# Multiple ecosystem services landscape index: a tool for multifunctional landscapes conservation.

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**Abstract**

The contribution of ecosystems to human well-being has been widely recognised. Taking into account existing trade-offs between ecosystem services (ES) at the farm scale and the dependence of multiple ES on processes that take place at the landscape scale, long-term preservation of multifunctional landscapes must be a priority. Studies carried out from such perspective, and those that develop appropriate indicators, could provide useful tools for integrating ES in landscape planning. In this study we propose a new integrative environmental indicator based on the ES provided by the landscape and named "multiple ecosystem services landscape index" (MESLI). Because synergies and trade-offs between ES are produced at regional or local levels, being different from those perceived at larger scales, MESLI was developed at municipality level. Furthermore, in order to identify main drivers of change in ES provision at the landscape scale an analysis of the relationship between the environmental and the socioeconomic characteristics of the municipalities was carried out. The study was located in the Basque Country and the results demonstrated that the MESLI index is a good tool to measure landscape multifunctionality at local scales. It is effective evaluating landscapes, distinguishing between municipalities based on ES provision, and identifying the drivers of change and their effects. This information about ES provisioning at the local level is usually lacking; therefore, MESLI would be very useful for policy-makers and land managers because it provides relevant information to local scale decision-making.

**Key-words:** ecosystem services indicators, drivers of change, socioeconomic aspects, municipalities, northern Spain.

## 1. Introduction

The contribution of ecosystems to the world's economy and human well-being has been widely recognised in science and policy (Corbera, 2012; Egoh et al., 2012; Müller and Burkhard, 2012; Van Oudenhoven et al., 2012). Ecosystems provide a number of goods and services to humans such as food, water, carbon sequestration, flood control, climate regulation, erosion control, aesthetic beauty and recreation (MEA, 2005). Nevertheless, most ecosystem services (ES) are external to the market system (e.g., flood control and climate regulation), thus their economic value is not quantified. Only a few services, such as food and timber, have real market value (Costanza et al., 1997; Seppelt et al., 2012). This has given rise to the degradation of non-marketed services as a result of actions taken to increase the supply of marketed ES (Gomez-Baggethun et al., 2010; Gutman, 2007). Safeguarding and enhancing the provision of non-marketed ES is crucial from both the human and economic perspectives. As a consequence, initiatives have been developed to promote the supply of non-marketed services (Gomez-Baggethun et al., 2010), such as payments for ecosystem services schemes (Schomers and Matzdorf, 2013; Wunder et al., 2008), habitat banking (Duke, 2013; Ten el al., 2010) or different subsidies.

One of the main drawbacks of these initiatives is that they usually follow a farm scale approach; which goes after the provision of a desired service on a particular land (Van der Horst, 2011). This farm scale approach is biased in two ways. First, it does not take into consideration the existing synergies and trade-offs between different services (Dymond, et al., 2012; Hauck et al., 2012; Onaindia et al., 2013a), it does not allow 'stacking' of ES in a trading scheme (Hein et al., 2013) and usually prioritises only one service such as water purification, mitigation of flooding, ecotourism, biodiversity conservation or carbon sequestration (Shapiro-Garza, 2013), leading to potential trade-offs with other services that are either not recognised or undervalued. Second, it is well known that the provision of many

ES depends on processes that take place at the landscape scale (de Koning et al., 2007; Van der Horst, 2011). For these reasons, efforts should focus on the conservation of multifunctional landscapes where many different services are provided (Gutman, 2007; Willemen et al., 2012).

In Europe, multiple services such as carbon sequestration, food and timber supply, water regulation and ecotourism are provided by the landscape (Maes et al., 2012; Onaindia et al., 2013a; Rodríguez-Loinaz et al., 2013). However, these ES are affected by different drivers of change. Here, a driver of change is defined as ecological or human-induced factors that affect ecosystem structure and function, thus altering the provision of ecosystem services (MEA, 2005). Drivers of change can be divided into 'direct' (e.g., harvesting) and 'indirect' (e.g., population growth, economic conditions). For example, during the 20$^{th}$ century, land use change was one of the most important "direct drivers" of change in ES worldwide (Foley et al., 2005; Geneletti, 2013; Nelson et al., 2006), because the amount and intensity of the services provides by the landscape are highly dependent on land uses. Among ecological indirect drivers highlights climate change that can induce land use changes in the long-term. However, there are a set of anthropogenic "indirect drivers", such as population dynamics and economic factors, that are described as the most significant drivers of land use change nowadays (Nelson et al., 2006; Zorrilla-Miras et al., 2014; Wu et al., 2013), and therefore, of the ES provided by the landscape.

The long-term preservation of multifunctional landscapes must be a priority; therefore, management actions on these landscapes should consider their dynamic nature, integrating the causes and consequences of different drivers of change (Folke et al., 2002; Nieto-Romero et al., 2014). In order to do it, two steps are necessary. First, a measure of landscape multifunctionality is mandatory. Second, it is necessary to know the main drivers of change in ES provisioning and their effects on the landscape multifunctionality. As a consequence, the two aims of this study were: a) to define an integrative environmental index of landscape multifunctionality based on the ES provided by the landscape. This indicator allows us to evaluate the state of the services provided by the landscape and their dynamics. Because synergies and trade-offs between ecosystems services are produced at regional or local levels, and they may differ from those perceived at larger scales (Hauck et al., 2012; Willemen et al., 2012), we defined this indicator at municipality level. The second aim was b) to analyse the relationship between ecosystem services provisioning and socioeconomic factors of the municipalities. As commented previously, one of the main "direct" drivers of change in ES provision are land use changes which are highly dependent on the socioeconomic issues.

## 2. Materials and Methods

### *2.1. Study area*

The study was carried out in the Basque Country, an autonomous community in the north of Spain. The study area extends over approximately 7,200 km$^2$ and is divided into three counties: Biscay, Alava and Guipuzcoa with 113, 53 and 91 municipalities, respectively (Fig. 1). For this study, only 251 out of the 256 municipalities were considered due to the lack of socioeconomic data for 5 municipalities.

#Figure 1 here approximately#

The population of the Basque Country is approximately 2,200,000 inhabitants and it is not homogeneously distributed between the three counties. More than 50% of the population lives in Biscay, where the population density is approximately 520 inhabitants/km$^2$, being mostly concentrated in a large nucleus around the city of Bilbao, the capital of the county. By contrast, Alava contains 320,000 inhabitants (15% of the total); 75% live in the capital, Vitoria, leaving the rest of the municipalities under-populated with a density of 30 inhabitants/km$^2$. Finally, Guipuzcoa represents an intermediate situation with a population density of 350 inhabitants/km$^2$ and population nuclei of intermediate size distributed throughout the county.

Geographically, the Basque Country is located on the border of the Atlantic and Mediterranean biogeographical regions. As a consequence, there are two climates. Biscay and Guipuzcoa have a temperate and humid climate with slight thermal oscillations (average temperature 12.5 ºC), uniform rainfall distribution throughout the year (average annual rainfall 1,500 mm), and a relative lack of frost. In contrast, Alava has a more Mediterranean climate with greater thermal oscillations (average temperature: 4ºC in winter and 20 ºC in summer), less precipitation (average annual rainfall 850 mm) that is concentrated in autumn and spring, and more frequent frosts. The topography also differs between the two regions. Biscay and Guipuzcoa have a mountainous topography, where approximately 50% of the region has slopes greater than 30%, while most of Alava is characterised by a wide plain. The differences in climate and topography have given rise to different land uses in the two regions. While timber plantations cover 45% of the area of Biscay and Guipuzcoa, 26% of Alava is characterised by intensive monocultures of potatoes, cereals and grapevines (Basque Government, 2010).

### *2.2. Spatial indicators*

#### *2.2.1 Indicators of ecosystem services*

The most relevant ES in the Basque Country were selected. Eleven important services in the study area were selected based on a combination of different ES described in the recent literature (Burkhard et al., 2012; de Groot et al., 2010; Gomez-Baggethun and Barton, 2012; Kandziora et al., 2012; Layke et al., 2012; MEA, 2005; Maes et al., 2012; TEEB, 2010). The individual ES were categorised within the three main groups: provisioning, regulating and cultural.

Provisioning services include all tangible products from ecosystems that humans use for nutrition, processing and energy, and they are usually divided into the subcategories of food, materials and energy (Kandziora et al., 2012). In this study, we selected food and wood production and freshwater supply services because of their relevance to the Basque Country. Other provisioning services, such as the provision of biochemical products or energy supply, were not considered in this work.

The benefits that people receive from the regulation of natural processes, such as climate and water flow regulation or erosion control, are considered regulating services. From the possible regulating services listed in the literature, we selected the six most relevant services for the study area: global climate regulation, water flow regulation, erosion control, local climate regulation, soil fertility maintenance and water purification.

Cultural ES include intangible benefits from ecosystems in the form of non-material, spiritual, religious, inspirational and educational experiences (Kandziora et al., 2012). Assessments of cultural ES are rather subjective because they are influenced by several factors such as the experiences, habits, behavioural traditions and lifestyles of each group of individuals (Burkhard et al., 2012; Kumar and Kumar, 2008). This makes cultural services valuation more challenging than that of the other ecosystem services categories. From the six cultural services that de Groot et al. (2010) consider, we only selected one, recreation, due to the difficulties in perceiving and valuating the other cultural services. Recreation and tourism is the most evaluated cultural service (UNEP-WCMC, 2011) because tourism statistics are usually collected by governments.

Apart from the above mentioned services, biodiversity was also considered. Biodiversity has been considered in different ways by different authors. In some works, the intrinsic value of biodiversity has been considered to be a cultural service (Burkhart et al., 2012; Kandziora et al., 2012). The Economics of Ecosystems and Biodiversity (TEEB, 2010) considers biodiversity to be a supporting service (of habitat), limited to function as a nursery and gene pool (de Groot et al., 2010). In this work, we have followed the Millennium Ecosystem Assessment framework (MEA, 2005) in which biodiversity is considered the foundation of the structure and function of the ecosystem (Onaindia et al., 2013a).

Finally, a set of indicators was selected for the evaluation of the ES. One main problem in evaluating ES is the identification of appropriate indicators (Wallace, 2007). First, appropriate ES indicators need to be quantifiable, sensitive to changes in land cover, explicit in time and space and scalable (van Oudenhoven et al., 2012). Second, that information must be communicated between scientists, practitioners and stakeholders, so indicators should be clear and understandable in order to be useful to these multiple end-users (Niemeijer and de Groot, 2008; van Oudenhoven et al., 2012). Finally, data availability, credibility, and portability were also considered to be important criteria. On the basis of these considerations, we selected 15 indicators for the eleven ES considered in this study (Table 1).

#Table 1 here approximately#

*2.2.2 Multiple ecosystem services landscape index (MESLI)*

Different indices of ecosystem services provision use different metrics, such as percentage of municipalities' area, tons of carbon per hectare or millimetres of water. However, in order to calculate an integrative index, all the data needs to be in a comparable form. Following the proximity-to-target methodology, all the ES indicators were transformed in a 0-1 scale. The proximity-to-target methodology measures each entity's performance on any given indicator based on its position within a range established by the lowest performance benchmark (equivalent to 0 on a 0-1 scale) and the highest performance benchmark or target (equivalent to 1). Sometimes clear low and high performance benchmark exist, either from biological thresholds, policy goals, or from established expert judgment. For MESLI calculation, when clear performance benchmarks exist, these were used (e.g. erosion prevention service: target =100%, low performance benchmark =0%). When clear performance benchmarks do not exist we used the entire time series data to set both, the low and high performance benchmarks, establishing the maximum observed value as the target and the minimum observed value as the low performance benchmark.

These standardised indices were summed for each landscape level considered, here municipalities, to obtain the multiple ecosystem services landscape index (MESLI) (equ. 1). In the case of services with two indicators, the average value was calculated previous to the aggregation.

Equation 1:

$$\text{MESLI} = \sum_{i=1}^{12} \frac{\text{Observed value}_i - \text{Low performance benchmark}_i}{\text{Target}_i - \text{Low performance benchmark}_i}$$

Once MESLI was calculated for a specific time, its change over time was calculated using TrendMESLI as follows (equ. 2):

Equation 2:

$$TrendMESLI = 100 * \left( \sum_{i=1}^{12} \frac{\text{Observed value}_{i\ t2} - \text{Observed value}_{i\ t1}}{\text{Target}_i - \text{Low performance benchmark}_i} \right) / MESLI_{t1}$$

$$MESLI_{t2} = MESLI_{t1} * (1 + TrendMESLI/100)$$

TrendMESLI calculates the percentage of variation, positive or negative, of the index between two times. In this study we calculated MESLI for the years 2000 and 2010, and TrendMESLI between them.

*2.2.3 Socioeconomic Indicators*

The socioeconomic variables were selected from information stored in the files of the regional administration (Eustat, 2010; Udalmap, 2010). Eleven variables were considered for the socioeconomic characterisation of the municipalities, comprising a total of 19 indicators (Table 2). In the case of economic activities, the proportion of the population occupied in the agricultural sector (AgrSec) was the only indicator used because of its correlation with the other selected three indicators of economic activity (Table 2). Life quality is characterised by more than one indicator; therefore, an integrative indicator was obtained using the same methodology used for MESLI, and using the maximum and minimum value observed in the study area as high and low performance benchmarks. However, if the socioeconomic variable represented a negative factor, such as students older than 16 years that study outside the municipality, 0 was assigned to the maximum value and 1 to the minimum. From the selected variables, population density (PopDen), percentage of urban soil (UrbSoi) and population occupied in agriculture (AgrSec) were considered to be indicators of rurality; the former two decrease in more rural municipalities while the latter increases.

#Table 2 here approximately#

*2.3. Data analysis*

Statistical analyses were performed in the R software environment (v.2.15.2; R Development Core Team, 2012). The data were analysed at two different scales: 1) for the whole autonomous community data-set, and 2) independently for the two dissimilar provinces of Biscay and Alava. This approach might help determine if our methodology is suited to different spatial scales. In any case, the methodology and the low and high performance benchmarks for scaling purposes used in considering autonomous community data-set and Biscay and Alava provinces independently were the same.

First, the correlations among ecosystem services indicators (ESI) were analysed. Using the correlation matrix, a principal component analysis (PCA) was used to distinguish spatial synergies, trade-offs and gradients between ESI and municipalities in a biplot. Next, the correlation of ES and the PCA ordination was determined using "enfit" (Oksanen et al., 2011), with 9,999 permutations, and plotted as passive variables on the ordination. At the same time, the most different municipality clusters were identified using the K-means method over the PCA matrix. The first two components (PCA1 and PCA2) that represented the main variation in ES were retained for further analyses. In addition, the differences in MESLI, TrendMESLI and ES between clusters were determined using ANOVAs, followed by Turkeys' HSD tests for pair-wise comparisons of means ($\alpha<0.05$).

Second, the relationships between socioeconomic factors and ES were modelled using linear regression models. In these models, MESLI, TrendMESLI and the first two PCA axes were considered as dependent variables, and the eleven socioeconomic variables measured in the municipalities were considered independent. The selection of the minimal adequate model

(MAM) followed Crawley (2007). In this study, all the environmental data analysis was done using MESLI and ESI for the year 2010.

## 3. Results

### *3.1. Ecosystem services in the Basque country municipalities*

In the Basque Country there were great differences between municipalities in the provision of multiple ES (Fig. 2a). On one hand, municipalities dominated by forest ecosystems, which are mainly situated on the northern part of the region, had the greatest multiple ecosystem services landscape index (MESLI>5). On the other hand, densely populated municipalities situated around Bilbao, the capital of the Biscay County, and municipalities from the southern part of the region characterised by intensive agricultural monocultures, had the lowest values (MESLI<3). There were also differences between municipalities in the ten years trend (Fig. 2b). In general, there has been an increase in the ES supplied (82.4% of the municipalities). The exceptions were the densely populated municipalities situated around Bilbao, and agricultural municipalities from the southern part of the region with lower MESLI values.

#Figure 2 here approximately#

The first two PCA axes of ESI to identify the synergies between municipalities accounted for 56% of the total variance (Fig. 3a, b). The first axis was positively related to stored C in soil and biomass, organic C in soil, areas without erosion problems, soil water storage capacity and soil water infiltration capacity indicators and only correlated negatively with agricultural production, suggesting that this component mainly represents a regulation gradient ($r^2$=0.90, $P<0.001$, Fig. 3a). Provisioning also had positive relationships with this axis (provisioning: $r^2$=0.66, $P<0.001$); although it also showed a slightly positive correlation with the second axis. Timber in forest plantations and evapotranspiration were positively correlated with the second axis, whereas cover of natural forest, habitats of community interest and special protection area were negatively correlated. The second axis clearly represents a biodiversity gradient ($r^2$=0.64, P<0.001).

#Figure 3 here approximately#

The PCA results clearly showed four clusters (Fig. 3b). Three clusters occupied different regions of the ordination space along the first axis. Cluster 1 was displayed to the left of axis 1, which was characterised by municipalities with low MESLI that are under great pressure either by high population density or by intensive agriculture. In contrast, cluster 4 was located to the right of axis 1 and was characterized by municipalities with mountainous topography covered by dense forests, where the regulation services domain. Cluster 2 was centered in the ordination and between these two extremes being composed by the municipalities with an intermediate cultural, provisioning and regulation services. Finally, cluster 3 was located at the negative end of axis 2, indicating that it was mainly composed of municipalities with important areas for biodiversity (Fig. 4).

#Figure 4 here approximately#

There were significant differences in MESLI between the four clusters ($F_{3,250}$= 382.73; p<0.001; Fig. 5a). There were also significant differences in the contribution of types of services to MESLI between the four clusters. In cluster 4, regulating and provisioning services were significantly greater than in the other three. The opposite happend with cluster 1, whereas cluster 2 and 3 presented intermediate values. Finally, the biodiversity component was significantly greater in cluster 3 than in the other three. As for TrendMESLI, significant differences were also found ($F_{3,250}$= 26.21; p<0.001; Fig. 5b). There was an increase in MESLI in all the clusters, except in cluster 1 where MESLI decreased, being it significantly greater in cluster 4. In general, cluster 1 municipalities showed a reduction in regulating services, while the other clusters showed an increase in regulating and provisioning services.

#Figure 5 here approximately#

*3.2. Relationships between socioeconomic factors and ecosystem services in the Basque country municipalities*

The analysis of the relationships between the socioeconomic variables and the main ESI variation gradients (the first two PCA axes) and MESLI produced some interesting results. There were significant relationships between MESLI and 6 out of 11 socioeconomic variables (Table 3). MESLI showed a significant increasing trend as life quality, unemployment, population density and agricultural sector decreased (negative slopes). An interesting result is that population density and agricultural sector showed the same decreasing trend, which is somewhat contradictory as higher population density values characterise more urban municipalities whereas higher agricultural sector is an indicator of more rural municipalities. Similar results were found when ESI PCA1 was considered (Table 3). The ESI PCA2 showed a significant positive relationships with population density, social services, education level and job opportunities (Table 3), indicating that biodiversity decreased in municipalities with higher values on these socioeconomic factors. TrendMESLI showed the same significant relationships as MESLI with the socioeconomic factors (data not shown).

#Table 3 here approximately#

*3.3. Contrasting highly industrial versus intensively agricultural counties (Biscay vs. Alava)*

MESLI in the industrialised Biscay was significantly correlated with 3 out of 11 socioeconomic variables (Table 4). MESLI increased when unemployment and population density showed a significant decreasing trend (negative slopes), which is identical to the results from the Basque Country analysis. However, in this case, MESLI showed a significant positive trend with agricultural sector, opposite to population density, indicating that more rural municipalities provide more services (higher MESLI). In contrast, the variables significantly related with MESLI on agricultural Alava were different from those of Biscay with the exception of agricultural sector and unemployment (Table 4). MESLI showed significant negative slope with unemployment, life quality and agricultural sector. It is remarkable that agricultural sector showed opposite slopes in these two analyses (Table 4). TrendMESLI showed significant negative relationship with population density and education level in Biscay and with agricultural sector and life quality in Alava, indicating that ecosystem services provision decreases (lower MESLI) when population density increases in Biscay and agricultural sector and life quality increase in Alava (Table 4).

#Table 4 here approximately#

Biscay County showed the same gradients and directions as found when considering the ESI PCA of the autonomous community as a whole (data not shown). PCA1 gradient was significantly negatively correlated with two socioeconomic indicators: unemployment, and population density (Table 4); indicating that when they increase ES are reduced. However, when agricultural sector increased ES increased in this gradient (positive correlation; Table 4). PCA2 gradient was significantly correlated with four indicators, being the most remarkable one the positive correlation with population density (Table 4), suggesting that greater population densities reduced biodiversity provided by the landscape.

In the case of Alava, the ESI gradients were slightly different from the autonomous community and Biscay general trends. Regulating services (r=0.98) and biodiversity (r=0.68) services showed stronger correlations with the PCA1 (48%), increasing through the positive end. PCA1 gradient was correlated with four socioeconomic indicators (Table 4), the most remarkable being agricultural sector and life quality that decreased (negative slope) through the positive end. This means that as agricultural sector and life quality increased regulation services and biodiversity decreased. The PCA2 (14%) was correlated with provisioning (r=0.70) increasing through the negative end. PCA2 gradient was significantly correlated with agricultural sector and age structure (Table 4). When primary sector increased and population age decreased there is an increase of provisioning services.

## 4. Discussion

The interest in conserving multifunctional landscapes that provide multiple services contributing to human well-being has been previously highlighted. Studies carried out from such perspective, combined with the development of appropriate indicators, could provide useful tools to evaluate and integrate ecosystem services in landscape planning processes (Roces-Díaz, et al., 2014). Synergies and trade-offs between ES are produced at regional or local levels, and they may differ from those perceived at larger scales (Hauck et al., 2012; Willemen et al., 2012). However, information about ES provisioning at the local level is usually lacking (Burkhart et al., 2012). An integrative index of ecosystem services provided by the landscape has never been applied at the local level as far as we know. Thus, the index presented here, MESLI, would be very useful for policy-makers and land managers because it provides relevant information to local scale decision-making. For example, this index would be an easy tool to measure ES diversity at the landscape level in a specific time, as it is a function of the number of services and the intensity which they are delivered. Furthermore, the combination of MESLI with TrendMESLI also reveals the effects that different land management decisions have on the provision of multiple ES.

The MESLI index used in this study to evaluate the multifunctionality of municipality landscapes has shown its capacity to sort municipalities as a function of their contribution to multiple ES. A similar index, called Total Ecosystem Services Value (TESV), was used by Maes et al. (2012) at the European scale. The main differences between MESLI and TESV are the establishment of targets and low performance benchmarks, being different from the maximum and minimum values observed in the data at the calculation time for scaling purposes in the former. The targets set for an index establish goals on the indicator level and allow not only for comparability between entities, but also to know how far an entity from an objective is, and how different actions taken move it close or away from that objective.

*4.1. Methodological concerns*

Environmental integrative indices, such as MESLI, are emerging as a powerful tools for decision-makers based on four reasons: a) they can summarise complex, multi-dimensional realities with a view to supporting decision-makers; b) they are easier to interpret than a battery of many separate indicators; c) they can assess progress of countries over time; and d) they reduce the visible size of a set of indicators without dropping the underlying information base (OCED; 2008). However, this type of indicators also has some limitations. In the case of MESLI two aspects should be highlighted. First, MESLI is dependent on the ecosystem services and the ecosystem services indicators selected. This is a common limitation of composite indicators (OECD, 2008). As a consequence, indicator selection is critical, because which indicators are considered in a decision making context highly influences the conclusions (Niemeijer and de Groot, 2008). Second, when clear low and high performance benchmarks do not exist, the selection of appropriate values for them can be subjective. For these reasons the transparency along all the process is needed.

For MESLI calculation, we have considered all services to be of equal weight. It can be argued that ES will differ in the amount they contribute to human well-being –some may be extremely important and others less so- and, therefore should not have the same weight in the calculation. However, the existing valuation techniques are not able to measure the real contribution of the different services to the human well-being (Baveye et al., 2013). Furthermore, the same service in the same region can be valued differently by different group of people of the same area depending on their education level, personal income, precious experience, and so on (Casado-Arzuaga et al., 2013). Usually, some services that are critical for the human well-being are undervalued, because they do not have a market value or are less visible (Gomez-Baggethun et al., 2010). To avoid the general tendency to prioritise marketed and more visible services, we highlight the importance of conserving multifunctional landscapes considering all services to be of equal weight. Thus, the MESLI index does not "value" landscape multifunctionality. It can be considered a measure of ES diversity as it is a function of the number of services and the intensity witch they are delivered.

*4.2. Socioeconomic drivers of ecosystem services change in the Basque Country*

In the Basque Country case study, the analysis of the relationship between ecosystem services provision by municipalities and their socioeconomic factors showed contradictory results. There was a negative correlation between population density and primary sector and MESLI. This result indicates that more rural municipalities (i.e., less densely populated) delivered more ES, and less rural municipalities (i.e., weaker primary sectors) also deliver more services. This can be explained by the fact that two very different types of municipalities were included in the same group, i.e. the urban municipalities around the city of Bilbao and the rural municipalities of the southern part of Alava County where the primary sector is focused on intensive monocultures. From the multiple ES provisioning point of view, both municipalities have low value. The ES provision in the urban municipalities was very low because most of the land surface is urban soil. In contrast, rural municipalities where most of the territory is devoted to intensive monocultures provide few ES, mainly because they are focused on food supply at the expenses of regulation services and biodiversity (Dale and Polasky, 2007; Hauck et al., 2012; MEA, 2005). These contradictory results reveal the importance of taking into account the different biophysical characteristics, socioeconomic aspects and territory land use history in this type of analysis. Although the study area was quite small, 110 km long and 140 km wide, the great differences between the northern and southern parts could generate erroneous conclusions if the area is considered as a whole.

When Biscay and Alava Counties were studied separately, the contradictions disappeared. However, the results were different in each county. In Biscay, the results showed that more rural municipalities, which are less densely populated with stronger primary sector, have greater MESLI. Nevertheless, in Alava, the results showed that more rural municipalities (stronger primary sector) deliver fewer ES (lower MESLI). This opposing relationship is due to the large differences in the primary sector between the two counties. In Biscay, the primary sector is mainly focused on forest plantations for timber production; in contrast, the primary sector of Alava is focused on intensive monocultures (i.e., viticulture and potatoes). Forest systems provide a wide array of services, such as carbon storage, timber production and water flow regulation, whereas intensive monocultures mainly produce food, being relatively poor at delivering other ES. It is well known that this type of monocultures creates environmental impacts that affect a wide range of ES (Dale and Polasky, 2007; Haaren and Bathke, 2008).

Similar results have been described in the recent ES literature (Butler et al., 2011; Laterra et al., 2012; Maes et al., 2012). It should be noted that the rural landscape of Alava, comprised by monocultures such as potatoes, grapes and olive trees, has a strong cultural background as it has been made by humans through their agricultural practices over hundreds of years. Due to the difficulties in measuring it, this cultural service was not considered in the study. However, its inclusion would not change the results as it is only one service out of twelve.

The trend described in the study period also showed significant negative relationship with population density and primary sector in Biscay and Alava, respectively. While, most of the municipalities described an increase in MESLI, the most populated municipalities in Biscay and the municipalities of Alava with the strongest primary sector described a reduction in the index. These results, together with MESLI overall results, suggest that there are two main indirect drivers of change in ES provision in the Basque Country: a) population grown and b) the agricultural sector. Population dynamics is influenced by factors that operated at global scales (Nelson et al., 2006); therefore, the ability of local or regional stakeholders to influence or control its impact on ecosystem services provision is quite limited. However, a lot of decisions about agricultural sector, such as localization of the different uses, species selection, management regimens, etc. are taken at regional and local level. This makes agricultural sector a key sector for the maintenance of multifunctional landscapes in the Basque Country. Similar results have been obtained in Mediterranean region where rural abandonment and intensification of agrarian practices has been described as main drivers of ES change (Nieto-Romero; 2014).

In the last decade, drop of wood prices has given rise to a crisis in the forest sector of the region (Onaindia et al., 2013b; Palacios-Agundez et al., 2014; Rodríguez-Loinaz et al., 2013). This explain the increment of ecosystem services provision (mainly provisioning and regulating) described in most of the north part of the Basque Country, where forest sector manages a great part of the territory (45% of the area). Initially, the reduction of clear-cutting has given rise to an increment of the amount of timber present on those plantations that explains the increment of provisioning services. Thus, the amount of C stored increased supposing an increment of global clime regulation service. Finally, the soil erosion problems are reduced as the impacts that timber plantations have on the soils during the clear-cutting operations and the soil preparation activities before planting are reduced, favouring the increase of plant biodiversity on these areas (González-Alday et al., 2009). This situation can represent an inflexion point for the management practices used until now in the area, and the future decisions about the sector would have a big impact on the services provided at landscape scale in the north part of the Basque Country.

In the case of intensive agriculture areas for food production that characterizes the south part of the Basque Country, the picture is very different. These monocultures are quite profitable; therefore, provisioning services are prioritized at the expenses of regulation services and biodiversity. In these regions, the new Common Agricultural Policy (CAP) (European Commission, 2013) could help to increase the services provided by these areas as it has addressed important changes to achieve this objective (e.g. 30% of direct payments are allocated to “green” measures).

### *4.3. Incentive mechanism*

Our results showed that the municipalities that supply more services, higher MESLI, have some worse socioeconomic aspects, such as higher unemployment or lower life quality, than the municipalities with lower MESLI. Recognising the contribution of these municipalities to human well-being during the distribution of government funds has the potential to improve their socioeconomic situation and reduce the differences between the municipalities (Vidal-

Legaz; 20013). However, in the Basque Country, the amount of money that each municipality receives from the government is fixed and based on factors such as its population and the contribution of its economic activities to the gross domestic product (GDP). In this scenario, the great differences between municipalities in relation to their contribution to ES provision are not considered even though they are fundamental for human well-being. Establishment of economic compensation of positive externalities produced by these communities could improve their socioeconomic situation and lead to an increment in ecosystem services provided by the municipalities. First, as the amount of money that each municipality receives would be a function of the services provided, the prospective of higher incomes could motivate them to devote their public lands to the provision of ES. Second, the actual system of protected areas, where the conservation of nature is the main goal, has been the cause of many conflicts between conservationists and the rural population (Gutman, 2007). Moreover, foresters of the region feel marginalised by the broader society as they are considered responsible for the negative effects that their activities can have on the environment, yet they receive little support or acknowledgement for good practices (Hecken et al., 2012). If municipalities invest the payments in community projects and infrastructure, these collectives would receive direct benefits, such as improvements to their quality of life, from the protection of nature and the use of good practices, which could increase their interest in conservation activities and the sustainable management of natural resources (Gutman, 2007).

## 5. Conclusion

The landscape approach presented in this study avoids the general tendency to prioritise marketed services that crowd out non-marketed ones, highlighting the importance of conserving multifunctional landscapes considering all services to be of equal weight, regardless of their relative market and non-market value. The MESLI index proposed in this study is a good tool to measure landscape multifunctionality at local scales. When it is combined with TrendMESLI, they allow us to evaluate landscapes based on ecosystem services, identifying the drivers of change and their effects. However, we have to be very careful about the scale used in this kind of studies, since the inclusion of areas with different biophysical characteristics, socioeconomic aspects and territory land use history together could lead contradictory results and erroneous conclusions.

## 6. Acknowledgements

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Figure 1: Study area.

Figure 2: Maps of the multiple ecosystem services landscape index (MESLI) (a) and TrendMESLI (b) by municipality.

Figure 3: First two axes of the principal component analysis (PCA) ordination of the Basque Country municipalities with respect to the ecosystem services indicators (ESI), which illustrate: a) the positions of ESI and ES overlaid as passive projections, and b) the municipality plot with the four clusters based on ES expressed as bivariate-deviational ellipses (95% confidence intervals). DC: Density of head of cattle, AP: Agricultural production, Timb: Timber in forest plantations, RO: Runoff, SCSB: Stored C in soil and biomass, OCS: Organic C in soil, Et: Evapotranspiration, SWS: Soil water storage capacity, SWI: Soil water infiltration capacity, RF: Cover of riparian forest in river margins, NF: Cover of natural forest, Eros: Areas without erosion problems, RTS: Density of rural tourism establishments, SP: Special protection area and HCI: Habitat of community interest.

Figure 4: Municipalities clusters: 1) very low provision of ecosystem services, 2) moderate provision of ecosystem services, 3) municipalities whose contribution to biodiversity conservation is very high, 4) high provision of ecosystem services with a predominance of regulating services.

Figure 5: Significant differences between clusters in: a) MESLI and the contribution of its different components (provisioning, regulating, biodiversity and cultural); and, b) TrendMESLI and the contribution of its different components.

Table 1. List of selected ecosystem services and biodiversity values with their potential indicators and low and high performance benchmarks (Min. t. s., Max. t. s.: minimum and maximum value in entire time series data). References that use the indicator, or a similar indicator, are noted.

Table 2. List of socioeconomic variables considered with their potential indicators.

Table 3. Summary of the MAM statistics from multiple regression models between MESLI and the two PCA axes of ESI and the socioeconomic indicators of the Basque Country municipalities.

Table 4. Summary of the MAM statistics of multiple regression models between MESLI, Trend MESLI and the two PCA axes of ESI and the socioeconomic indicators of the two contrasting counties: Biscay and Alava.

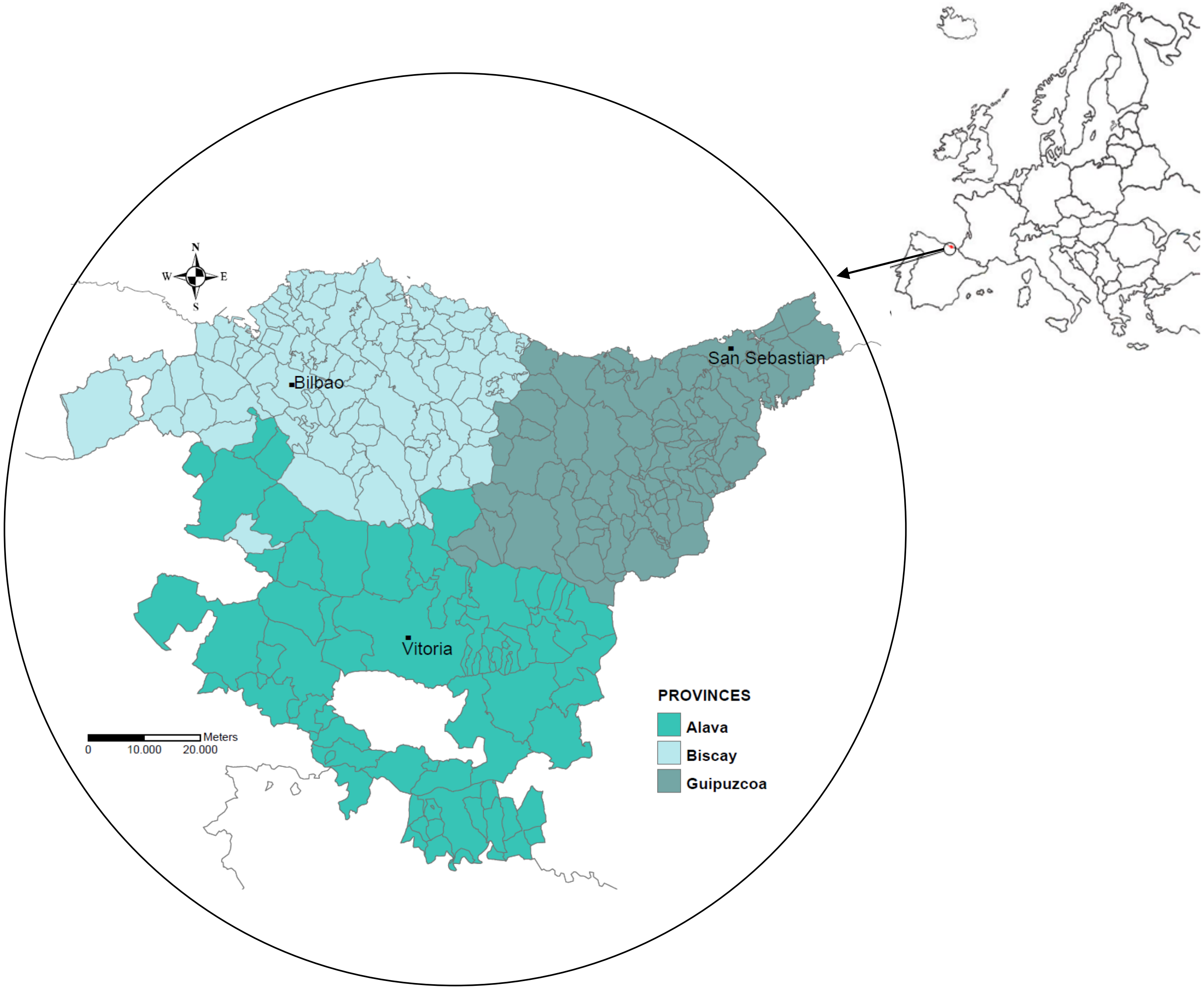
| Services | Indicators | Low performance benchmarks | Target | References |
|---|---|---|---|---|
| **Provisioning** | | | | |
| Food | DC: Density of head of cattle (Nº/100 ha) | 0 | Max. t. s. | Burkhard et al., 2012; Kandziora et al., 2012 |
| | AP: Agricultural production (Ton/ha) | 0 | Max. t. s. | Maes et al., 2012; European Commission, 2014 |
| Raw materials | Timb: Timber in forest plantations (m3/ha) | 0 | Max. t. s. | Burkhard et al., 2012; Maes et al., 2012 |
| Freshwater | RO: Runoff=renewable water supply (mm) | Min. t. s. | Max. t. s. | MEA, 2005 |
| **Regulating** | | | | |
| Global climate regulation | SCSB: Stored C in soil and biomass (Ton C/ha) | 0 | Max. t. s. | Maes et al., 2012; Kandziora et al., 2012; van Oudenhoven et al., 2012; Layke et al., |
| Maintenance of soil fertility | OCS: Organic C in soil (Ton C/ha) | 0 | Max. t. s. | Maes et al., 2012 |
| Local climate regulation | Et: Evapotranspiration (mm) | Min. t. s. | Max. t. s. | Burkhard et al., 2012; Kandziora et al., 2012; Layke et al., 2012 |
| Water flow regulation | SWS: Soil water storage capacity (mm) | 0 | Max. t. s. | van Oudenhoven et al., 2012; Layke et al., 2012 |
| | SWI: Soil water infiltration capacity (cm/h) | 0 | Max. t. s. | Maes et al., 2012; Layke et al., 2012; Gomez-Baggethun and Barton, 2012 |
| Water purification | RF: Cover of riparian forest in river margins (% in 25 m buffer) | 0% | 100% | Plieninger et al., 2012; European Commission, 2014 |
| | NF: Cover of natural forest (% of municipality's surface) | 0% | Max. t. s. | European Commission, 2014 |
| Erosion prevention | Eros: Areas without erosion problems (% of municipality's surface) | 0% | 100% | Kandziora et al., 2012 |
| **Cultural** | | | | |
| Tourism | RTS: Density of rural tourism establishments (Nº/km$^2$) | 0 | Max. t. s. | Burkhard et al., 2012; Kandziora et al., 2012 |
| **Biodiversity** | | | | |
| | SP: Special protection area (% of municipality's surface) | 0 | Max. t. s. | Maes et al., 2012 |
| | HCI: Habitat of community interest (% of municipality's surface) | 0 | Max. t s | Burkhard et al., 2012; Kandziora et al., 2012 |

| Socioeconomic variables | Indicators |
|---|---|
| Population density (PopDen) | Population density (inhabitants/km$^2$) |
| Age structure of the population (AgeStr) | Population ageing index (no units) |
| Unemployment (Unempl) | Unemployed population (% of active population) |
| Economic activities (EcoAct) | (AgrSec) Population occupied in agriculture (% of active population) |
| | (IndSec) Population occupied in industry (% of active population) |
| | (ConSec) Population occupied in construction (% of active population) |
| | (SerSec) Population occupied in services (% of active population) |
| Municipalities' economic situation (MunEco) | Municipalities' debt (€/inhabitant) |
| Population's economic situation (PopEco) | Personal rent/income (€) |
| Social Services (SocSer) | Municipalities' investment in social services (€/inhabitants) |
| Life quality (QuaLife) | Access time to a main highway (minutes) |
| | Housing comfort index (no units) |
| | Number of banks (Nº/10000 inhabitants) |
| | Number of outpatient clinics (Nº/10000 inhabitants) |
| | Number of elementary school vacancies (Nº/100 inhabitants) |
| | Students older than 16 years that study outside the municipality (%) |
| Education level of the population (EduLev) | Population older than 10 years with higher education (%) |
| Job opportunities (JobOpp) | Jobs (Nº/100 Inhabitants) |
| Town planning (TownPlan) | (UrbSoi) Urban soil (% of municipal surface) |

| | Variables | Estimate(±SE) | t-value | p-value |
|---|---|---|---|---|
| ***MESLI-t2*** | | | | |
| | Intercept | 6.05±0.24 | 25.77 | <0.001 |
| | PopDen | -0.03±0.01 | -8.12 | <0.001 |
| | Unempl | -0.09±0.02 | -4.49 | <0.001 |
| | QuaLife | -2.75±0.62 | -4.40 | <0.001 |
| | SocServ | 0.06±0.02 | 3.72 | 0.010 |
| | PopEco | 0.01±0.001 | 2.40 | 0.017 |
| | AgrSec | -0.10±0.01 | -11.14 | <0.001 |
| ***PCA 1*** | | | | |
| | Intercept | 0.72±0.11 | 6.64 | <0.001 |
| | PopDen | -0.01±0.001 | -7.86 | <0.001 |
| | Unempl | -0.05±0.01 | -5.27 | <0.001 |
| | QuaLife | -1.25±0.30 | -4.38 | <0.001 |
| | SocServ | -0.03±0.001 | 4.53 | <0.001 |
| | AgrSec | -0.04±0.01 | -13.21 | <0.001 |
| ***PCA 2*** | | | | |
| | Intercept | -0.33±0.24 | 1.42 | 0.159 |
| | PopDen | 0.001±0.001 | 2.52 | 0.012 |
| | AgeStr | -0.001±0.001 | -4.22 | <0.001 |
| | SocServ | 0.004±0.001 | 3.92 | 0.001 |
| | EduLev | 0.02±0.008 | 2.51 | 0.013 |
| | PopEco | -0.001±0.001 | -2.96 | 0.004 |
| | JobOpp | 0.002±0.001 | 2.81 | 0.005 |

| | Variables | Estimate (±SE) | t-value | p-value |
|---|---|---|---|---|
| ***Biscay*** | | | | |
| ***MESLI*** | Intercept | 5.26±0.27 | 19.76 | <0.001 |
| | PopDen | -0.01±0.001 | -9.61 | <0.001 |
| | Unempl | -0.64±0.03 | -2.36 | 0.020 |
| | AgrSec | 0.07±0.02 | 3.37 | 0.002 |
| ***TrendMESLI*** | Intercept | 13.57±4.12 | 3.29 | 0.001 |
| | PopDen | -0.01±0.001 | -2.95 | 0.003 |
| | EduLev | -0.24±0.09 | -2.42 | 0.016 |
| ***PCA 1*** | Intercept | 0.01±0.001 | -2.56 | 0.012 |
| | PopDen | -0.002±0.001 | 10.73 | <0.001 |
| | Unempl | -0.04±0.02 | 2.10 | 0.038 |
| | AgrSec | 0.04±0.01 | -2.88 | 0.005 |
| ***PCA 2*** | Intercept | 1.89±0.38 | 4.95 | <0.001 |
| | PopDen | 0.01±0.001 | 3.37 | 0.002 |
| | Unempl | -0.05±0.02 | -1.80 | 0.075 |
| | AgeStr | -0.04±0.01 | -3.05 | 0.003 |
| | EduLev | -0.06±0.02 | -6.59 | <0.001 |
| ***Alava*** | | | | |
| ***MESLI*** | Intercept | 4.48±0.79 | 5.68 | <0.001 |
| | AgeStr | 0.002±0.001 | 3.05 | 0.004 |
| | Unempl | -0.11±0.02 | -4.90 | <0.001 |
| | QuaLife | -4.40±1.15 | -3.80 | 0.001 |
| | AgrSec | -0.05±0.01 | -5.20 | <0.001 |
| | EduLev | 0.07±0.03 | 2.34 | 0.023 |
| ***TrendMESLI*** | Intercept | 11.57±3.14 | 3.67 | <0.001 |
| | AgrSec | -0.16±0.06 | -2.50 | 0.015 |
| | QuaLife | -19.74±9.83 | -2.01 | 0.05 |
| ***PCA 1*** | Intercept | 1.90±0.28 | 6.66 | <0.001 |
| | AgeStr | 0.002±0.001 | 2.99 | 0.004 |
| | Unempl | -0.09±0.02 | -5.50 | <0.001 |
| | QuaLife | -3.09±0.88 | -3.49 | 0.002 |
| | AgrSec | -0.05±0.01 | -8.39 | <0.001 |

| | | | | |
|---|---|---|---|---|
| ***PCA 2*** | Intercept | -0.97±0.39 | -2.47 | 0.017 |
| | AgrSec | -0.002±0.001 | -2.54 | 0.014 |
| | SocSer | 0.01±0.001 | 1.97 | 0.050 |
| | AgeStr | 0.002±0.001 | 2.74 | 0.008 |



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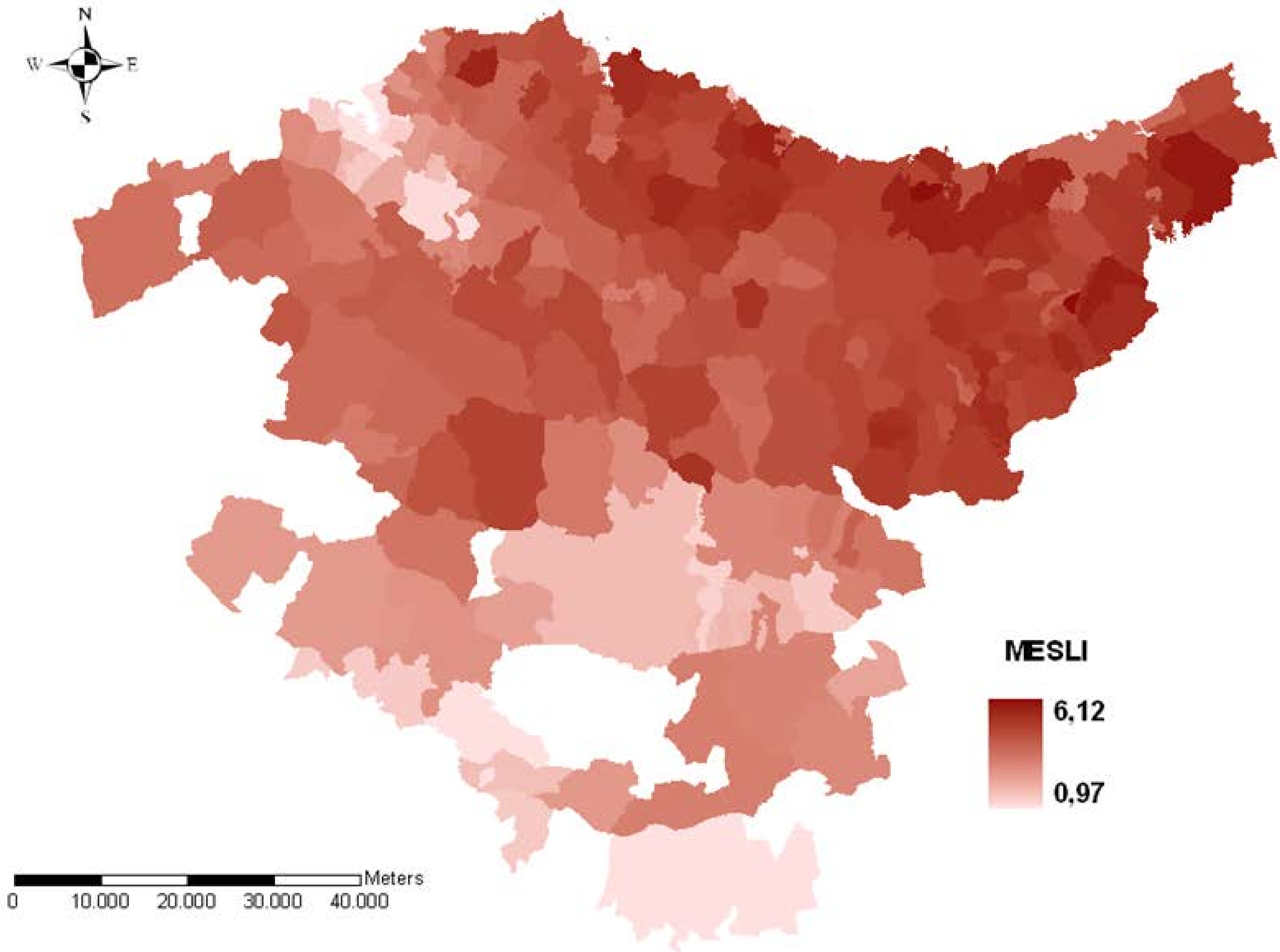
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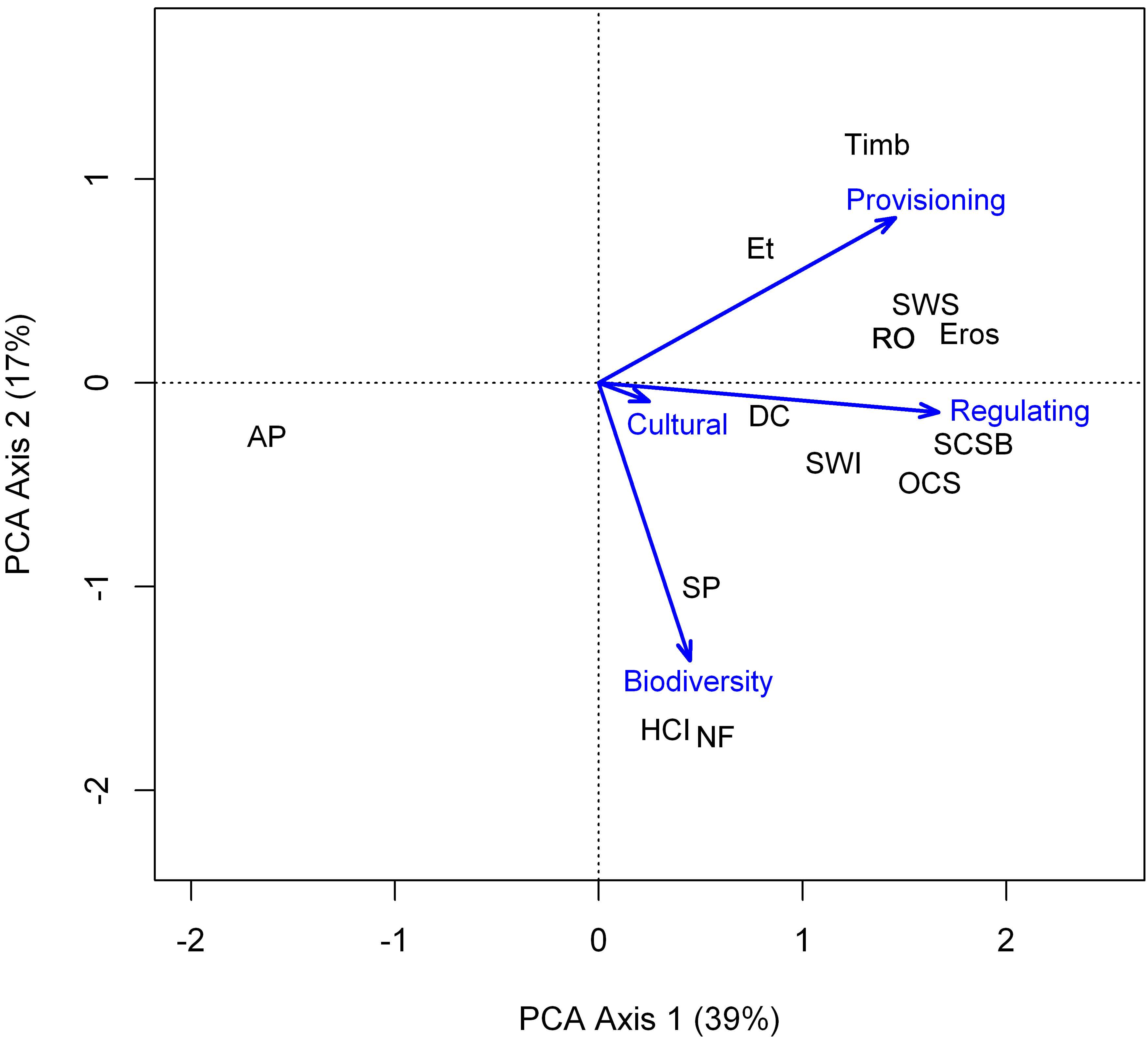

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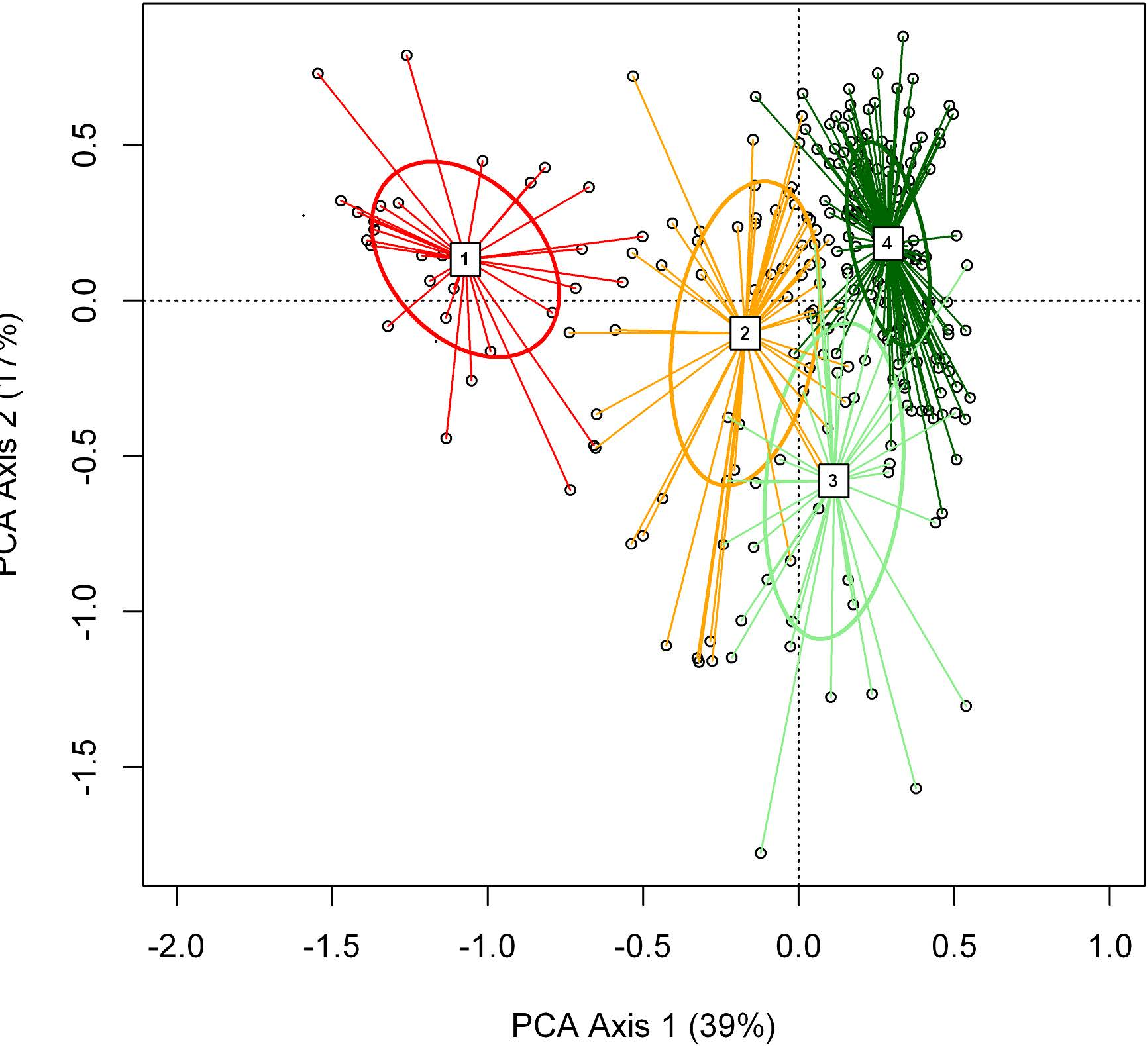

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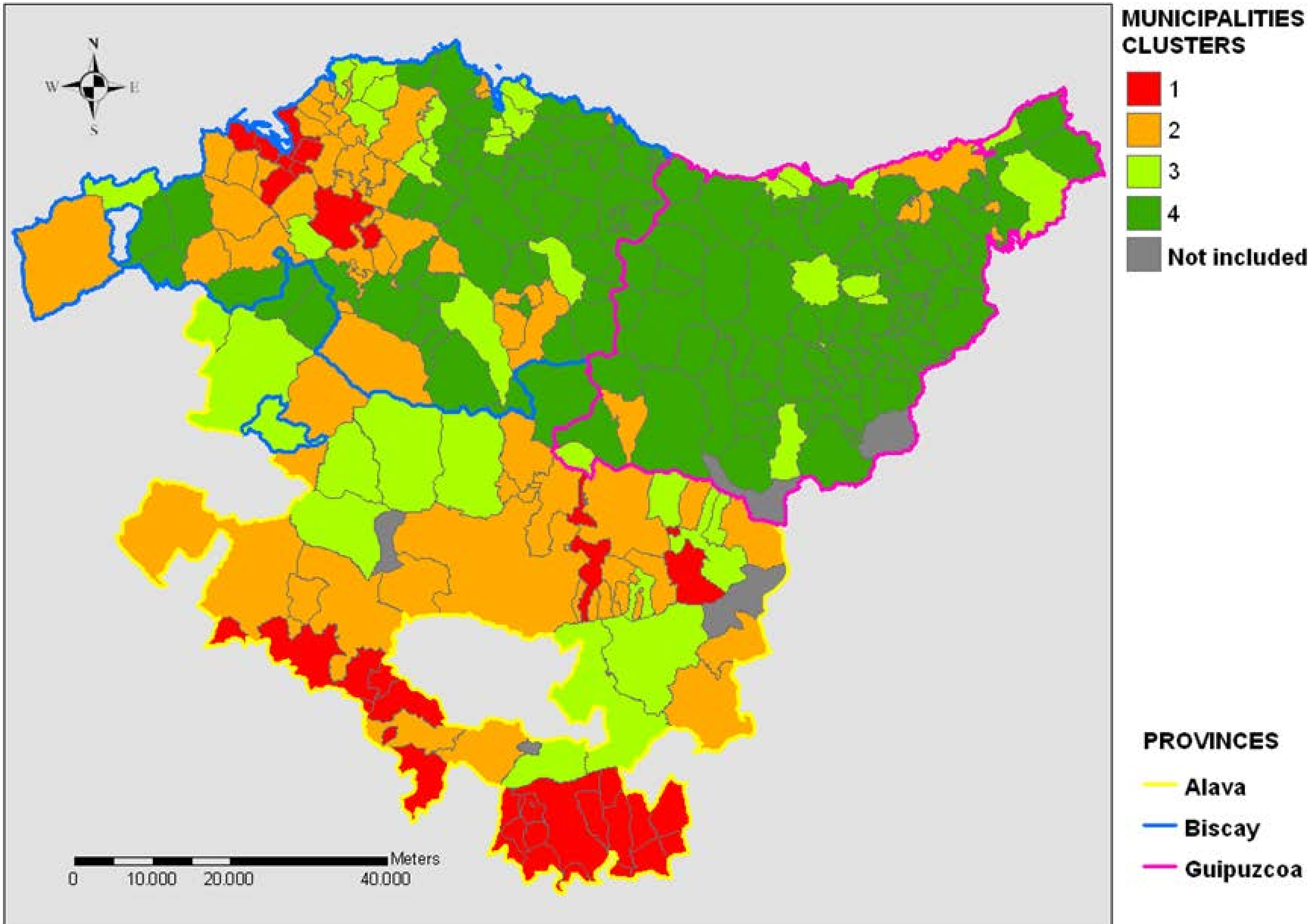
3
4



N
W
E
S
MUNICIPALITIES CLUSTERS
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Not included
PROVINCES
Alava
Biscay
Guipuzcoa
Meters
0
10.000
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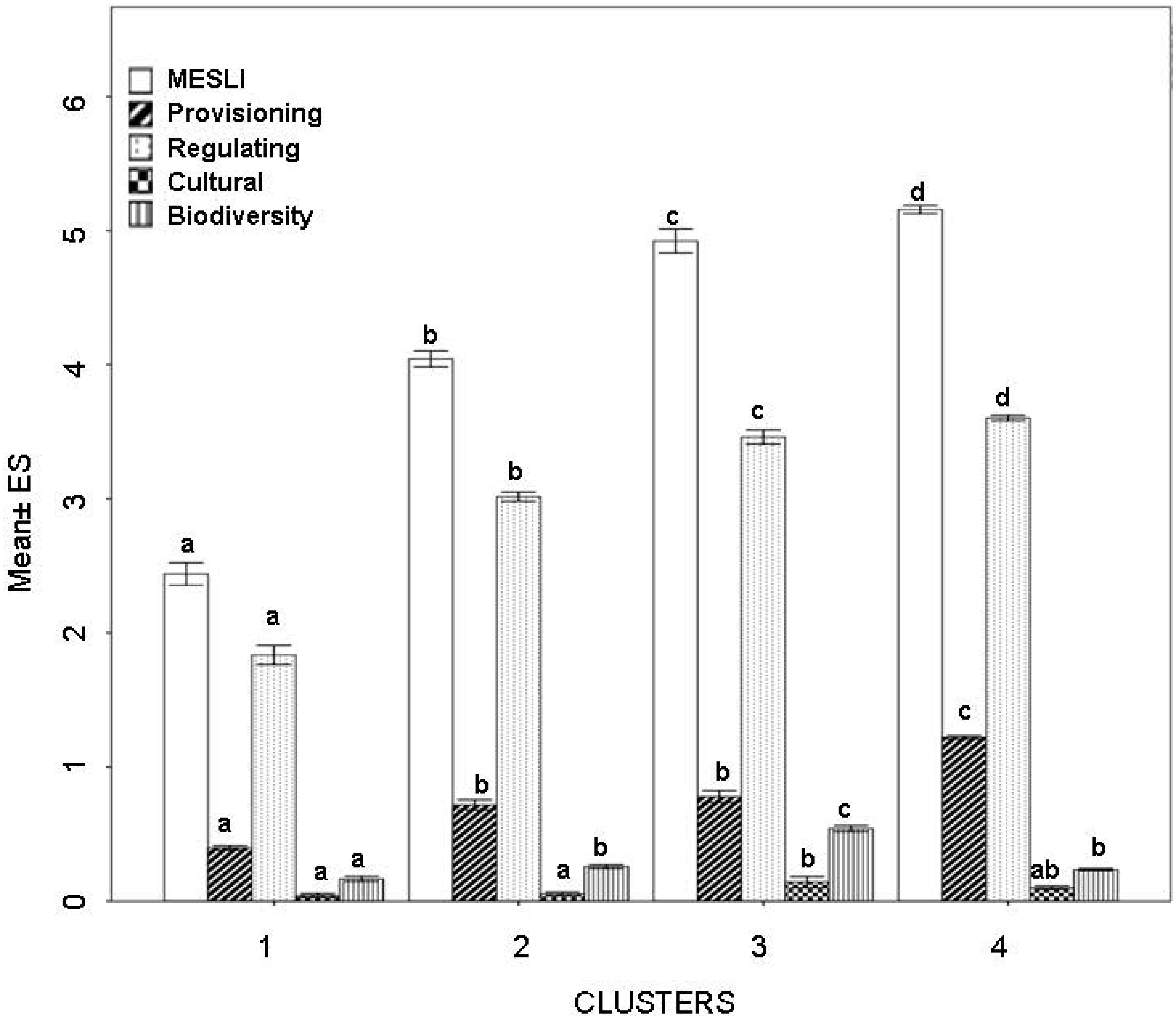
40.000


MESLI
Provisioning
Regulating
Cultural
Biodiversity
Mean± ES
CLUSTERS
0
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3
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5
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ab
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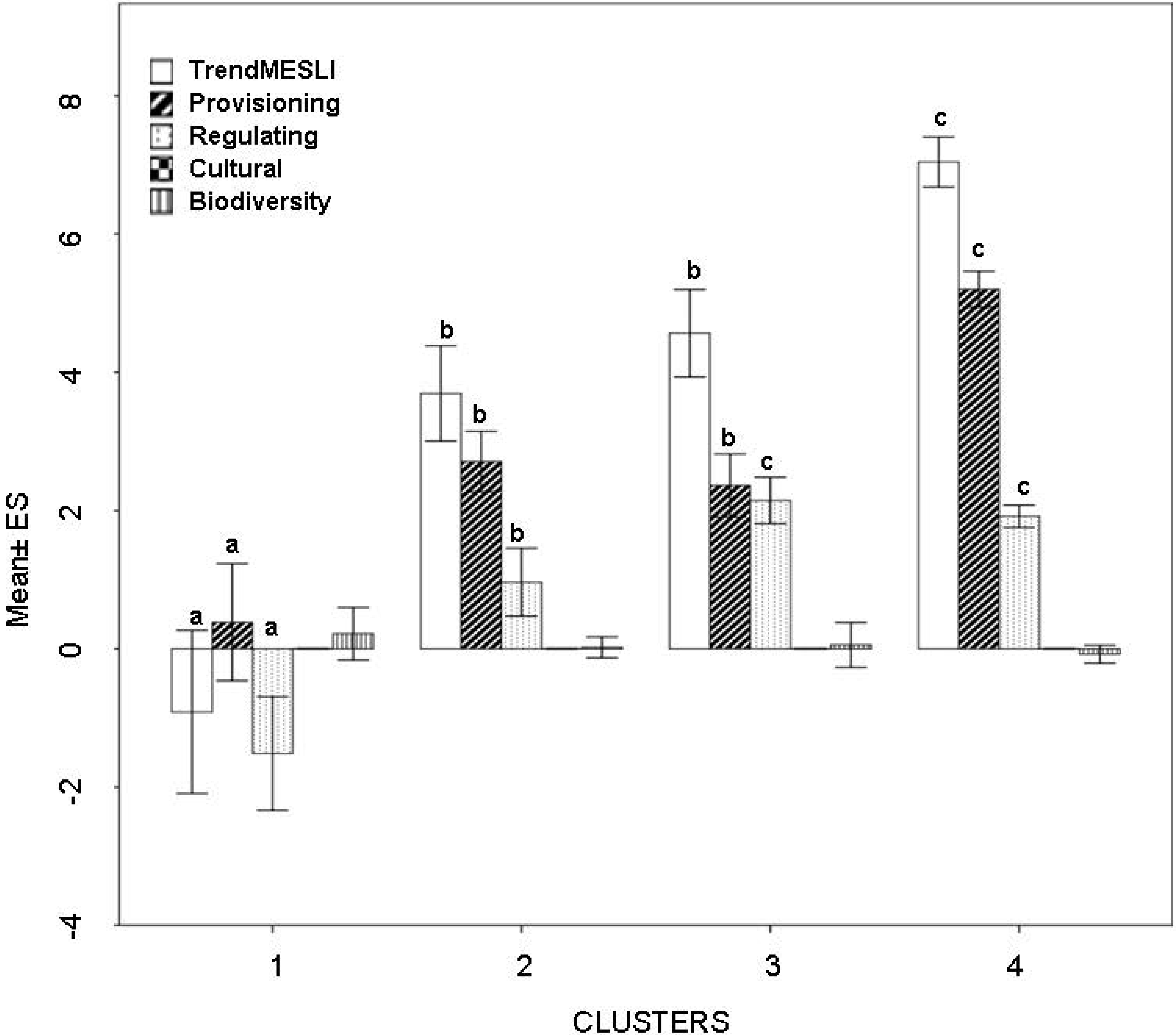
TrendMESLI
Provisioning
Regulating
Cultural
Biodiversity
Mean± ES
CLUSTERS
-4
-2
0
2
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8
1
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4
a
a
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b
b
b
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b
c
c
c
c