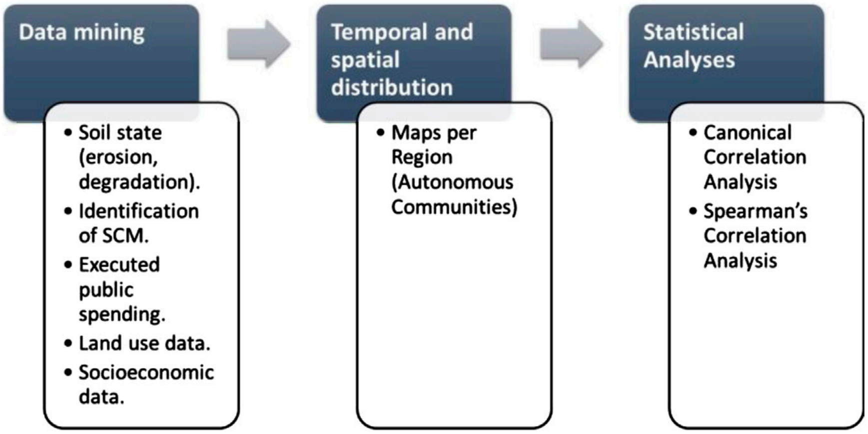

FIGURE 2 | Methodology workflow.

TABLE 1 | Indicators and sources of data used in analysis.

Group	Subgroup	Indicator	Unit	Description	Source
Executed public spending	Public spending per hectare	SCM/ha	€/ha	Public spending on soil conservation measures per applicable area (in hectares)	Ministerio de Agricultura, Pesca y Alimentación (2023a), Ministerio de Agricultura, Pesca y Alimentación (2023b)
		SCM-RDP	%	Percentage of RDP budget allocated to soil conservation measures	
		AECM	€/ha	Public spending on agri-environmental and climate measures per applicable area (in hectares)	
		Forestry measures	€/ha	Public spending on afforestation and forestry related to soil conservation measures per applicable area (in hectares)	
Spatial	Land use	UAA	%	Utilized agricultural area	Instituto Nacional de Estadística (2023)
		Meadows	%	Surface of permanent meadows and pastures	
		Fallow lands	%	Surface of fallow lands at the moment of survey	Ministerio de Agricultura, Pesca y Alimentación (2023b)
		Shrubland	%	Surface of plant communities dominated by shrubs	
		Forest	%	Surface of forests composed of tree species	
		Irrigated UAA	%	UAA with irrigated crops	
Soil condition	Land cover	WASL	$t \cdot ha^{-1} \cdot yr^{-1}$	Weighted average soil loss (soil loss in tonnes per hectare and year)	Ministerio para la Transición Ecológica y el Reto Demográfico (2022)
		SL-crops	%	Soil losses in crops over total soil losses	
		S-Gullies	%	Surface covered by gullies and ravines	
	State	S-Severe	%	Surface affected by severe erosion	
		S-Degraded	%	Surface with degraded soils	Sanjuán et al. (2014)
Socio-economic	Population	Inhabitants	%	Proportion of national population	Instituto Nacional de Estadística (2023)
	Rural Population	Rural pop.	%	Number of people living in population centers of no less than 30,000 inhabitants and 100 inhabitants/km^2 over total population	Instituto Geográfico Nacional (2023), Instituto Nacional de Estadística (2023)
	GDP	Agri. GDP *per capita*	M.€/ppl	Agriculture, ranching, silviculture and fishing GDP per rural inhabitant	Instituto Nacional de Estadística (2023)
Political	Ruling party	PSOE	%	Spanish Socialist Workers' Party (left-wing) (days in power during a programming period)	Senado de España (2023)
		PP	%	Peoples Party (right-wing) (days in power during a programming period)	
		Regionalist	%	Regionalist parties (days in power during a programming period)	

Variables with high multicollinearity that were not used in CCA do not appear in this table.

AECM during the last programming period, were taken into account as well. This data provided a comparable framework among the three programming periods. Sub-measures, including knowledge sharing or in an advisory capacity by professionals, were discarded as results were not quantified or published in all programming periods.

Land Use

Land use data were included to explore potential drivers of public spending. It was hypothesized that land use could be a strong driver of funding due to the regions' differences in extension and overall characteristics. Therefore, the most relevant variables with publicly available data from the INEBase website (Instituto Nacional de Estadística, 2023) were the region's total area, Utilized Agricultural Area (UAA), meadows, fallow lands, shrublands, forest, forest (tree species only), rainfed crops area, and irrigated crops area. **Table 1** shows the variables that were chosen for the statistical analyses.

Soil Condition

Erosion rates were considered as a key process of soil degradation, and data at the regional scale were available. Data were obtained from the National Soil Erosion Inventory (INES), which detected, quantified, and mapped the main erosion processes in Spain (Ministerio para la Transición Ecológica y el Reto Demográfico, 2022). The National Soil Erosion Inventory considered soil loss tolerance to be dependent on its capacity to maintain its fertility, which is, in turn, dependent on topsoil depth. In this way, tolerance can vary between 11.2 t ha^{-1} year $^{-1}$ for soils with an effective depth higher than 150 cm and 2.2 t ha^{-1} year $^{-1}$ when the effective depth of the soil is less than 25 cm. Tolerance also decreases when soil substrate is not favorable for its regeneration (Alonso Mielgo et al., 2001).

Weighted average soil loss (t ha^{-1} year $^{-1}$) was used to measure erosion intensity and could be divided by land cover (*WASL-forest* and *WASL-crops* in **Table 1**). The National Soil Erosion Inventory provided a supplementary categorization that took soil quality based on field work into account, for which categories "*severe*" and "*very severe*" were used in this study (*S-severe* in **Table 1**). Surface areas covered by gullies and ravines (*S-Gullies* in **Table 1**) were also used.

Land degradation (*S-Degraded* in **Table 1**) was extracted from the publication "*Mapa de la Condición de la Tierra en España*" (Sanjuán et al., 2014), which uses the UNCCD's definition of land degradation as being the point where an exploited ecosystem loses its productivity (United Nations, 1994), to show areas of low vegetation production and its evolution over time and thus establish degradation categories.

Other Variables: Socio-Economic and Political Dimension

Georeferenced spatial data for municipal borders and areas were obtained from the National Geographic Institute (IGN) and used to calculate population density by crossing the data with population records from the National Statistics Institute (*Rural Population*, **Table 1**). The rural population was calculated using the definition "*density of less than 100 inhabitants/km2 in population centres of no more than 30,000 people*" (Law 45/2007 of 13 of December). Yearly data on agriculture, ranching, silviculture, and fishing Gross Domestic Product (GDP) were also extracted from this website.

Days governed by a political party were extracted from the Spanish Senate's website (**Table 1**). The political parties were the (i) PSOE (Spanish Socialist Workers' Party), (ii) PP (People's Party), and (iii) Regionalist parties, which are the only parties to have governed regional parliaments to date.

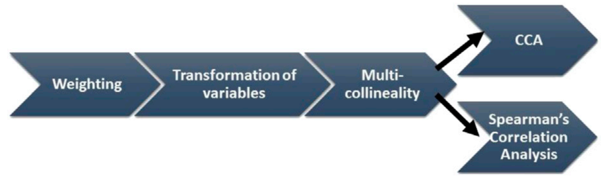

FIGURE 3 | Workflow diagram for correlation analysis between different subsets.

Spatial and Statistical Analyses

Spatial analysis of executed public spending and soil condition (**Figure 6**) was carried out for visual representation using the GIS software QGIS 3.16.13 (QGIS Development Team, 2022). It was also used to calculate the rural population variable, extracting the municipalities' areas and population.

Additionally, an efficacy index was calculated as the coefficient of SCM/ha divided by SCM-RDP. This index showed the relationship between each region's effort toward soil conservation and the amount of financing implemented per hectare. This index was used as a proxy for the efficiency of SCM in executing public spending and helped account for situations where regions might prioritize soil conservation but end up with lower spending per hectare, due to either having a smaller overall RDP budget or a larger number of hectares eligible for subsidy. In this sense, the previous case would show a higher value than regions that ended up with high spending per hectare (due to high budgets) but low soil conservation effort (as a percentage of RDP total budget).

Before conducting the statistical analyses, all variables were weighted (**Figure 3**) as follows:

- SCM executed public spending was weighted by each region's RDP budget (SCM-RDP in **Table 1**) to establish the prioritization of soil conservation within their land management strategies.
- SCM executed public spending was also weighted by area of applicability (hereafter eligible areas) for each measure (*SCM/ha* in **Table 1**). The eligible areas for agri-environmental measures for soil conservation (direct SMC) were UAA, fallow lands, and shrublands. On the other hand, forestry measures (used as indirect SCM) could be applied in UAA, fallow lands, shrublands (afforestation measures), or forests (restoration and prevention measures).
- All land use variables were weighted by the region's size.
- Population was weighted by national total, whilst rural population was weighted by each region's population.
- Agriculture, ranching, silviculture, and fishing GDP was weighted by rural population to obtain rural GDP *per capita* (*Agri.GDP per capita* in **Table 1**).
- Specific political parties' days of governance were weighted by total number of days of each programming period.

For statistical analyses, data were organized into a 24-variable matrix composed of five subsets: (i) SCM executed public spending as the dependent variables and (ii) land use, (iii) soil condition, (iv) socio-economic, and (v) political variables as the independent variables (**Table 1**).

To identify the possible drivers of executed public spending in SCM, associations between sets of variables were explored, and multivariate statistics was applied. Dimensionality reduction of the variables in subsets i-iv was used to explore correlations among the different subsets, as it considers the interaction of all variables within the subset. This was achieved via the Canonical Correlation Analysis (CCA), as seen in **Figure 2**. CCA was performed to measure possible correlations between the dependent variables' and the independent variables' subsets. R software (R Core Team, 2023) package *candisc* (Friendly and Fox, 2024) was used. Assumptions of normality and homoscedasticity were checked using the Shapiro-Wilk and Breush-Pagan tests. Transformations were applied to variables that failed to meet the previous assumptions based on the method that provided the lowest sum of absolute values of skewness and kurtosis. Transformation methods were

➢ Logarithmic: applied with a shift (+1) to ensure non-positive values were handled when data was highly skewed.
➢ Box-Cox: applied when all values were positive.
➢ Square root: applied to non-negative values when the data was moderately skewed.

Multicollinearity within the subsets was also checked, extracting variables with a variance inflation factor higher than 5. Irrigated and rainfed crops area (0.99 correlation), forest and forest (tree species only) (0.91 correlation), and SL-forest and SL-crops (0.89 correlation) were redundant. For this reason, the variables with the highest VIF factor were discarded, resulting in the extraction of the rainfed-crops area, forest (tree species only), and SL-forest variables.

Four CCA runs were performed, where the dependent variables (SCM executed public spending subset) were plotted against the (i) land use, (ii) soil condition, and (iii) socio-economic subsets. Correlations among the first and second pairs of canonical variates (linear combinations of the variables within each dataset that best explained the variability both within and between datasets) for each subset were explored. Canonical correlation R^2, adjusted R^2, and p-values were calculated.

Spearman's correlation analysis was also performed for the governance variable, as they had an exclusionary nature toward one another (when one political party is governing, the others are forcefully not), making it unsuitable for CCA.

RESULTS

Identification of Soil Conservation Measures Within the Rural Development Programmes

Fifty-four documents were analyzed, ten measures that were common to all regions and with an impact on soil conservation were identified, and total executed public spending to date was calculated. As seen in **Figure 4**, the SCMs that remained unchanged throughout the periods were mostly forestry, afforestation, and agri-environmental measures.

During the first programming period (2000–2006), agri-environmental SCM could be found in **Measure 6** and **Measure 8** (measure to combat badly degraded soils such as abandoned industrial land or quarries). On the other hand, forestry measures SCM were found in **Measure 9**.

In the second programming period, subsidies in pillar 1 continued to be decoupled from production rates with no major changes. In pillar 2, AECM were found in **Measure 214**, while afforestation was set in **Measures 221** and **223**. **Measure 226** dealt with the recovery of forest masses and the prevention of soil erosion after wildfires.

The 2014 CAP reform incorporated the '*greening*' of single payments, aiding farmers to comply with the CAP's environmental targets. *Greening* supported farmers who applied crop diversification, maintained permanent grassland, or dedicated 5% of their arable land to areas beneficial for biodiversity (Regulation (EU) No 1307/2013) (European Parliament and Council of the European Union, 2013). It also aimed to achieve higher equity in subsidizing farmers by lowering payments for larger farms (van Leeuwen et al., 2019). In pillar 2, agri-environmental SCM were part of **Measure 10**. Ecological agriculture which, in the previous programming period was considered as an AECM in Measure 214, was separated in **Measure 11**. Finally, forestry measures were part of **Measure 8**.

The selected measures related to soil conservation for the three programming periods were similar enough (**Figure 4**) to provide a comparable framework for analyzing executed public spending over time and regions.

Temporal and Spatial Distribution of Soil Conservation Executed Public Spending Within the Rural Development Programmes

Overall, RDP budgets decreased over the three programming periods. Notably, after the first programming period, some of Spain's regions were no longer considered underdeveloped in regards to the EU average (Álvarez-Martínez and Clemente, 2017), which affected the total RDP budget of said regions. **Table 2** shows that, despite budgets steadily decreasing over three programming periods, the commitment towards SCM grew, peaking during the 2014–2020 period with an 18% increase. Indeed, total executed public spending in SCM increased by 13% at the end of the last programming period when compared to the first, whilst the overall RDP budget decreased by 78% over the same 20-year period. This resulted in SCM having an increasingly higher weight within the RDPs after each programming period (**Figure 5**).

Some measures showed low adoption (deciding against allocating funds toward a specific measure) or low execution of programmed public spending. Specifically, during the 2000–2006 period, **measure 3.6** "*Protection and regeneration of the natural environment*" was not contemplated by Aragon whilst the Balearic Islands reported zero execution after initially

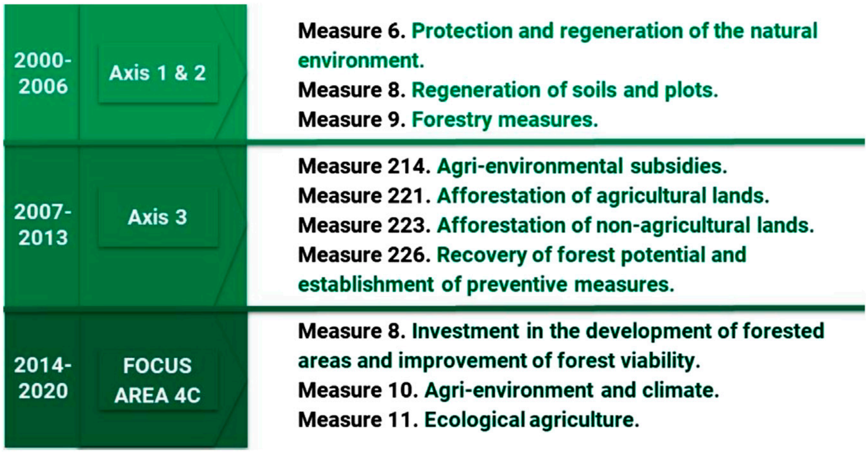

FIGURE 4 | Soil conservation measures during the programming periods.

TABLE 2 | Means and standard error of executed public spending (millions of euros) within Rural Development Programs in Spain.

Public spending indicator	2000–2006	2007–2013	2014–2020
RDP	2,775.40 ± 823.38	771.93 ± 175.56	614.26 ± 138.59
SCM	206.52 ± 70.27	242.85 ± 74.85	233.02 ± 62.88
AECM	121.17 ± 52.01	147.98 ± 44.36	145.41 ± 42.96
Forestry SCM	85.35 ± 21.74	94.87 ± 31.85	87.61 ± 28.24

RDP, *Rural Development Programmes;* SCM, *Soil conservation measures;* AECM, *Agri-environmental and climate measures.*

programing over 3M. € to the measure. **Measure 3.8**, "*Regeneration of soil and plots*," was not programmed by ten regions, whilst the Canary Islands only spent 56.12% of the original programmed public spending. M**easure 3.9**, "*Forestry measures*," also showed the Balearic Islands only spent 37.64% of what was originally programmed.

During the 2007–2013 programming period, **measure 221**, "*Agri-environmental subsidies*," was not contemplated by Asturias or the Canary Islands. Similarly, **measure 223**, "Afforestation of non-agricultural lands," was not adopted by 11 Regions, being the most unsuccessful measure.

During the last 2014–2020 programming period, **measure 8**, "*Investment in the development of forested areas and improvement of forest* viability," had a low execution of initially programmed public spending in eight regions. In addition, **measure 11** "*Ecological agriculture*" showed a low execution of what was initially programmed in the Canary Islands.

Spatial variability was notable for the accumulated executed public spending over the 20-year period (**Figure 6**). **Figure 6A** shows the regions that prioritized soil conservation above other rural development measures were mostly the central and north-eastern regions. **Figure 6B**, on the other hand, shows *SCM/ha* (**Table 1**) regardless of RDP's overall budget. In this case, the north-western, southern, and eastern regions showed the highest spending per eligible hectare. **Figure 5C** shows that the regions that spent most in *AECM* (as in **Table 1**) were similar to the previous case, whilst **Figure 6D** shows that regions that spent most in *forestry measures* (as in **Table 1**) were the northern regions, close to the Cantabrian mountains, and the Canary Islands.

The efficacy index (**Table 3**) showed that the most efficient region in spending for soil conservation (higher spending per eligible hectare at a lower cost within the RDP) was the Canary Islands, very distant from the rest. Other regions above the median were Asturias, Murcia, Galicia, Valencia, Cantabria, Andalusia, Extremadura, and Castile and Leon. On the other hand, the least efficient regions were Basque Country, La Rioja, Castilla-La Mancha, Navarra, the Balearic Islands, Catalonia, Aragon, and Madrid, which must make more effort but without achieving high amounts of spending per hectare.

The heterogeneity of the regions that resulted from the temporal and spatial distribution, as well as the efficacy index, suggested there is a complex interaction of factors that explain the distribution of SCM executed public spending as opposed to a single variable, validating the use of multivariate statistics CCA to study their relation.

Statistical Analysis and Patterns in Executed Public Spending

Patterns in the allocation of SCM funds and executed public spending were explored to identify which combination of factors explained the spatial distribution of funds within Spain. The CCA showed the first and second ordinations that maximized correlations among two subsets (a subset of independent variables against a subset of dependent variables). These ordinations were used as canonical variates. Two levels of analysis were explored: (i) accumulated executed public spending over the 20-year period and (ii) segmented by programming period.

Regarding accumulated executed public spending, CCA showed significant correlations with two of the subsets

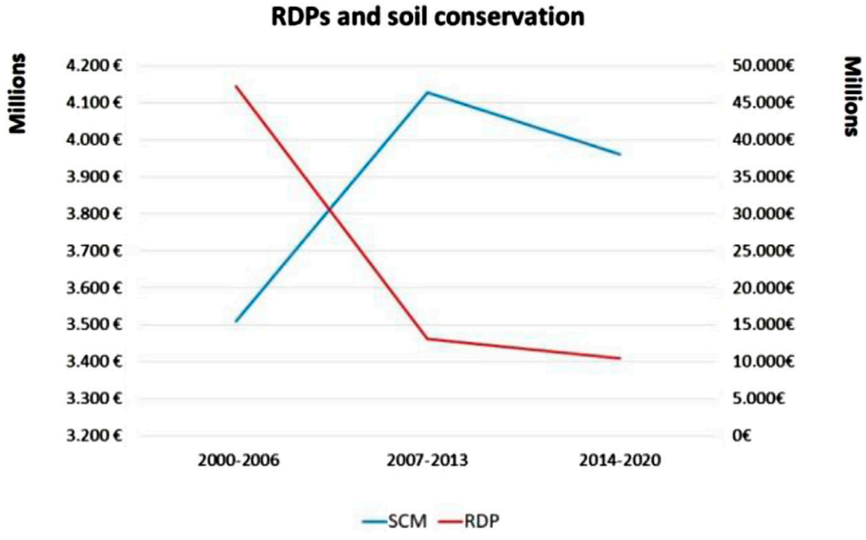

FIGURE 5 | Chart shows executed public spending in soil conservation measures (blue line, left axis) against Rural Development Programmes' total budget (red line, right axis) over time. Source: Spanish Ministry of Agriculture.

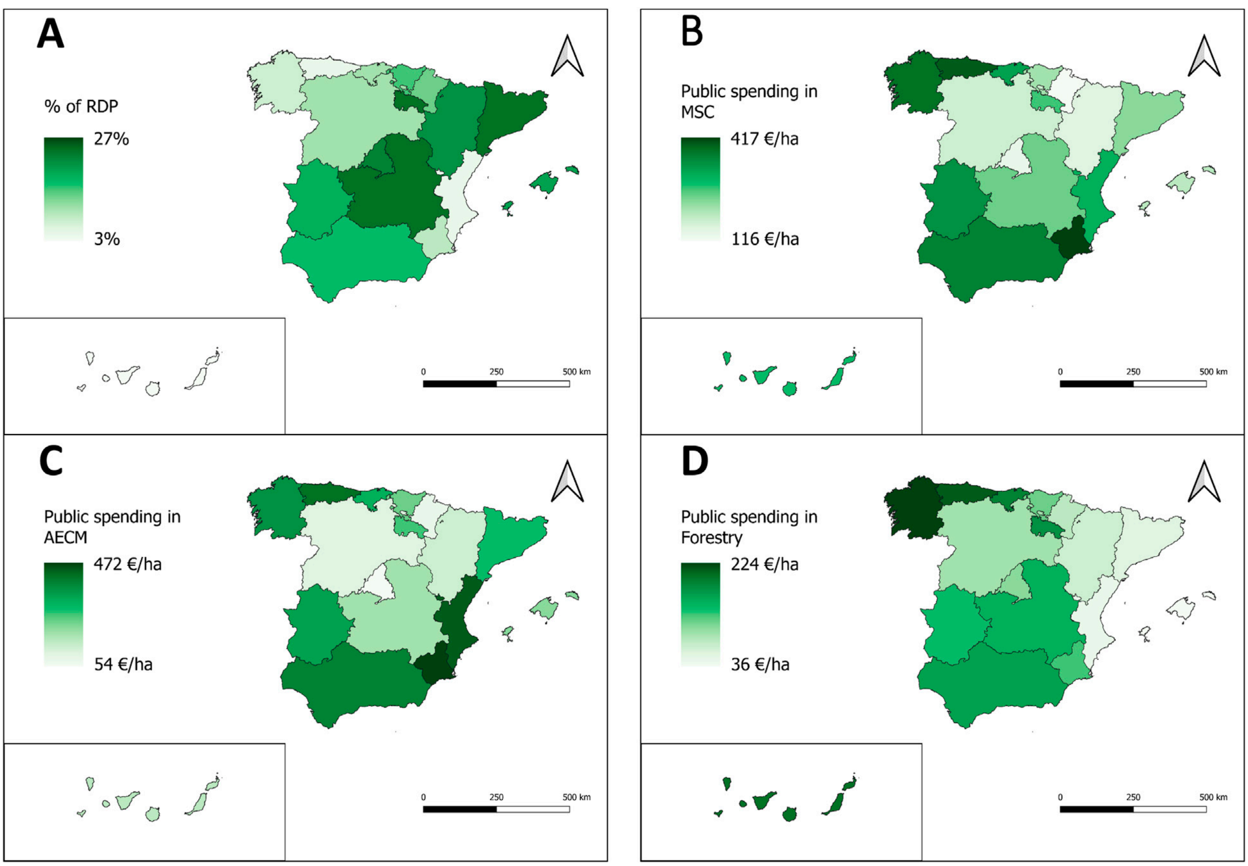

FIGURE 6 | Public spending in soil conservation measures and their distribution among the 17 regions (Autonomous Communities) in Spain.

TABLE 3 | Executed public spending per region.

(a) SCM-RDP (%)		*(b) SCM/ha* (€)		(b/a) Efficacy index	
1. Castilla-La Mancha	27.44	1. Murcia	417.42	1. Canary Islands	78.52
2. Catalonia	26.78	2. Asturias	375.27	2. Asturias	35.31
3. La Rioja	26.60	3. Galicia	348.72	3. Murcia	32.33
4. Madrid	25.94	4. Andalusia	329.01	4. Galicia	29.13
5. Aragon	23.92	5. Extremadura	305.33	5. Valencia	24.20
6. Balearic Islands	20.95	6. Cantabria	280.50	6. Cantabria	20.13
7. Extremadura	19.32	7. Valencia	268.52	7. Andalusia	17.87
8. Andalusia	18.41	8. Canary Islands	231.71	8. Extremadura	15.80
9. Basque Country	17.13	9. La Rioja	229.00	9. Castile and Leon	10.06
10. Navarra	15.17	10. Castilla-La Mancha	214.04	10. Basque Country	9.39
11. Cantabria	13.94	11. Catalonia	175.79	11. La Rioja	8.61
12. Castile and Leon	13.72	12. Basque Country	160.85	12. Castilla-La Mancha	7.80
13. Murcia	12.91	13. Balearic Islands	147.33	13. Navarra	7.65
14. Galicia	11.97	14. Castile and Leon	137.99	14. Balearic Islands	7.03
15. Valencia	11.10	15. Aragon	121.39	15. Catalonia	6.56
16. Asturias	10.63	16. Madrid	117.57	16. Aragon	5.08
17. Canary islands	2.95	17. Navarra	115.99	17. Madrid	4.53

*Percentage of RDP budget allocated to soil conservation measures (*SCM-RDP*); Public spending in soil conservation measures per applicable area in hectares (*SCM/ha*). Efficacy index shown in column b/a.*

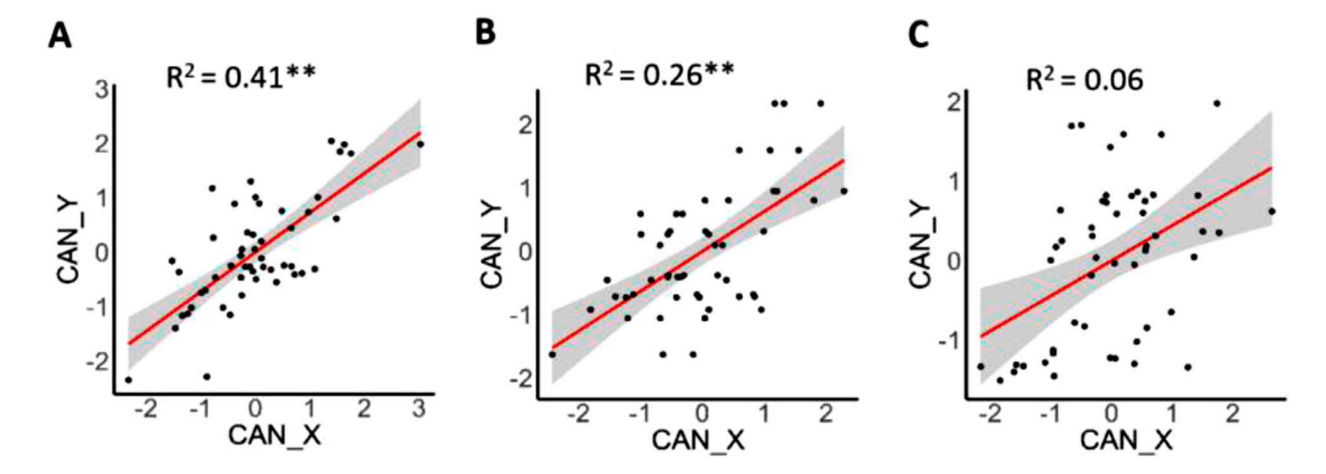

FIGURE 7 | Scatterplot of the first canonical variates for CAN_X on the horizontal axis shows the executed public spending subset. CAN_Y on the vertical axis are **(A)** the land use subset's canonical variate, **(B)** the soil condition subset's canonical variate, and **(C)** the socio-economic subset's canonical variate. P-values under 0.05 (*) and 0.01 (**) and adjusted R^2 are shown.

(**Figure 7**). The first canonical variates of each subset were plotted in **Figure 7**, where the X-axis represents the canonical variate for the executed public spending subset, whilst the Y-axis represents the canonical variates of the other variable subsets. The scatterplots shows executed public spending was moderately correlated to land use (**Figure 7A**) and weakly correlated to soil condition variates (**Figure 7B**), with highly significant p-values. No significant correlations were found with the socio-economic variates used (**Figure 7C**).

Table 4 shows the variable coefficients for the CCA results in **Figures 7A,B**. The table indicates the weight of individual variables within the first and second canonical variates, and, thus, shows which ones are responsible for the association between the two subsets.

Land Use Variate CAN1: A high score was driven by a strong positive influence from irrigated utilized arable areas (+1.15) and meadows (+0.56). This is contrasted by a strong negative coefficient for UAA (−0.83). This indicates that, as irrigated land and meadows increased, UAA tended to decrease.

Soil Condition Variate CAN1: A high score on the corresponding soil variate was primarily associated with a strong negative coefficient for severe erosion (−1.33), meaning less severe erosion. However, this was countered by a significant positive coefficient for overall soil loss (+1.23), indicating more general runoff.

The association between the second canonical variate (CAN2) explained a smaller amount of the variance shown by a lower R^2 (although still highly significant).

TABLE 4 | Coefficients for the first and second canonical variate of each subset against public spending variate.

Public spending	Land use		Soil condition	
Subset variable	CAN1	CAN2	CAN1	CAN2
SCM-RDP	0.56	−0.50	−0.60	0.09
SCM/ha	0.31	−1.14	−0.62	−1.28
AECM	0.42	1.46	0.76	−0.03
Forestry measures	−0.43	1.09	1.12	0.72

Land use variable	Public spending CAN1	Public spending CAN2	Soil condition variable	Public spending CAN1	Public spending CAN2
UAA	−0.83	−0.22	*WASL*	1.23	−0.70
Meadows	0.56	0.45	*SL-crops*	−0.83	−0.35
Fallow lands	−0.05	0.19	*S-severe*	−1.33	0.25
Shrubland	0.02	−0.60	*S-degraded*	−0.32	0.13
Forest	−0.17	0.20	*S-Gullies*	0.29	−0.59
Irrigated UAA	1.15	0.14			
Adjusted R2	0.41	0.21		0.26	0.10
p-value	7.97e-07**	4.23e-03**		0.01**	0.17

*P-values under 0.05 (*) and 0.01 (**). Percentage of RDP budget allocated to soil conservation measures (*SCM-RDP*); Public spending in soil conservation measures per eligible areas in hectares (*SCM/ha*); Public spending in soil conservation agri-environmental and climate measures per eligible areas in hectares (*AECM*); Public spending in afforestation and forestry related to soil conservation measures per eligible areas in hectares (*Forestry measures*); utilized arable area (UAA).*

Land Use Variate CAN2: This variate was defined by a strong opposition between the type of spending and the intensity of the expenditure. The high score on the variate was driven by significant positive coefficients for spending on agri-environmental measures (+1.46) and forestry measures (+1.09). This is strongly opposed by a significant negative coefficient for public spending per eligible hectare (−1.14).

Soil Condition Variate CAN2: A high score on this variate indicated better soil health. This is shown by negative coefficients for overall water and soil loss (−0.70) and for gullies (−0.59). The variate was also strongly and negatively influenced by public spending per eligible hectare (−1.28).

Figure 8 shows CCA for the segmented data on executed public spending. The association between SCM executed public spending and land use significantly strengthened from the first to the second programming period, as shown by **Figures 8A,A′**, before decreasing in the last programming period (**Figure 8A′′**). Correlation remained strong and significant during the last period. Meanwhile, the association between SCM executed public spending and soil condition remained stable during the first two programming periods (**Figures 8B,B′**) but significantly increased during the last period to a strong significant correlation (**Figure 8B′′**). No significant or strong correlations were found between SCM executed public spending and the socio-economic variables used in this study when segmented by programming period.

As mentioned in Section *Spatial and Statistical Analyses*, political variables had to be analyzed using univariate statistics due to their nature. Spearman's correlation matrix was performed, obtaining statistically significant correlations between executed public spending on SCM and regionalist parties governance (**Table 5**). The analysis showed a significant moderate correlation in the first programming period with *forestry measures*, which at the time was **measure 9** (**Figure 4**). During the second and third programming period, regionalist parties showed a negative moderate and highly significant correlation with *SCM-RDP*, indicating that soil conservation may have not been a priority within the RDPs when conducted by these governments.

The two major political parties that have governed regional chambers during 2000–2020 displayed, at best, a weak to moderate correlation, and none were found to be statistically significant.

In summary, CCA analysis showed that executed public spending was driven by (i) land use and (ii) soil condition. Within those subsets, correlations were mostly driven by irrigated land (land use subset) and severe erosion and soil loss (soil condition subset). Associations changed over time. The correlation between spending and land use was strongest during the 2007–2013 period, and the correlation between spending and soil condition was strongest during the 2014–2020 period. In addition, Spearman's correlation analysis of the governance variable showed that regional politics matter little. The only correlations found were for Regionalist governments (very few regions had them), where negative correlation with executed public spending in SCM was found.

Changes in Rural Development After the 2023 CAP Reform

Spain's National Strategic Plan (Ministerio de Agricultura, Pesca y Alimentación, 2023c) has planned to spend 1.76 M.€ per year on rural development, which amounts to 7.05 M.€ over a four-year period. This follows the downward trend that started after the first planning period. Of this amount, 48.7% is directed toward environmental measures, which amounts to 3,368.94 M.€. This amount was spent on soil conservation alone in the previous planning periods. As stated in Section *Interaction of Rural Development Programmes With Other STrategies*, this could be due to SCM being incorporated into pillar 1. Enhanced conditionality in pillar 1 changed previous *greening* measures to compulsory GAEC. Those that affect soil conservation are GAEC 1 "*maintenance of permanent grassland*" and GAEC 8 on "*non-productive features*." Also, GAEC 2 "*Protection of wetlands and peat bogs*" is a new addition to conditionality that could affect soil condition. Besides pillar 1 conditionality, rural development continues to offer an array of measures that affect soil conservation, shown below:

- Intervention **6501.2**. Sustainable crops.
- Intervention **6841.1**. Aid for productive investments on farms linked to environmental and climatic objectives.
- Intervention **6881.3**. Non-productive investments in forest damage restoration.
- Intervention **6501.6**. Maintenance or improvement of habitats.
- Intervention **6501.8**. Soil improvement and erosion control.
- Intervention **6502.1**. Forest management commitments.
- Intervention **6881.1**. Non-productive forest investments in reforestation and agroforestry systems.

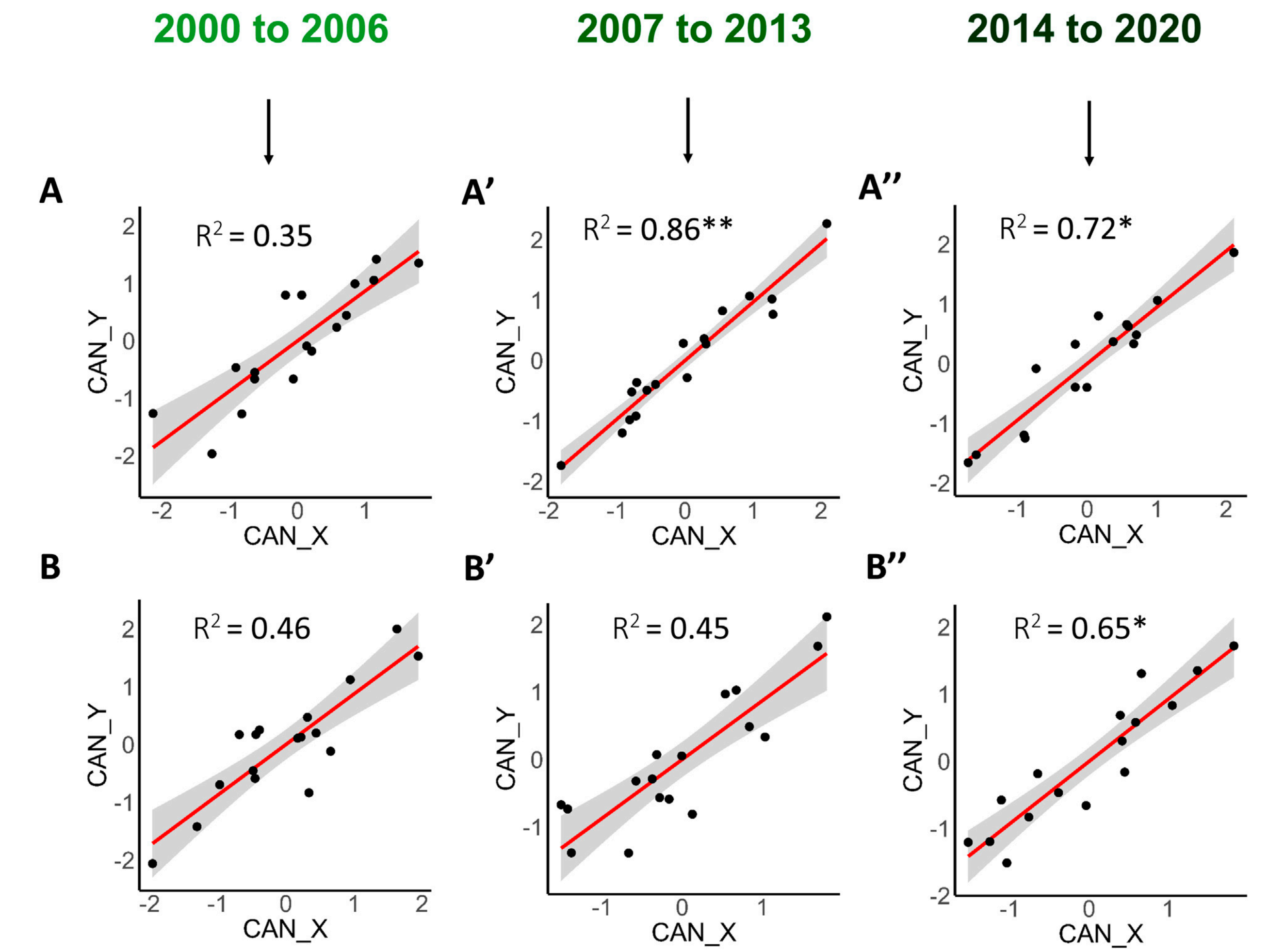

FIGURE 8 | Scatterplot for executed public spending in SCM segmented by programming period. CAN_X on the horizontal axis shows the first canonical variate of the executed public spending subset. CAN_Y on the vertical axis shows the first canonical variate of the following subsets: **(A,A′,A′′)** SCM land use. **(B,B′,B′′)** soil condition. P-values of 0.05 (*) and 0.01 (**). Adjusted R^2 is shown.

- Intervention **6881.2**. Forest investments for damage prevention.
- Intervention **6502.2**. Commitments to the maintenance of forestations and agroforestry systems.
- Intervention **6503**. Organic farming.
- Intervention **6844**. Aid for non-productive investments.
- Intervention **6501.3**. Promotion and sustainable management of pastures.
- Intervention **6881.4**. Non-productive forest investments in other silviculture actions with environmental objectives.

There are still shortcomings in the application of certain measures. For example, currently, the only regions that have implemented measure 6501.8 (soil improvement and erosion control) are Aragon, the Canary Islands, Castile and Leon, and Navarra, and measure 6881.1 (reforestation and agroforestry) has been ignored by almost half of the regions (Ministerio de Agricultura, Pesca y Alimentación, 2023c)

DISCUSSION

This study has shown how RDP executed public spending steadily decreased over a 20-year period, a trend that seemingly continues after the 2023 CAP reform, indicating a shift in EU and national priorities, focusing heavily on the agricultural aspect of the CAP rather than rural development. At the same time, the environmental aspects were incorporated into the CAP framework with increased importance after each reform, mostly into pillar 1, and, in particular, into compulsory conditions toward receiving CAP payments.

Regarding soil conservation, despite the continuous decrease in RDP overall budgets, executed public spending in SCM increased. The execution rate of the majority of SCM was close to 100% of what had been planned, indicative of the willingness to adopt said measures when made available and adequately funded. On the other hand, one of the most significant shortcomings was that some regions did not program certain

TABLE 5 | Spearman's correlation matrix of SCM executed public spending and political parties.

2000–2006	PSOE	PP	Regionalist
SCM-RDP	0	–0.16	0.16
SCM/ha	–0.2	–0.06	0
AECM	0.08	0.18	0.38
Forestry measures	–0.15	–0.35	0.5*
2007–2013	**PSOE**	**PP**	**Regionalist**
SCM-RDP	0.31	0.24	–0.64**
SCM/ha	0.16	–0.05	–0.16
AECM	–0.01	–0.08	0.22
Forestry measures	0.21	0.01	–0.31
2014–2020	**PSOE**	**PP**	**Regionalist**
SCM-RDP	0.12	0.47	–0.61**
SCM/ha	0.17	0.27	–0.47
AECM	0.13	–0.12	–0.02
Forestry measures	0.07	0.22	–0.3

*Spanish Socialist Workers' Party (PSOE). People's Party (PP). Regionalist parties (Regionalist). P-values under 0.05 (*) and 0.01 (**). Percentage of RDP budget allocated to soil conservation measures (*SCM-RDP*); Public spending in soil conservation measures per eligible areas in hectares (*SCM/ha*); Public spending in soil conservation agri-environmental and climate measures per eligible areas in hectares (*AECM*); Public spending in afforestation and forestry related to soil conservation measures per eligible areas in hectares (*Forestry measures*).*

measures, thus denying their farmers and rural inhabitants the possibility of implementing them. This action could be justified if the region's conditions were different from those of others that had activated these measures, but it was not found to be the case. In some instances, regions did not programme a measure during a programming period but programmed it for the other two with a high rate of execution.

Data was highly variable even when weighted by unit area or RDP budget, as seen in **Table 3**, which showed the contrast between the regions' effort to combat soil degradation and their effectiveness. The most effective regions were not necessarily those that made a bigger effort. Regions that made a bigger effort had lower funds left in their RPDs to cover other strategic rural development needs. This could potentially become a conflict of interest with soil conservation strategies.

CCA found that executed public spending of SCM was significantly correlated with land use and soil condition, with a moderate, though highly significant (*p-value* < 0.01), adjusted R^2. The association with soil condition was more concerning, as it was found to be weak though also highly significant. Soil condition variables used were obtained from all current available soil-condition cartography data at the national level. This information was mostly published during the second programming period (2007–2013). Correlations with soil condition became stronger and more significant over time (**Figure 8**), coinciding with the availability of soil condition data from the second period onwards, highlighting the importance of soil health monitoring at the regional and national scales. Some regions have not had an update of the INES cartography since 2002, which may conceal significant changes in soil erosion and other degradation processes since then. Another constraint was the limitation in the availability of executed public spending data, missing the set deadline (measures were not fully executed well into 2023, and the final *ex-post evaluations* were not fully available for the 2014–2020 programming period). In this case, partial data up to December 2022 was used, but as the program was still ongoing, it may be subject to corrections.

Our results are a clear indication that other factors outside the studied variables were influencing public spending on SCM within RDPs. Nevertheless, the existence of the correlations found in CCA and Spearman's correlation analysis were taken as a good sign, as it confirmed distribution of executed public spending was not arbitrary. The explanation entails that the regions with worse soil conditions put forward somewhat higher public spending for soil conservation, and the recipients implemented it accordingly (farmer engagement and social awareness), although not always (variability and low R^2).

Among the other factors that might influence soil conservation within RDPs, the political aspect showed a correlation with Regionalist governments. It should be noted that only six regions had these types of government during the studied period (Asturias, the Canary Islands, Cantabria, Catalonia, Navarra, and Basque Country), and the two major parties did not show any significant correlation with executed public spending, suggesting the implementation of SCM within the CAP's RDPs remain mostly apolitical. Nevertheless, a positive correlation between Regionalist governments and forestry measures was found during the first programming period, and a negative correlation was found with their effort toward soil conservation (percentage of their RDP used for soil conservation). The negative correlations can be partially explained by most Regionalist governments being located in areas with better soil conditions (north of Spain) or with a lower need for SCM, except Catalonia.

The 2023 CAP reform introduced a new approach toward environmental goals, which included an enhanced conditionality and voluntary eco-schemes (Regulation (EU) No 1307/2013), as seen in Section *Present and Future Framework: The European Green Deal*. These agro-ecological parameters are a key driver for achieving sustainable societies (Marsden et al., 2010). The recognition that food consumption had to be part of the system transformation for sustainable soil management was highlighted via the Farm to Fork initiative, yet measures on consumption remain unclear (Buckwell et al., 2022). While these types of policies seek to encourage farmers to meet social demands for 'non-productive' functions of agriculture and value their multifunctionality, they simultaneously advocate to improve competitiveness (Dominati et al., 2010). Nonetheless, they are still far from being well understood by parts of society, and most of the ecosystem services agricultural land provides are not accounted for (Rac et al., 2023).

The new enhanced conditionality changed some previously voluntary measures into compulsory ones (Section *Changes in Rural Development After the 2023 CAP Reform*) in order to receive CAP payments (e.g. GAEC 8, regarding minimum soil cover). In some agricultural sectors or areas, small and medium-sized farms are largely uncompetitive without the CAP's subsidies and feel obliged to comply with its conditions out of fear of going out of business and disappearing. The cost of adopting new techniques has been identified as one of the major barriers for implementing soil sustainable management practices in numerous studies (Brown et al., 2021) and is a major concern for farmers protesting the 2023 CAP reform. As pointed out by Guyomard et al. (2022), there is a need for eco-schemes to reward farmers for efforts beyond basic requirements, targeting global and local public goods. Furthermore, ecosystem services prove difficult to quantify, and it is unclear whether all actors involved, including consumers, are aware of their benefits or willing to absorb the costs (Hossard et al., 2024). Operating costs may at times exceed benefits in the short run, but recent studies have proven their long-term feasibility in certain conditions (Van Oudenhove et al., 2024). In this sense, the lessons gained by this study show that, when made available, comprehensive spending with environmental goals (in this case soil conservation) was done through voluntary schemes in pillar 2 with a generally positive uptake. It could be further strengthened by addressing the shortcomings that stem from the lack of information about soil conditions. National plans like the PAND have increased awareness on soil condition but, without appropriate monitoring, the information can quickly become obsolete. Another important shortcoming identified in the study showed that regions did not make certain measures available to their citizens during a specific period, sometimes with little justification. This could be solved by activating horizontal measures at the national level when they are of sufficient importance.

CCA showed that SCM followed a logical pattern of distribution at the regional level but could do a lot better in ensuring that executed public spending is allocated where its most needed and that it does not come at a cost of other rural development needs.

CONCLUSION

Spatial and temporal analysis of SCM within the RDPs had many obstacles related to the (i) heterogeneity of *ex post* evaluations in the first programming period; (ii) accessibility of data and annual reports for some regions and years; and (iii) final data on the programming period 2014–2020 that lingered for longer than its intended deadline, causing some re-structuring of executed public spending.

The data emphasize the discrepancy between regional efforts and effectiveness in combating soil degradation. Regions investing heavily in SCM often face financial limitations for other rural development needs, suggesting the need for balanced resource allocation. Significant correlations between SCM's executed public spending, land use, and soil condition suggest that its distribution is not completely arbitrary, with worse soil conditions prompting slightly higher spending in SCM. Political factors may also influence SCM, with Regionalist governments showing varying correlations with forestry measures and soil conservation efforts though SCM being largely apolitical in most regions. This complexity highlights the need for region-specific strategies.

This study can extract important lessons from over 20 years of RDPs regarding soil strategies and their success. If some strategies (Farm to Fork, Biodiversity Strategy and Soil Strategy) are to be incorporated into pillar 1, a comprehensive distribution of the measures and their executed public spending must support them. Conditionality should be flexible enough to adapt its measures to regional conditions, as they can be very restrictive in places like Spain's semi-arid areas. On the voluntary side, soil conservation eco-schemes and SCM in Rural Development in those regions with higher soil degradation must be promoted and made available, as well as properly funded, by Regional governments to ensure its implementation. Lastly, the availability of information to assess the dimensionality of soil degradation in Spain's regions is key. This study showed that, after the findings and publication of soil condition data at the national level, regions adapted and strengthened their associations with SCM. Updating of soil condition databases (INES, 2002–2012; Land Condition Map in Spain, 2010; Desertification Risk Map, 2008) is necessary, considering the most recent data is over 10 years old and some datasets are based on 24 (or more) year-old data. For example, the 1989–2000 data is used to calculate the aridy index, which in turn is used to calculate the desertification risk cartography.

In conclusion, our study indicates a logical but imperfect pattern of SCM distribution in Spain, requiring improvements in public spending allocation to ensure effectiveness without compromising other rural development needs. The challenge lies in harmonizing the European Green Deal with the CAP, considering the lessons drawn from previous programs. Those can help in the future design of tailor-made measures with sufficient public funds to back them up to ensure their uptake, implementation, and overall success in different regions.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://www.mapa.gob.es/es/desarrollo-rural/temas/programas-ue/, https://www.ine.es/dyngs/INEbase/listaoperaciones.htm.

AUTHOR CONTRIBUTIONS

MV conducted the research, analysis and writing of the paper; PP-C conducted methodological design and reviews; CB-F is credited with the original idea and conducted methodological design, analysis and reviews of the paper. All authors contributed to the article and approved the submitted version.

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CONFLICT OF INTEREST

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

GENERATIVE AI STATEMENT

The author(s) declare that no Generative AI was used in the creation of this manuscript.

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