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Accounting for Regional Heterogeneity of Agricultural Sustainability in Spain

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Abstract: Agriculture is increasingly facing major challenges such as climate change, scarcity of natural resources and changing societal demands. To tackle these challenges there is a pressing need to evolve towards more sustainable agricultural practices. As a result, sustainability stands among the most relevant topics in agricultural research worldwide, and Spain is no exception. Agricultural sustainability has been analysed in Spain mainly at a national and farm scale. This contribution aims at assessing agricultural sustainability in Spain at a provincial scale, allowing the scrutiny of regional variability induced by the existing differences in extension, relevance and policies of the agricultural activity at this level. The sustainability assessment performed is based on a selection of twenty-two indicators covering the three classical dimensions of sustainability—environmental, economic and social. The methodology implemented is based on normalising and aggregating selected indicators according to three composite indicators for the fifty Spanish provinces. Numerous statistical and cartographic sources are used. Cluster analysis establishes four different groups of provinces according to their performance in terms of agricultural sustainability. Higher economic sustainability in provincial agriculture seems to be mostly associated with more intensive use of agricultural labour and agricultural machinery and faster wealth growth. Social sustainability seems to be linked to greater diversification of economic activities and to quality productions under Protected Designations of Origin (PDO) and Protected Geographical Indications (PGI). Best environmental sustainability is achieved where extension of agricultural land is larger, less agricultural area is burned, and carbon stock and sequestration by agricultural ecosystems is better. It is expected that the results could improve the policy coherence and decision-making for more sustainable agricultural systems in Spanish regions.

Keywords: agriculture; sustainability assessment; province level; Spain

1. Introduction

Since the concept of sustainable development was established as a guiding principle for policy action [1], diverse sustainability tools and assessments have been developed. In this context, agriculture is one of the productive activities that have been most interesting for analysts of sustainable development [2–4]. The increasing concerns regarding the deterioration of natural resources on which agricultural output and rural economies rely are behind this development. Agriculture constitutes the basis for the provision of a set of private goods (food and agricultural raw materials) and public goods such as the contribution to the viability of rural regions (According to the European Commission [5], in Spain both predominantly rural and intermediate regions represent 77% of the total territory, 37% of total population, 34% of total gross value-added and 36% of total employment), the function of carbon dioxide (CO_2) sinks, or the generation of landscapes and biodiversity valued by society [6,7]. However, more than other productive activities, agriculture is also associated with the extensive use of natural resources (especially land, water, energy) that need appropriate and pressing sustainable management.

This means that the challenges for the sustainability of many agricultural systems are numerous and diverse. These challenges can be grouped from the socioeconomic and environmental perspectives, while implying important management actions to reach a balance between obtaining food and other basic products, and the conservation of natural resources. Revealed evidence suggests that biodiversity conservation, environmental protection and social empowerment are preconditions for medium and long-term sustainable economic development.

In the Spanish and European case, the challenges of sustainable agriculture correspond to a large extent with the strategic challenges proposed in the current reform of the Common Agricultural Policy (CAP) 2014–2020 [8,9]. Yet, the most innovative sustainability scheme introduced by CAP 2014–2020 is the green payments regulation, which imposes new conditions for receiving 30% of the direct payments. The greening measures consist of maintaining permanent grassland at the 2014 level, crop diversification, and maintaining an Ecological Focus Area. This approach seems to respond to the principle of "public money for public goods" increasingly advocated to boost the legitimacy of the CAP payments [10,11]. (In most advanced countries and an increasing number of emerging countries, agriculture is supported by costly public policies whose effectiveness is often questioned in terms of their ability to improve the adaptation and resilience of the agricultural sector to generate long-term sustainability. According to OECD [12], most agricultural policies in place are not well-aligned with shared objectives for the sector "to increase productivity sustainably, enhance environmental performance, and improve farmers' ability to manage risks and shocks.").

Sustainability also has been gaining more momentum within the policy debate on the future of the CAP currently underway [13]. The objectives of the future CAP post 2020 tend to be designed in a close linkage to the principles of sustainable development as conceived in international frameworks such as the Sustainable Development Goals (SDGs). In addition, objectives and targets for specific themes (e.g., climate change mitigation, water management) should be strongly aligned to relevant frameworks such as the 2030 climate and energy package of the Paris Agreement COP21. This means that targets should be formulated to ensure that European agriculture contributes in a significant manner to the achievement of the commonly agreed international objectives.

Moreover, the concept of sustainability should be applicable at multiple levels (supranational, national, local) in order to provide policy coherence between the different administrative levels and ensure that resources are directed towards specifically established targets. This implies the formulation of clear and tangible objectives according to national and regional priorities, taking into account both the structure of the agricultural sector and international obligations.

There are many different approaches and tools for assessing agricultural sustainability [14–16]. Although all methods aim at contributing to a more sustainable agriculture in general, they can be distinguished according to their level of assessment (product, sector, farm, country, region) and the more or less emphasis put on the pursued sustainability goals. Moreover, some tools concentrate on single dimensions of sustainability while others address the three dimensions of sustainability—the environmental, social and economic dimensions [17]. Tools covering more than three dimensions are very scarce. The most salient exception is the Guidelines for Sustainability Assessment for Food and Agriculture Systems (SAFA), which includes four dimensions: environment, economic aspects, social issues and governance [18]. The SAFA provides a hierarchical structure of sustainability dimensions, themes and subthemes making the assessment results more comparable [19].

The vast majority of these methods use indicators to provide a picture of the sustainability status. The choice of indicators is a critical aspect for the development of appropriate sustainability assessments, since the data used for the calculation of each indicator will influence the outcome of the analysis [20,21]. Several selection criteria are provided in the literature, including representativeness, transferability, adaptability and measurability at an assumable cost [22]. Indicators are also used to establish benchmarks to improve sustainability performance [23–25], or to set regional sustainability targets [26].

Despite the important role of agriculture and the interest of sustainable agricultural systems at administratively smaller units such as provinces, no studies have been conducted at this level in Spain to the best of our knowledge. Agricultural sustainability has been analysed in Spain mainly on a national and farm scale [27–30], the same as internationally (recent comprehensive overviews on farm sustainability assessment and adoption can be found in several contributions [22,31–34]).

This study contributes to overcoming this limitation by assessing regional heterogeneity of agricultural sustainability in Spain. Therefore its objective is threefold: (1) to propose a conceptual approach to selecting a multidimensional set of sustainability indicators suggested as most relevant for Spanish agriculture, (2) to provide a quantitative measurements for these indicators at provincial scale (Spain is administratively divided into 17 Autonomous Communities and 50 provinces with administrative competence in several policy areas), and (3) to contribute to scientific literature on agricultural sustainability from a regional perspective.

This type of assessment can be especially useful for national and regional public managers when taking locational decisions aiming at prioritising practical actions, including (i) coordination of national agricultural policy, (ii) distribution of CAP and national agri-environmental payments to farms and regions, (iii) implementation of differentiated policies in specific provinces due to their singularities, (iv) enhancing sustainable agricultural practices where appropriate, e.g., organic and integrated productions), providing resources to provinces with high socio-economic vulnerability or high risk of rural depopulation (a quite pressing problem in numerous Spanish provinces).

2. Materials and Methods

2.1. Indicator Selection and Data Collection

Based on a review of the specialised literature and international indicator systems used in assessing sustainable agriculture [16–18,35–40], 22 agricultural sustainability indicators were selected in this study: eight economic, five social and nine environmental indicators (see detailed description of indicators in Appendix A). The selection process of indicators was carried out based on three premises: the coherence with the established frameworks for sustainable development (UN, OECD, EU frameworks [7,14,16,41]), the relevance of these indicators in the Spanish context, and data availability at provincial level. The acceptance of the schemes and frameworks proposed by international organisations has helped the construction of indicators less arbitrarily and more systematically.

The approach used for the empirical evaluation of agricultural sustainability allows the transformation of general and abstract frameworks to a concrete proposal of a consistent set of indicators that can be quantified, monitored and evaluated. Selected indicators should capture strategic sustainability goals and translate the accepted principles into measurable parameters. They should be independent as much as possible from each other. Their number should not be very large in order to avoid major inconsistencies. Small sets of indicators are more effective and keep the focus on truly important factors. The approach followed also assumes the objective of reaching a certain state (target) considered as sustainable for the regional agricultural system. It should be pointed out that several indicators conceptually relevant for sustainable agriculture (e.g., soil quality, animal health, water and pesticide usage, risk management, working conditions, gender balance—see for instance [18,34]) have not been included due to the lack of data at the required spatial scale.

2.2. Data Analysis and Statistical Methods

Statistical and spatial analyses were performed by means of SPSS v22 and ARC-GIS v10.3, respectively. Following Martínez-Vega et al. [42], the original data were transformed (TfV: transformed values) in line with the method proposed for calculating each indicator, and are expressed in the corresponding unit of measurement. In some cases, the raw data were related to surface units to make them comparable and to establish a ranking of provinces.

With regard to four indicators that are considered a threat for social (SO1, SO3) and environmental (EN5, EN8) sustainability, the original values of the indicators were reversed deducting them from 100 (best sustainability), in order to be added to the rest of indicators which are positively correlated to social and environmental sustainability of each province. Indeed, this operation was not necessary for the rest of the indicators because the desirable trends move in an upward direction in terms of positive sustainability added value. Based on the recommendations of Morse and Fraser [43] and in order to standardise the data and achieve normalised values (NV), the TfV were divided by a target value (TV) for each indicator, this being the desirable threshold in the context of sustainability [44], so that:

$$\mathrm{NV_i} = \frac{\mathrm{TfV_i}}{\mathrm{TV}} \quad (1)$$

$$\mathrm{i} = 1 \ldots 50 \text{ provinces}$$

Table 1 provides detailed information about the extreme values (minimum, maximum) as well as the target values used and how these were established for each indicator. In some cases, the forecasts and targets set in territorial strategies (e.g., Convention on Biological Diversity; scenarios on agricultural land [45]) were taken into account. In other cases, the target value was established at level 100 expressing a no-loss situation (EC7, EN2). However, for most indicators where there are no clear, widely accepted references in the scientific literature, the regulatory setting or the agriculture sectoral plans as well as the distribution of frequency of values for each province were considered, and the target value was set at percentile 85.

Table 1. Extreme and target values by selected agricultural sustainability indicator.

Sustainability Dimension	Code	Indicator	Lowest Value (LV)	Highest Value (HV)	Target Value (TV)	
					Value	Criterion Used
Economic	EC1	Agricultural productivity	11,892.93	86,723.98	40,488.53	85th percentile of data set
	EC2	Capital stock	1006.20	11,242.17	7551.18	85th percentile of data set
	EC3	Rural development	1.53	39.49	23.83	85th percentile of data set
	EC4	Agricultural labour intensity index	0.72	63.28	12.68	85th percentile of data set
	EC5	Full-time farmers	0.45	20.51	9.13	85th percentile of data set
	EC6	Agricultural machinery intensity index	1.72	63.77	23.34	85th percentile of data set
	EC7	Variation in per capita Gross Domestic Product (GDP)	76.27	105.76	100	100 (no loss in per capita GDP)
	EC8	Investment in R&D	0.0035	0.0190	0.0149	85th percentile of data set
Social	SO1	Farmers aging index	28.56	58.83	50.47	85th percentile of data set
	SO2	Non-farm enterprises	35.66	98.41	68.00	Median of data set, in this case 68.00
	SO3	Small farms	4.06	81.06	62.40	85th percentile of data set
	SO4	Salaried labour	3.47	80.61	53.18	85th percentile of data set
	SO5	Quality areas	28.62	100.00	100.00	Best of the serial data—value already reached by more than 50% of provinces
Environmental	EN1	Agricultural land	14.14	81.20	45.00	According to Prieto and Ruiz [45], it is expected that the agricultural area of Spain will be equivalent to 45% of the total area in 2030
	EN2	Variation of agricultural land	80.35	100.35	100.00	100 (no loss in agricultural land)
	EN3	Organic farming	0.10	43.55	10.30	85th percentile of data set
	EN4	Livestock pressure	0.30	5.52	1.80	85th percentile of data set
	EN5	Burned agricultural area	96.95	100.00	99.80	We hypothesize that 0.2% of agricultural area will be burned by 2030, the same proportion expected for forest area according the Spanish Forestry Plan 2002–2032
	EN6	Terrestrial protected areas	0.08	65.17	17.00	In the Convention on Biological Diversity, Goal 11 of Aichi proposes that by 2020 at least 17% of terrestrial and inland water areas must be protected
	EN7	Natura 2000 network	2.51	34.56	17.00	Idem EN6
	EN8	Soil erosion	37.60	96.11	90.45	85th percentile of data set
	EN9	Carbon stock	53,881.16	9,639,114.83	Dynamic	TV is dynamic in each province searching for at least a balance between CO_2 emissions and captures

Source: Authors' construction.

At this stage, a decision on whether or not to apply weights to the different indicators was necessary, taking into account that some of the selected indicators are considered by international systems to have priority while others are considered complementary. However, several authors [46,47] indicate that the processes of assigning weights usually are highly arbitrary. This is in part attributable to the fact that there is no agreed methodology to weight individual indicators [48,49]. In addition, authors such as Sajeva et al. [50] have shown that weighting often has no significant effect on the ranking of the indicators. As a consequence, no weights have been assigned to indicators in this study.

In the next stage, the normalised indicators relating to each sustainability dimension were integrated in a unique index for the purpose of obtaining, for each province, one index for economic sustainability (ECSI), another for social sustainability (SOSI) and another for environmental sustainability (ENSI). The average value for each dimension (economic, social and environmental) was calculated using the following equations:

$$\mathrm{ECSI_i} = (\mathrm{Mean}\ (\mathrm{EC1_i}, \ldots, \mathrm{EC8_i}) - 1) \times 100 \tag{2}$$

$$\mathrm{SOSI_i} = (\mathrm{Mean}\ (\mathrm{SO1_i}, \ldots, \mathrm{SO5_i}) - 1) \times 100 \tag{3}$$

$$\mathrm{ENSI_i} = (\mathrm{Mean}\ (\mathrm{EN1_i}, \ldots, \mathrm{EN9_i}) - 1) \times 100 \tag{4}$$

$$\mathrm{i} = 1 \ldots 50 \text{ provinces}$$

The values obtained for the economic, social and environmental indices for the agricultural sector in each province were transformed into Z units in order to harmonise their measurements, allowing a uniform unit of measure useful to have a reference baseline [39,40]. This was done using the following formula:

$$\mathrm{Z_i} = \frac{\mathrm{X_i} - \overline{\mathrm{X}}}{\hat{\sigma}_\mathrm{X}} \tag{5}$$

where X_i are values resulting from operations (2), (3) and (4), $\overline{X}$ the mean of the series (50 provinces), and $\hat{\sigma}_X$ the standard deviation of the series. Z_i indicates how many units each province is away from the general mean. Z scores are designed in such a way that users know if a province is above or below average and by how much. With this design, obviously, the average is zero and the standard deviation is 1. It should be noted that the Z-score is among the most widely used standardisation techniques [48,49,51]. The advantage of this technique is that it provides dimensionless values and individual scores from different distributions can be directly compared [48,52].

Subsequently, a k-means cluster analysis on the standardised values of the three indices was performed in order to classify the Spanish provinces in relatively homogeneous groups according to their economic, social and environmental characteristics in the agricultural sector. Lastly, the positioning of the 50 provinces studied was shown graphically to compare their relative positions regarding each sustainability dimension.

3. Results and Discussion

The results of the provincial distribution of the integrated sustainability dimension indices resulting from operations (2), (3) and (4) show high inequality across provinces: only three provinces (6%) are above the desirable minimum value (target value) for economic sustainability (values above zero): A Coruña, Pontevedra and Santa Cruz de Tenerife (see Figure A1 in Appendix B). At the same time, no province reaches the desirable minimum value for social sustainability (Figure A2 in Appendix B), while 28 provinces (56%) surpass the established target values for environmental sustainability (Figure A3 in Appendix B) (Note that at this stage these indices represent the integration in one value for each province of the values of all indicators of the corresponding sustainability dimension, allowing a ranking of provinces within each dimension but not comparisons across dimensions).

Once these data are normalised (Z values), the positions of different provinces in different indices can be directly compared, and it is visually easy to notice whether a province is above or below average (zero) and by how much. Table 2 summarises the normalised values reached in each province in the economic, social and environmental sustainability indices, and indicates the cluster to which each province belongs.

Table 2. Normalised values (Z) of sustainability indices and grouping of provinces.

Cluster	Province Name	Z-ECSI	Z-SOSI	Z-ENSI
1	Álava	0.23567	0.06047	−1.21002
	Alicante	−0.06283	−1.30247	0.33438
	Almería	0.50368	−0.83074	0.17179
	Asturias	0.32236	−0.68014	−0.67319
	Ávila	−0.57997	−0.46249	−0.53317
	Cantabria	0.49215	−0.59168	−0.95342
	Castellón	−0.25010	−1.23613	0.44213
	Ciudad Real	−1.12803	0.06333	0.04305
	Cuenca	−0.79398	−0.14511	−0.92607
	Guadalajara	−0.90163	−0.73908	−0.85478
	León	−0.15300	0.04910	−0.98702
	Madrid	−0.32981	−0.01857	−0.03073
	Palmas, Las	0.59035	0.00284	0.41489
	Teruel	−0.22561	−0.35073	−1.10441
	Valencia	0.07453	−1.33040	0.73070
	Zamora	−0.29918	0.03415	0.08309
2	Coruña, A	2.23977	−1.58990	−0.77717
	Guipúzcoa	0.95158	−1.82564	−1.03559
	Lugo	1.59810	−0.76542	0.11038
	Ourense	0.97567	−1.30399	−0.86675
	Pontevedra	2.76118	−1.71282	−1.39656
	Santa Cruz de Tenerife	3.02382	0.10824	0.56617
	Vizcaya	0.65626	−2.28596	−1.12941
3	Albacete	−1.00878	0.54521	−0.54505
	Barcelona	1.05291	0.30746	−0.71691
	Burgos	−0.36056	0.78483	−1.13567
	Girona	0.54998	1.46797	−0.10676
	Huesca	−0.29163	0.92242	−0.77150
	Lleida	−0.19873	0.99908	0.46460
	Navarra	0.15733	0.40545	−0.30797
	Palencia	0.69634	1.33972	−0.70445
	Rioja, La	0.85245	0.38243	−0.61960
	Salamanca	−0.70390	1.01322	0.28122
	Segovia	−0.54879	1.50733	−0.63035
	Soria	0.29586	1.01569	−1.06106
	Valladolid	0.29364	1.96862	−0.27887
	Zaragoza	−0.85630	1.00210	−0.60789
4	Badajoz	−1.23007	0.44775	0.61609
	Baleares	−0.42362	−0.41867	0.68566
	Cáceres	−1.66964	−0.16310	1.20293
	Cádiz	−0.27508	0.95820	1.49708
	Córdoba	−1.16906	1.02796	1.32213
	Granada	−1.04827	0.43923	0.55216
	Huelva	0.23172	1.78891	3.60461
	Jaén	−1.36536	−1.45722	1.89115
	Málaga	−1.21869	−.21087	0.87715
	Murcia	0.26039	0.88636	1.20089
	Sevilla	−0.65818	0.10259	0.98278
	Tarragona	0.12225	−0.40924	1.65097
	Toledo	−1.18717	0.19971	0.23835

Legend: Z-ECSI = Z-values of economic sustainability index, Z-SOSI = Z-values of social sustainability index, Z-ENSI = Z-values of environmental sustainability index.

Hierarchical clustering of the three standardised sustainability indices yielded four clearly distinguishable groups of provinces according to their performance in terms of agricultural sustainability (Table 3). Cluster 1 is formed by provinces presenting balanced values in all three sustainability dimensions. Cluster 2 is composed of provinces presenting rather high values for economic sustainability and low values for social sustainability. Cluster 3 includes provinces with relatively high values for social sustainability, while the provinces of Cluster 4 present relatively high values for environmental sustainability.

Table 3. Average values of sustainability indices in each cluster of provinces (Z values).

	Cluster			
	1	**2**	**3**	**4**
Z-ECSI	−0.15659	1.74377	−0.00501	−0.74083
Z-SOSI	−0.46735	−1.33935	0.97582	0.24551
Z-ENSI	−0.31580	−0.64699	−0.48145	1.25554
Nº provinces	16	7	14	13

Figure 1 presents the positioning of the provinces belonging to each cluster according to their agricultural sustainability in different dimensions. As shown, no province is highly positioned simultaneously in all dimensions. Moreover, the rank values obtained for composite dimension indices (see supplementary data) indicate that higher economic sustainability of the agricultural sector is observed mainly in Northern provinces and seems to be associated with more intensive use of agricultural labour (number of annual agricultural work units per 100 ha of tilled farmland) and agricultural machinery (agricultural machines density per 100 ha of cultivated area), as well as to higher increase of average wealth in the province (variation in per capita GDP 2004–2014).

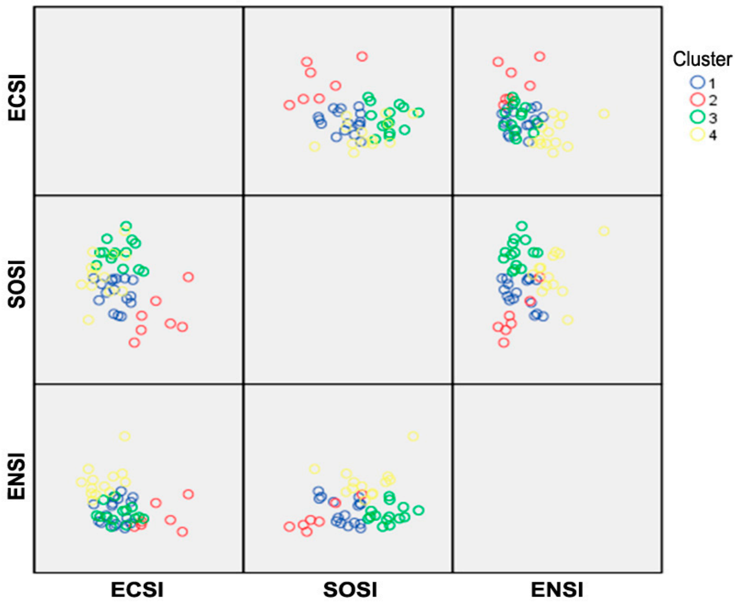

Figure 1. Distribution of clusters of provinces according to their agricultural sustainability. Legend: ECSI = economic sustainability index, SOSI = social sustainability index, ENSI = environmental sustainability index.

Meanwhile, social sustainability seems to be positively associated with higher diversification of economic activities (higher proportion of non-farm enterprises in total firms operating in the province), lower share of small farms (less than 10 ha), and higher share of agricultural area under Protected Designations of Origin (PDO) and Protected Geographical Indications (PGI).

As for environmental sustainability, the best positioned provinces are those where there are a higher share of agricultural and grassland area in the total province area combined with higher increase of this share between 2006 and 2012, where there has been less burned agricultural area between 2006 and 2012 in proportion of total agricultural land, and where there is better carbon stock and sequestration by agricultural ecosystems and grassland of the province.

Methodologically, the evaluation carried out depends obviously on the normative options that have been introduced at the beginning in relation to the target values or tolerance ranges established for the indicators [44–47,53–55]. A controversial point is the feasibility of using, for each indicator, a common target value for the whole of Spain or, alternatively, a dynamic and different target value adapted to the peculiarities of each province (in this study dynamic values have been used only for indicator EN9: carbon stock). A priori, this idea is suggestive [56], though its implementation could hinder the comparison of results across provinces and with the national average, in addition to the complexity of finding target values adapted to the specificities of each province.

Data standardisation makes it easier to compare different geographical areas [57]. Thus, the methodology used can be replicated (with the necessary adaptations) in other countries, especially those presenting similar agricultural ecosystems. However, there are still conceptual and methodological caveats that need to be explored and resolved in future research. For instance, the debate concerning the convenience to integrate indicators with [42,54,57,58] or without [46,53] weights remains open. Furthermore, the analysis performed is primarily static. It would be desirable to build a time series data making it possible to analyse agricultural sustainability in a dynamic way over time and adapt agricultural policy according to the results achieved.

It is also necessary to bear in mind that the results should be interpreted within the numerous limitations faced in the construction of a viable system of indicators at the subnational (regional) level. The first limitation is that currently the effort of both national and supranational organizations (OECD, European Commission, European Environment Agency, FAO, the World Bank) for the construction of sustainability indicators is mainly focused on a national scale. This implies that information is often not collected or available at lower geographical settings. A second type of difficulty is the intrinsically ambiguous nature of the sustainability indicators [59,60], which are commonly contingent on the contextual and geographical viewpoint. A third limitation is that sustainability indicators hardly allow the causes of the unsustainability of the systems scrutinised to be explained. Finally, the open nature of regional systems allows a portion of the environmental and social externalities to be exported to other neighbouring systems or imported from them, hence a part of the considerations that can be made regarding the sustainability of a regional system will be influenced by external causes [61].

The approach used and the results obtained provide a reference point that may be of use to policymakers when designing or adjusting socio-economic and environmental policies related to agriculture. As stated by Schader et al. [17], sustainability assessment can support agricultural policy, inter alia, in designing and targeting agricultural policy more effectively according to the principles of sustainable development and according to societal needs, in monitoring and controlling the sustainability performance, in allocating payments according to the degree of achieving sustainability goals, and in enabling farmers to develop individual farm sustainability strategies in line with the sustainability goals.

4. Conclusions

Sustainability currently represents one of the main concerns of analysts and political agents involved in regional development. Despite the interest and topicality of sustainable agriculture analysis at the regional level, very few studies have been conducted in this area in Spain and actually none at provincial scale. Hence, the main motivation for this study was the need for assessments of sustainable agricultural systems accounting for regional diversity.

The provincial scale approach helped to point out the significant discrepancies in agricultural sustainability between different groups of provinces as well as by sustainability dimension, which advocates for the relevance of sustainability analysis at this scale. The fact that no Spanish province is highly sustainable simultaneously in all dimensions indicates that, despite the growing efforts undertaken in Spain to implement sustainable agriculture principles, many agricultural areas are still far from the minimum desirable sustainability levels from a balanced, multidimensional perspective.

The top-performing provinces do not necessarily have top performance in all three sustainability dimensions, and vice versa the bottom performing provinces do not necessarily have the lowest performance in all three dimensions. The greatest weaknesses are evident in social and economic sustainability. Structural factors make it difficult to reach desirable sustainability levels. Rural depopulation, the aging of the agrarian population and the scarce diversification of the rural economy are significant factors that negatively influence these two dimensions of sustainability. Conversely, environmental sustainability shows more encouraging results: 56% of the Spanish provinces are already above the reference level. The Spanish agricultural ecosystems provide valuable ecosystem services and are the support of extensive protected areas integrated into the European Natura 2000 network and into the national network of protected natural areas. They are the habitats of species of flora and fauna that are threatened or at risk of extinction.

The assessment carried out can be quite useful for ensuring policy coherence between different national and subnational administrative levels, and also for assisting national and regional decision-makers. It could enhance the effectiveness and the acceptability of agricultural policy for regions and society by bridging the gap between action-based and results-oriented measures at the regional level. Findings could also support the regional dimension of the notion of "public money for public goods", which is playing a growing role in the debate on the CAP post 2020 currently underway, where environmental and climatic objectives are high on the agenda. Each indicator considered individually is the reflection of a specific evaluation criterion which varies according to the users (political decision-makers, farmers, society), who could use it either for the purpose of simple evaluation or as a guide for decision-making.

In the different clusters of provinces, sustainable agriculture should target positive progress in all three dimensions simultaneously. The progress of one sustainability dimension must not be achieved at the expense of the deterioration of the others. Moreover, even though each province has unique characteristics and policy priorities, cross comparisons between different provinces and clusters can yield useful insights. The cross-province comparisons allow the identification of leaders, learners, laggards and best practices on an indicator-by-indicator as well as aggregate basis. Low-performing provinces on some aspects can learn from the success of peer provinces.

Specific policies to incentive sustainable agriculture will be needed in Spain for a while, as the challenge over the coming decades will continue to be the increase of agricultural production and productivity while at the same time managing natural resources sustainably, including the impacts of climate change. As a corollary, it seems logical to continue supporting extensively rural development programs, the establishment of young farmers and the promotion of initiatives that reinforce the diversification of the rural economy. The implantation of new agrifood and agrotourism companies are welcome as drivers of sustainability in the rural areas. In parallel, it is necessary to increase investment in specific R & D actions and in the improvement of rural services and infrastructure. From the environmental perspective, it is essential to continue promoting actions to further value ecosystem services, so that social agents that facilitate them can be properly recognised and remunerated. Also, it is highly recommended to involve the rural population in the definition of the management plans of protected areas established in agricultural areas or in their borders (agricultural-forest and grassland-forest interfaces). The feasibility of economic compensation for the limitations of certain land uses within these protected areas needs to be addressed. Participatory planning is an effective way to achieve plans acceptable to all the agents involved and thus reduce hostile behaviour that can hinder the achievement of goals relating to biodiversity. Implementing measures of this type could, for instance, reduce the arson in some provinces of Northwestern Spain or burned areas caused by negligence of farmers.

Finally, additional research would be needed to perform sensitivity analysis by applying different thresholds for sustainability targets and different weighting methods to the selected indicators, and exploring their impact on the results. Another interesting avenue would be conducting a dynamic analysis of agricultural sustainability through building time-series data; the analysis performed in this contribution is essentially static. In any event, it is important to highlight the synergies between the different components of sustainability and the need for an appropriate balance between them, avoiding as much as possible the competition between the three dimensions. Sustainability requires a parallel development of economic, social and environmental dimensions.

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Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Sustainability Indicator Description.

Sustainability Dimension	Sustainability Indicator Code	Indicator Definition	Indicator Measurement	Data Source
Economic	EC1	Agricultural productivity	Ratio of gross value added in agriculture, livestock and fisheries, and work units per year, AWU (€/AWU).	National Statistical Institute (NSI) and Agricultural Census 2009. http://www.ine.es/CA/Inicio.do?locale=en_US
	EC2	Capital stock	Market value of tangible assets in agriculture per labour unit (€/AWU).	Sources: BBVA Foundation, NSI
	EC3	Rural development	Share of public support allocated to rural development programmes (2008), in %.	[62]
	EC4	Agricultural labour intensity index	Number of annual agricultural work units per 100 ha of tilled farmland (AWU/100 ha).	Agricultural Census 2009, NSI
	EC5	Full time farmers	Ratio of full time farmers whose main professional activity takes place in the farm to the total number of registered farmers (in %).	Agricultural Census 2009, NSI
	EC6	Agricultural machinery intensity index	Agricultural machines density per 100 ha of cultivated area.	Census of machinery 2010, MAPAMA. http://www.mapama.gob.es/es/agricultura/temas/medios-de-produccion/maquinaria-agricola/estadisticas/
	EC7	Variation in per capita Gross Domestic Product	Index base 100 in constant prices: $EC7 = \frac{GDP2014/cap}{GDP2004/cap} \times 100$	NSI: http://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736167628&menu=resultados&idp=1254735576581
	EC8	Investment in R&D	Ratio of investment in research and development per Gross Domestic Product	2013, BBVA-IVIE and NSI
Social	SO1	Farmers aging index	Ratio of farmers older than 55 years to the total number of farmers (in %). The value of this indicator has been reversed (100—indicator value) in order to be additive to other indicators positively related to sustainability.	Agricultural Census 2009, NSI
	SO2	Non-farm enterprises	Percentage of non-farm enterprises in total.	Agricultural Census 2009, and Central Business Directory 2009, NSI: http://www.ine.es/dynt3/inebase/en/index.htm?padre=51&dh=1
	SO3	Small farms	Percentage of farms with an acreage of less than 10 ha. The value of this indicator has been reversed (100—indicator value) in order to be additive to other indicators positively related to sustainability.	Agricultural Census 2009, NSI
	SO4	Salaried labour	Share of paid work units in total work units per year.	Agricultural Census 2009, NSI
	SO5	Quality areas	Share of agricultural area and grasslands under Protected Designations of Origin and Protected Geographical Indications.	MAPAMA: http://www.mapama.gob.es/es/cartografia-y-sig/ide/descargas/

Table A1. *Cont.*

Sustainability Dimension	Sustainability Indicator Code	Indicator Definition	Indicator Measurement	Data Source
Environmental	EN1	Agricultural land	Share of agricultural and grassland area in total area.	Copernicus Land Monitoring Services (2016). Pan-European. CORINE-Land Cover, CLC 2012. 18.5 version. http://land.copernicus.eu/pan-european/corine-land-cover/clc-2012/view Accessed 26 June 2018 and GIS data (Total surface—of each province)
	EN2	Variation of agricultural land	Variation of agricultural land and grassland between 2006 and 2012. The difference is quantified relative to 100 (100=base index value CLC2006 surface).	CORINE Land Cover maps 2006 and 2012
	EN3	Organic farming	Share of organic land in total agricultural land (CLC 2012).	MAPAMA, 2012 and CLC 2012
	EN4	Livestock pressure	This indicator can be interpreted from different perspectives. From the environmental point of view, we have considered it as positive: livestock keeps a less dense vegetation cover, hence the wildfire risk is lower.	Agricultural Census 2009, NSI for Animal Units and CLC2006 for Permanent Pastures Area
	EN5	Burned agricultural area	Percentage of the burned agricultural area (BAA) between 2006 and 2012 with respect to the total agricultural land (AL): $EN5 = 100 - \left[\frac{\sum_{2006}^{2012} BAA}{AL} \times 100\right]$ The value of this indicator has been reversed (100—indicator value) in order to be additive to other indicators positively related to sustainability.	CLC 2012 and European Forest Fire Information System—EFFIS http://effis.jrc.ec.europa.eu, European Commission Joint Research Centre, [63]
	EN6	Terrestrial protected areas	Percentage of terrestrial protected areas (Nationally Designated Spaces and Biosphere Reserves) located in agricultural areas over the total arable land	Database of Biodiversity (MARM-Ministry of Environment), GIS of Europarc-Spain and GIS data, CLC 2012
	EN7	Natura 2000 network	Percentage of area occupied by areas under Natura 2000 network (Special Protection Areas for Birds, SPA, Sites of Community Importance, SCI, Habitats of Community Importance priority) in agricultural areas over arable land	Database of Biodiversity (MARM-Ministry of Environment), GIS of Europarc-Spain and GIS data, CLC 2012
	EN8	Soil erosion	Percentage of geographical area (ha) affected by intense or extremely intense laminar and gully erosion (>25 ton/ha/year) in total erodible surface. The value of this indicator was reversed (100—indicator value) in order to be additive to other indicators positively related to sustainability.	National Inventory of Soil Erosion and statements erosive map (1987–2002)
	EN9	Carbon stock	First we calculated the CO_2 sequestration made by the agricultural ecosystems and grasslands of each province taking into account the surface area of each class of CORINE Land Cover 2012 (LC). Then, we applied a coefficient of CO_2 density (D)—tons/ha ([64–66] and our modification). Second we considered emissions (E) related to agricultural management in 2012 [54] in each province based on the area occupied by these ecosystems. The indicator is the ratio: $EN9 = \left[\frac{\sum_{i=0}^{n} LC \times D}{E}\right]$ The target value is dynamic looking for at least the balance between CO2 emissions and sequestration in each province.	CLC 2012, [67] (http://www.fao.org/faostat/en/#country/203)

Source: Authors' construction.

Appendix B Provincial Distribution of Composite Sustainability Indices

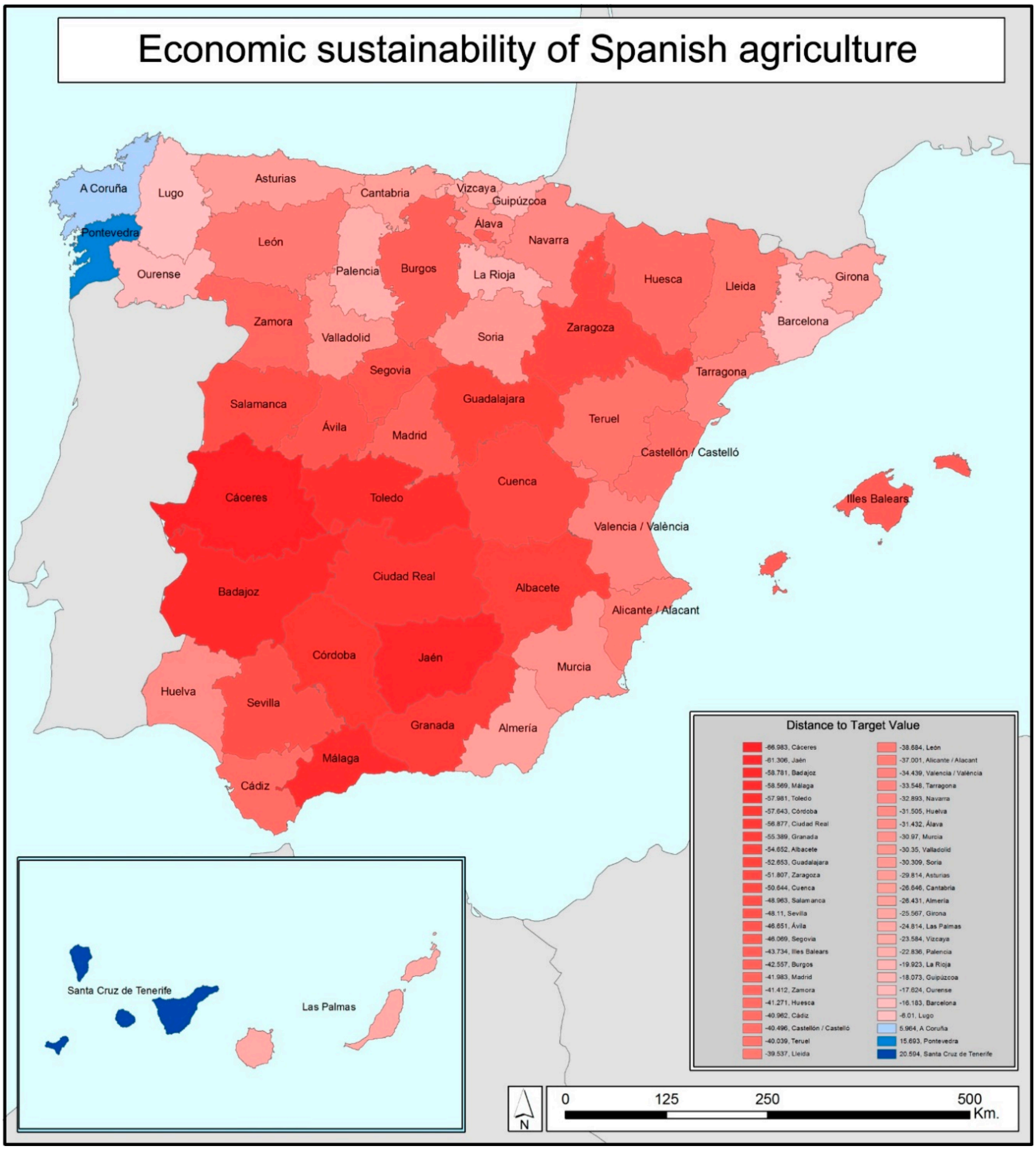

Figure A1. Economic sustainability of Spanish agriculture.

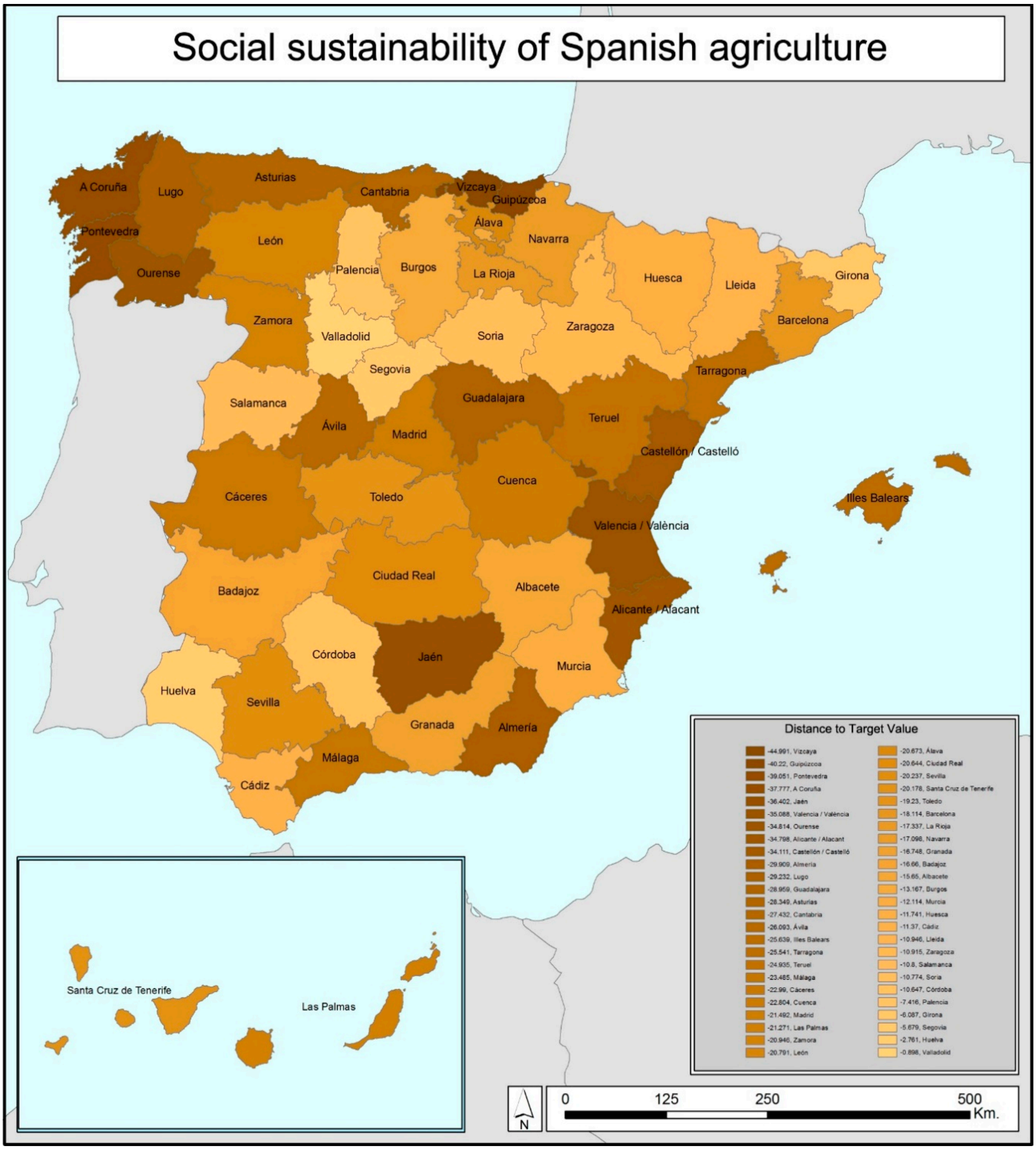

Figure A2. Social sustainability of Spanish agriculture.

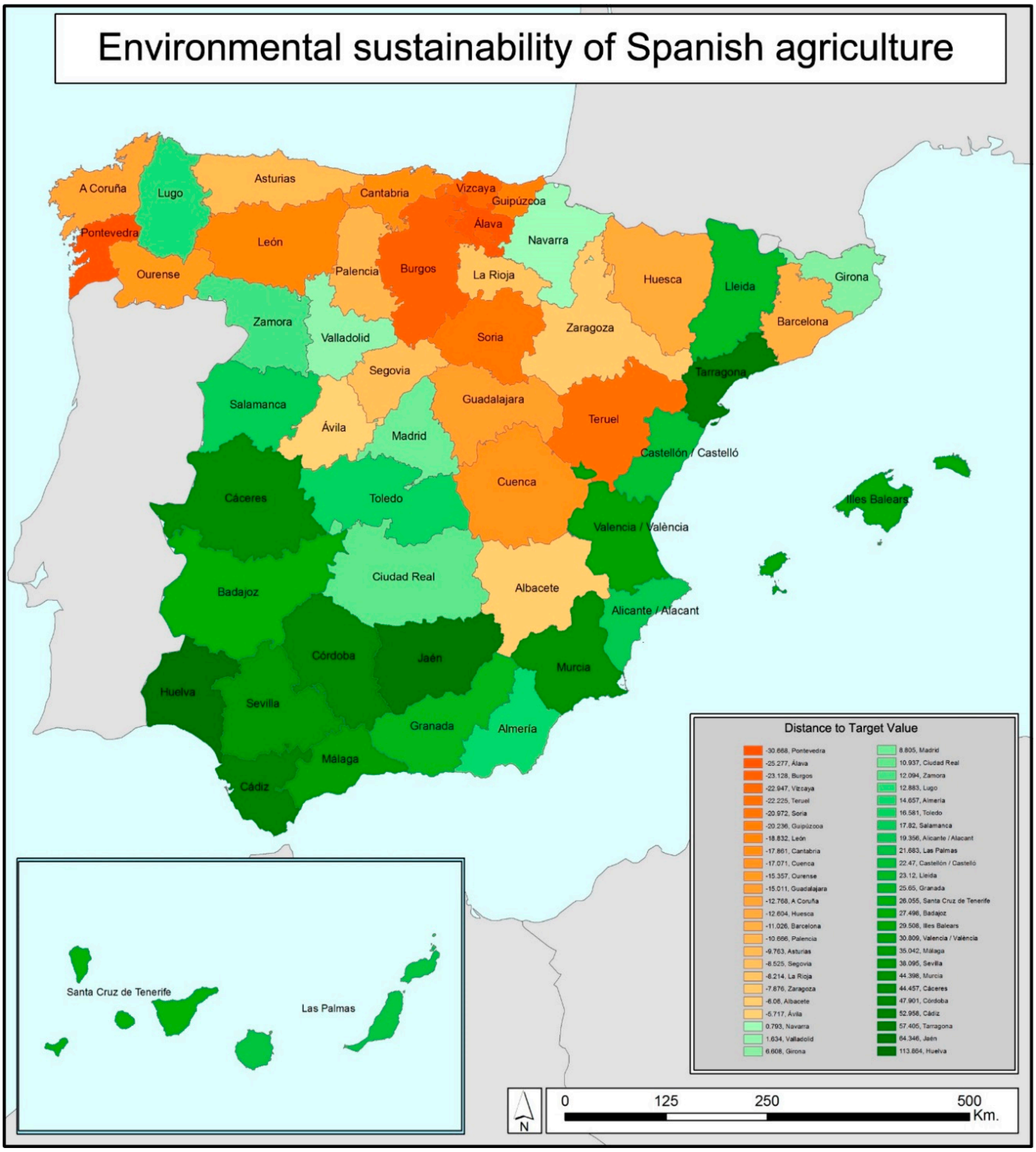

Figure A3. Environmental sustainability of Spanish agriculture.

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