Do rural development measures have an impact on farm nature value indicators in France?

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Abstract

This paper proposes an approach for assessing the effectiveness of those agri-environmental schemes and rural development measures aimed at enhancing the natural value of farmland and, more generally, aimed at releasing the pressure on the environment due to agriculture. Using regional and local data, an indicator derived from the High Nature Value (HNV) concept is elaborated at a LAU1 spatial resolution, for both France as a whole as well as for Midi-Pyrénées NUTS2 region.. The effect of rural development measures on the evolution of this indicator in France, between 2007 and 2010, is explored. Given that the indicator is built from three different indices (addressing crop diversity, grassland share, and wooded and afforested farmland) the effect of rural development measures on each of these individual indices is also explored. Results indicate that measures from both 2000-2006 and 2007-2013 rural development programming periods affect the changes in the indicator and indices, and the spatial scale of the analyses matters. Indeed, trends observed at the national scale do not necessarily apply at the regional scale (e.g. impacts of conversion to organic farming, the grassland premium, payments for water and biodiversity protection) underlining the importance of multi-scale assessments. This enables the main structure and the magnitude of policy impacts to be captured and helps with the understanding of why certain objectives were not met. Key findings are relevant in the context of policy monitoring and evaluation, while the methodology proposed, that incorporates spatial effects, is an important contribution to the implementation of the Common Monitoring and Evaluation Framework by Member States to account for national, regional or local characteristics.

Key-words: High Nature Value; Environmental Indicators; Rural Development; Spatial econometrics; Impact evaluation; Common Agricultural Policy

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1. Introduction

This paper explores the possibilities of systematically and quantitatively evaluating the impact of agri-environmental schemes (AESs) and, more broadly, rural development measures, on the quality of the environment, particularly the natural value of farmland. As one of the main objectives of AESs is to promote and enhance the environment and the countryside, it is considered that exploring the relationships between the implementation of AESs (or the wider rural development measures) and environmental benefits helps in assessing the efficiency of the policy.

Since a large part of the land area in Europe is used by farmers, on-farm nature conservation can be an important instrument in restoring, maintaining and enhancing ecosystems dependent on agriculture. AESs are a European Union (EU) mandatory instrument within the Common Agricultural Policy (CAP), under which farmers receive payment for their voluntary efforts in nature conservation, environment-friendly practices or the maintenance of valuable landscapes. The interest in knowing the extent to which these schemes actually enhance the quality of the environment, of nature or the landscape, has driven much research that has examined the effectiveness of AESs and nature-friendly practices (e.g. Kleijn et al., 2006; Kleijn and Sutherland, 2003; Ovenden et al., 1998; Whittingham, 2011). Moreover, the need for such research has been further underlined by the European Court of Auditors (2011, p.28) highlighting that there is "*very little information on the environmental benefits of agri-environment payments*". Agricultural land uses have positive and negative effects on the environment and particularly in the biodiversity. On the one hand, streamlined and homogenised land uses have accompanied farm specialisation into fewer arable crops or fewer animal products, with intensive use of machinery and chemical agricultural inputs. Field and farm enlargement often lead to the destruction of landscape features such as hedges and buffer zones, disrupting ecological corridors and fragmenting natural habitats. On the other hand, semi-natural vegetation in agricultural land enhances biodiversity (Doxa et al., 2010) and the supply of regulating ecosystem services such as pollination, maintenance of soil quality, erosion control, and water storage (Garcia-Feced et al., 2014). Maintaining an adequate level of the nature value of agricultural land therefore has multiple benefits. This has been recognised in the CAP. Starting in the programming period 2007-2013, the concept of High Nature Value (HNV) farmland was introduced into the CAP (European Commission, 2006a) in order to strengthen the role of farming practices in biodiversity maintenance (Beaufoy et al., 1994; EEA, 2004). Many efforts have been made to derive operational indicators from existing data (Peppiette, 2011), but analyses of the effectiveness of policy measures in maintaining and enhancing farmland nature value are less numerous.

This article addresses the extent to which an HNV-derived indicator, based on agricultural statistical data and existing modelling, can support the evaluation of the impact of rural development measures (with a focus on AESs). To tackle this issue, a set of indicators, based on Pointereau et al. (2010), is proposed and tested. Proposed indicators are empirically tested on France where investigations are based on an LAU1 regional resolution, for both the national level and the Midi-Pyrénées NUTS2 Region.[1] In each case, attempts are made to link changes in the indicators to a set of rural development measures and AESs. Given the heterogeneity (e.g. in terms of natural conditions, environmental concerns, agricultural features, production systems, etc.) of our case-

[1] Nomenclature of territorial units for statistics (NUTS) was set up by Eurostat as a single, coherent system for dividing up the EU's territory in order to produce regional statistics. At the local level, two levels of Local Administrative Units (LAU) have been defined: the upper LAU level (LAU1), formerly NUTS4, is defined for most, but not all, EU countries, while the lower LAU level (LAU2), formerly NUTS5, consists of municipalities or equivalent units in all 27 EU Member States.
Additional information can be retrieved from http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction

study areas spatially explicit analyses might be required. Piorr et al. (2009) argue that it is necessary to take regional heterogeneity into account while conducting policy assessments. Moreover, considering spatial issues in assessments of the impacts of AESs, such as the one we present, is in line with Farmer et al. (2008) who: i) point to a lack of studies relating CAP measures to information on the condition and location of the biodiversity resource; and ii) state that studying the relationship between CAP expenditure and its environmental impacts in a spatial way helps underpin an analysis of the future rationale for European agricultural policy post-2013. A similar recommendation is made by Piorr et al. (2009) who highlight the fact that spatial approaches are required in order to properly evaluate the policy impacts on environmental services provided by agriculture. Conducting spatial analyses is therefore relevant where the focus is placed on complex policy instruments, such as rural development policy (RDP), which targets various objectives.

The paper is structured as follows. The next section briefly presents EU rural development (RD) and agri-environmental contexts along with the HNV concept, while the following section details the data, the indicators, and the proposed methodology. The fourth section presents the results. The final sections provide discussion, conclusions and recommendations.

2. Rationale and background

2.1. Rural development programming in the EU

AESs were first introduced into EU agricultural policy at the end of 1980s through the integration of environmental considerations into structural policy, with the objective of supporting specific farming practices that protect the environment and maintain the countryside. Implementing agri-environmental programmes was then made compulsory for EU Member States from 1992 through the MacSharry CAP reform. Three main measures accompanied this reform:

- EC Regulation n°2078/92, being the main pillar for agri-environmental programmes, introduced aids for agricultural production methods supporting the protection of the environment and the maintenance of the countryside;
- EC Regulation n°2079/92, set up an aid scheme for early retirement from farming;
- EC Regulation n°2080/92, set up an aid scheme for forestry measures in agriculture.

Although Regulation n°2078/92 was seen as the backbone of AESs, the other two regulations were likely to have indirect environmental impacts. The early retirement scheme may, for instance, lead to the conversion of land from agricultural into non-agricultural uses, while forestry measures contribute to countryside management. Since the MacSharry reform, the CAP (and its environmental component) has undergone several reforms.

In 1999, the enforcement of the 'Agenda 2000' CAP reform divided the CAP into two pillars. While measures aimed at supporting agricultural production were gathered under the first pillar, the RDP was introduced as the second pillar (European Commission, 2003). In the following, this RDP is also referred to as RDP1. RDP1 is based on an integrated approach towards the rural economy, acknowledging the multifunctional features of agriculture. RDP1 encompasses 22 measures, falling into two main groups:

- Accompanying measures introduced from the MacSharry reform: early retirement, less-favoured areas (LFA) and areas with environmental restrictions, agri-environment, and forestry;

- Measures to modernise and diversify agricultural holdings: investments in agricultural holdings; the setting up of young farmers; training; improving processing and marketing of agricultural products; promoting the adaptation and development of rural areas.

The 2003 reform involved an important reshaping of the CAP, with the introduction of the decoupling of first pillar CAP payments, subject to cross-compliance (i.e. all farmers benefiting from CAP subsidies are required to comply with mandatory standards and maintain the land in good agricultural and environmental conditions). Although the reformed CAP was to be implemented from 2005 onwards, most EU Member States requested a transitional period so delaying the full implementation of the reform in their country until 2007. With regards to RDP, this CAP reform did not greatly modify the basic framework, mainly due to the fact that the reform was designed while RDP1 was only half way through its programming period. Nevertheless, the reform introduced new measures to the second CAP pillar, mainly: i) to promote quality products; ii) to consider animal welfare; and iii) to support farmers in meeting new EU standards. This revised RDP, referred to as RDP2 in the following, was adopted in 2005. RDP2 pursues three main objectives, and is therefore organised around three main thematic axes (European Commission, 2008):

- Axis 1: Increasing the competitiveness of the agricultural and forestry sector. Axis 1 measures fall into three categories: i) Human resources (schemes related to vocational training and information actions, the setting up of young farmers, early retirement, use of farm advisory services); ii) Physical capital (schemes related to farm or forestry investment, processing/marketing/co-operation for innovation, agricultural or forestry infrastructure, restoring agricultural production potential); and iii) Quality of agricultural production and products (schemes related to meeting standards temporary support, food quality).
- Axis 2: Enhancing the environment and the countryside. Axis 2 measures are of two types: i) Sustainable use of agricultural land (schemes related to mountain LFAs, other areas with natural handicaps, Natura 2000 agricultural areas, agri-environment and animal welfare, support for non-productive investments); and ii) Sustainable use of forestry land (schemes related to afforestation, agroforestry, Natura 2000 forest areas, forestry, support for non-productive investments).
- Axis 3: Enhancing the quality of life in rural areas and promoting the diversification of rural economic activities. Axis 3 encompasses three types of measures: i) Quality of life (schemes related to basic services for the rural economy, renovation and development of villages, protection and conservation of the rural heritage); ii) Economic diversification (schemes related to diversification into non-agricultural activities, support for micro-enterprises, favouring of tourism activities, presentation and management of the natural heritage); and iii) Training skills acquisition and animation.

Each axis is made up of a certain number of measures, and some of them are further divided into more specific sub-measures.

2.2. Agri-environmental measures in RDP

Agri-environmental measures, as a key element for environmental integration into the CAP, are the only compulsory measures included in the rural development programmes. Although it is compulsory for Member States to design and implement AESs, the uptake of AESs by farmers is on a voluntary basis. Therefore, farmers' behaviour plays a key role in the mechanism aimed at providing environmental services. Under AESs, farmers voluntarily commit to adopt environmentally-friendly farming techniques that go beyond European and national standards for a five-year minimum period. Payments are given to farmers on an annual basis and are calculated according to additional costs and income loss (incurred from the implementation of the AES).

Basically, AES commitments can concern (European Commission, 2006b):

- Actions to convert to or to maintain organic farming;
- Actions related to integrated production or integrated farm management;
- Other activities in favour of the extensification of farming systems: reducing the use of fertilisers and pesticides and the extensification of livestock farming;
- Crop rotation, maintenance of set-aside areas;
- Actions to prevent or reduce soil erosion;
- Actions in favour of the promotion or conservation of genetic resources (local breeds in danger of being lost to farming, plants under threat of genetic erosion);
- Biodiversity conservation and enhancement actions;
- Preservation of landscape and historical features on agricultural land, such as hedgerows, ditches.

As regards budget issues, AESs are an important component of the EU Rural Development Programme, with a budget of 37 billion Euros over the period 2007-2013 (i.e. 25% of the total RDP budget). As most AESs are designed and orientated towards actions and not results (or impacts), conducting evaluation on the outcomes is essential.

In order to support the evaluation process of the RDP2 and to better gauge the extent to which the objectives of the policy are met, the European Commission has designed a Common Monitoring and Evaluation Framework (CMEF) providing a single framework for monitoring and evaluating all rural interventions for the programming period 2007-2013 across EU Member States. The Handbook on CMEF (European Commission, 2006a) includes a series of evaluation guidelines and guidance sheets on various common indicators for monitoring and evaluation.[2] Nevertheless, since it has to be applicable across all EU Member States and across a large number of programmes, the CMEF provides guidelines and indicators that need to be adapted or fine-tuned to account for national/regional/local characteristics of the programme to be evaluated. Indeed, there is a need to supplement the CMEF by environmental evaluations that are (more) specific to the situation of a region or of a EU Member State (Finn et al., 2009). Moreover, some aspects of the CMEF are quite new and challenging for EU Member States as regards the implementation of a common approach. Considering HNV issues (and related indicators) is one of these challenges.

2.3. High Nature Value farming

HNV farmland is characterised by farmland that supports a high degree of biodiversity, and is usually associated with extensive forms of agriculture (EEA, 2004). It was first defined by Andersen et al. (2003), and revised by Paracchini et al. (2008). The authors categorised three types of HNV farmland:

- Type 1: Farmland with a high proportion of semi-natural vegetation;
- Type 2: Farmland with a mosaic of low-intensity agriculture and natural and structural elements;
- Type 3: Farmland hosting rare species, or supporting a high proportion of European or World populations.

[2] The CMEF includes the lists of common indicators for use during the development of baseline data as well as the monitoring of programme outputs, results and impacts.

It is acknowledged that Type 3 areas mostly overlap with Type 1 or Type 2 areas and, besides, whether a particular farm plot can be assigned to one of these categories is not straightforward but rather distributed along a gradient. Hence, this makes it difficult to draw a clear line between HNV and non-HNV farmland.

Within the CMEF, the HNV farmland indicator appears: i) as a result indicator (indicating the number of hectares where HNV is successfully maintained); ii) as a baseline indicator (indicating the total area of HNV farmland); and iii) as an impact indicator (indicating changes in HNV farmland). Moreover, in their attempt to make the HNV concept operational for the CMEF, and more particularly the CMEF HNV baseline indicator and the impact indicator on the maintenance of HNV farmland and forestry, Beaufoy and Cooper (2009) emphasise that, apart from the diversity of land cover and the presence of semi-natural vegetation, low intensity of farming is a principal characteristic of HNV farmland. In addition, these authors acknowledge that an increase or a decrease in the area under HNV farming may not provide sufficient insights into what is actually changing. Indeed, the quality of such areas can in fact deteriorate while HNV requirements are still met (Doxa et al., 2012). In addition to the CMEF context, the need to monitor the impact of agricultural activities on biodiversity has led to the development of indicators focusing on farming practices, as a main driver for conservation or loss of the natural value. An example is developed by Paracchini and Britz (2010), who, through the biodiversity-friendly farming practices indicator, qualitatively measure the extent to which an agricultural system supports biodiversity by separating HNV indices for arable land, grassland, and permanent crops (with a separate index for olive groves). Besides, the composite indicator as proposed by Pointereau et al. (2010), has some similarities with the indicator developed by Paracchini and Britz (2010).

In this context, our contribution may provide significant insights into answering various CMEF evaluation questions (see European Commission, 2006b) related to the extent to which AESs (or other RD measures) contribute to improving the environment or enhancing the high natural values of farmland.

3. Methodology

The methodology we apply is manifold, as described below.

First, various indices based on Pointereau et al. (2010), as well as an aggregated indicator, are elaborated and computed, accounting for data availability at the geographical scale and resolution of interest.

Then, a correlation analysis is performed to explore the nature of the relationship that may exist between the various indices/indicator on the one hand, and indicators representing the uptake of a set of RDP2 measures on the other hand. The measures considered depend on the RDP2 data availability in our case studies and are: i) measure 121 (modernisation of agricultural holdings; ii) AES 214a (extensive grassland management); iii) AES 214d (conversion to organic farming); iv) AES 214i (targeted actions focused on water and biodiversity protection); and v) measures 311 and 313 (diversification into non-agricultural activities, and encouragement of tourism activities).

Finally, the relationship, investigated in the previous step between indicators and RDP2 measures, is further analysed through an econometric approach accounting for spatial effects (if any).

3.1. *Data and indicator design and computation*

An approach similar to the one developed by Pointereau et al. (2010) is followed, although some modifications were made so that it can be applied to both 2007 and 2010 data, for which data on farming practices and landscapes management issues are not available. In particular, single indices are used for the areas of grassland and afforested farmland, in addition to the crop diversity index for arable land. Therefore, three indices, proxying the crop diversity, the share of permanent grassland and the share of afforested farm area, respectively, are computed at the farm level from Land Parcel Identification System (LPIS) data, and then aggregated over a spatial reference unit: LAU1 level, slightly modified to account for LFAs. As all three single indices are area based, they can be aggregated into a single composite indicator: the Farm Nature Value Indicator[3] (FNVI) (Table 1).

Table 1: Details of the indices and indicator computed for empirical applications.

Names	Calculation formula	Details
Crop Diversity Index (CDI)	$\mathrm{CDI}(i,j)=10+\sum_{i,\mathrm{C}(i)\geq\frac{\mathrm{UAA}(i,j)}{20}}\left[1-\frac{\mathrm{C}(i)\times 10}{\mathrm{UAA}(i,j)}\right]$	CDI of farm (i) in LAU1 region (j), where: i = Farm j = LAU1 region C(i) = Cultivated area (in ha) of each crop present on the farm i, considering only crop areas covering at least 5% of the farm's utilised agricultural area (UAA). Fifteen groups (or aggregated groups) of crops are considered. UAA(i,j) = Sum of cropping areas (ha) of farm i within LAU1 j, excluding areas under permanent grass and afforested farmlands. Then CDI(i,j) is computed for each LAU1 level j as the sum of results at the farm level weighted by the respective UAA.
Grassland Index (GI)	$\mathrm{GI}(j)=\frac{10\times\mathrm{GA}(j)}{\mathrm{UAA}(j)}$	GI reflects the share of permanent grasslands within the UAA (and to some extent the extensification level of the LAU1 region considered), where: GA(j) = Permanent Grassland area (ha) within j. UAA(j) = Total UAA (ha) of j. Afforested farmland areas are excluded.
Forest Index (FI)	$\mathrm{FI}(j)=\frac{10\times\mathrm{AA}(j)}{\mathrm{UAA}(j)}$	FI reflects the share of afforested farmland areas within the UAA, where: AA(j) = Afforested farmland area (ha) within j. UAA(j) = Total UAA (ha) of j.
Farm Nature Value Indicator (FNVI)	$\mathrm{FNVI}(j)=\mathrm{CDI}(j)+\mathrm{FI}(j)+\mathrm{GI}(j)$	

[3] In order to avoid confusion between the different categories of HNV indicators, and because we are addressing the pressure from agricultural practices on a continuum scale and not on HNV farmland only, the term Farm Nature Value indicator is preferred here.

For each of the three indices as well as for the FNVI aggregated indicator, the change in the indices/indicator is calculated as the relative change between 2007 and 2010 computed as the value of the index (or indicator) in 2010 over the value of the index (or indicator) in 2007.

3.2. Statistical analyses

In order to assess the relationships that may exist between the indicators (and their change in value during the period) and RDP2 measures' uptakes (in terms of share of UAA), Spearman's correlations analyses are firstly undertaken.

In addition, in a study of spatial patterns and processes, we may logically expect that close observations are more likely to be similar than those far apart. Therefore, assuming that the bio-physical features and agricultural characteristics of our regions of interest are spatially clustered, spatial autocorrelation of our indicators is explored by computing the Moran's I index (Moran, 1950), using and row-standardised contiguity weights matrix. The value of the Moran's I coefficient is the slope of the regression line when observations are regressed over their lagged values.

3.3. Spatial econometrics

Given the spatial characteristics of our indicators observed in the previous step (spatial autocorrelation), analyses based on spatial econometrics are conducted in order to identify the determinants of the indicators considered. Therefore, regressions (with spatial econometric techniques) are conducted to assess the impact of RD measures on the change in the calculated indices (i.e. CDI, GI, and FI) and FNVI.

Considering the effect of RDP2 measures, an endogeneity problem is suspected, since the indices (and the composite indicator) are also indirect farm type descriptors. Endogeneity refers to the fact that an independent variable included in a model is potentially a choice variable at the same time, and hence may be correlated with unobservable variables captured by the error term. The strategy to address this causality problem is to consider predictors of the RDP2 measures' uptakes rather than observed uptake indicators, in order to remove every potential endogeneity bias. Predictors of RDP2 measures' uptakes, representing the probability of a positive uptake involving significant spatial effect, are retrieved from spatial probits (LeSage and Pace, 2009) run on each of the measures considered. These predicted uptake estimates are then introduced as explanatory variables in the regressions (estimated by the Ordinary Least Squares (OLS) method).

However, spatial dependence in the regression models has to be considered carefully since it removes the independence of observations. Spatial correlation can consist of a spatial dependence of the dependent variable (spatially lagged dependent variable), or a spatial dependence of the error term (error terms across different spatial units are correlated). Ignoring spatial effects in a regression may lead to biased and inconsistent estimates of the model parameters when a spatial lag is omitted, or to inefficient estimates and biased inference when a spatial autoregressive error is omitted. Various statistical procedures can help to characterise spatial dependencies in the data, and therefore help in the choice of the correct specification of the model to be implemented. The most common tests for spatial correlation are the Moran's I test applied on the residuals of the OLS regression, as well as Lagrange Multiplier (LM) tests (Anselin, 1988; Anselin and Rey, 1991). The latters provide a basis for choosing between spatial lag and spatial error model specifications: LM_{lag} tests against the spatial lag autoregressive model (SAR model, where the spatial autocorrelation is introduced through a spatial lag of the endogenous variable)[4], while LM_{error} tests against the spatial error model (SEM model, where the spatial correlation is introduced through a spatial autoregressive error term).[5] In some of our applications, results from LM_{lag} and LM_{error} do not differ widely. In such cases, we have decided to specify a simultaneous autoregressive (SAC) model which accounts for spatial dependence in both the dependent variable and the error term.[6]

Since SAR and SAC models account for a spatial lag of the dependent variable, the effect on an explanatory variable differs across regions (LAU1 in our case). Hence, a coefficient estimate in one of these models cannot be interpreted analogously in the same way as those obtained through OLS regressions, since explanatory variables in region i have a "direct impact" on region i as well as an "indirect impact" on the neighbouring regions (information on the connections is given by the weights matrix) through the spatial lag parameter ρ. Therefore, to properly evaluate the impacts of any explanatory variable it is necessary to include information from neighbouring observations. To cope with this, Pace and LeSage (2006) propose a summary measure of these two types of impacts, considering that the average total impacts are the sum of the average direct impacts and the average indirect (neighbours) impacts. In order to correctly interpret the regression coefficients of SAR and SAC models, the total impacts of changes in explanatory variables on our indices (and the composite indicator) are computed.

To sum up, the changes in the three indices (i.e. CDI, GI, and FI), and in the FNVI are regressed against their potential determinants using an OLS regression and with spatial regressions specified according to LM tests. Total impacts are additionally computed. As regards the models' specifications, although numerous variables describing the economic, natural, and agricultural characteristic of the LAU1 regions have been tested, only significant ones are kept in the final specifications and are presented in Table 2. Furthermore, as some impacts cannot be detected within short time horizons (Primdahl et al., 2003; Primdahl et al., 2010), dummies indicating whether the region had benefited from some specific RDP1 measures are included in order to test for potential delayed effects of the corresponding measures. In sum, the effects of 14 policy measures (i.e. nine RDP1 and five RDP2 measures) are modelled (see Table 2 for details, and Appendix A for descriptive statistics).

Table 2: Details of explanatory variables

Variable name	Details
sh_grassl_2000	Share of grassland within the UAA, in 2000
log_lab06	Log value of labour (farm heads, family labour and hired labour in Annual Working Units) present on farm at the end of 2006
rainf_2004_2006	Yearly average of total rainfall (rainfall+snowfall) over the period 2004-2006, in mm
d_mecha_rdp1	Dummy variable for previous existence of 'mechanisation' payments from RDP1

[4] Formally a spatial lag model is expressed as $y = \rho Wy + X\beta + \varepsilon$, where y is a vector of observations of the dependent variable, Wy a spatially lagged dependent variable with a weights matrix W, X a matrix of observations of the independent variables, ε a vector of independent and identically distributed (iid) error terms, β a matrix of parameters to estimate, and ρ a spatial autoregressive coefficient to estimate.

[5] Formally a spatial error model is expressed as $y = X\beta + \varepsilon$, with $\varepsilon = \lambda W\varepsilon + u$, where ε is a vector of spatially autocorrelated error terms, u a vector of iid error terms, and λ a spatial autoregressive coefficient to estimate, reflecting the interdependence between the regression residuals.

[6] Formally a SAC model is expressed as a combination of spatial lag and spatial error models: $y = \rho Wy + X\beta + u$, with $u = \lambda Wu + \varepsilon$

d_aes_rdp1	Dummy variable for previous existence of 'AES payment' (other than grassland or crop diversification) payments from RDP1
d_aesDiv_rdp1	Dummy variable for previous existence of 'AES crop diversification' payments from RDP1
d_youngF_rdp1	Dummy variable for previous existence of payments for setting up of young farmers from RDP1
d_afforest_rdp1	Dummy variable for previous existence of 'afforestation' payments from RDP1
d_train_rdp1	Dummy variable for previous existence of 'training' payments from RDP1
d_LFA_rdp1	Dummy variable for previous existence of LFA payments from RDP1
d_markproc_rdp1	Dummy variable for previous existence of 'improving processing and marketing' payments from RDP1
d_retir_rdp1	Dummy variable for previous existence of 'early retirement payments' from RDP1
PredS_121_benef	Predicted probability retrieved from the spatial probit explaining the uptake, in terms of the share of farms engaged in the 'farm modernisation' measure (Measure 121, RDP2) over the overall number of farms at the beginning of the RDP2 period (2007)
PredS_214a_area	Predicted probability retrieved from the spatial probit explaining the uptake, in terms of the share of area engaged in the 'grassland premium' (Measure 214A, RDP2) over the overall area of permanent and temporary grasslands at the beginning of the RDP2 period (2007)
PredS_214d_area	Predicted probability retrieved from the spatial probit explaining the uptake, in terms of the share of area engaged in a 'conversion to organic farming' measure (Measure 214D, RDP2) over the overall UAA at the beginning of the RDP2 period (2007)
PredS_214i_area	Predicted probability retrieved from the spatial probit explaining the uptake, in terms of the share of area engaged in local measures for water or biodiversity protection in designated zones (Measure 214I, RDP2) over the overall UAA at the beginning of the RDP2 period (2007)
PredS_axis3_benef	Predicted probability retrieved from the spatial probit explaining the uptake, in terms of the share of beneficiaries of 'diversification into non-agricultural activities' and/or of 'encouragement of tourism activities' measures (Measures 311 and 313, RDP2) over the overall number of farms at the beginning of the RDP2 period (2007)

As regards the RDP2 indicators (i.e. *indic_121_benef, indic_214a_area*, *indic_214d_area*, *indic_214i_area*, and *indic_axis3_benef*), and although they relate to the number of farms, to the area of grassland, or to the UAA, it is believed that they properly reflect the level of uptake of related RDP2 measures and are proper proxies of policy response.

4. Results

4.1. Mapping and descriptive statistics

The period covered by the data used to build the FNVI and its three component indices runs from 2007 to 2010. The changes in FNVI (and its components) over the period are mapped in Figure 1, while a mapping of the values of the indicator and indices is provided in Appendix B.

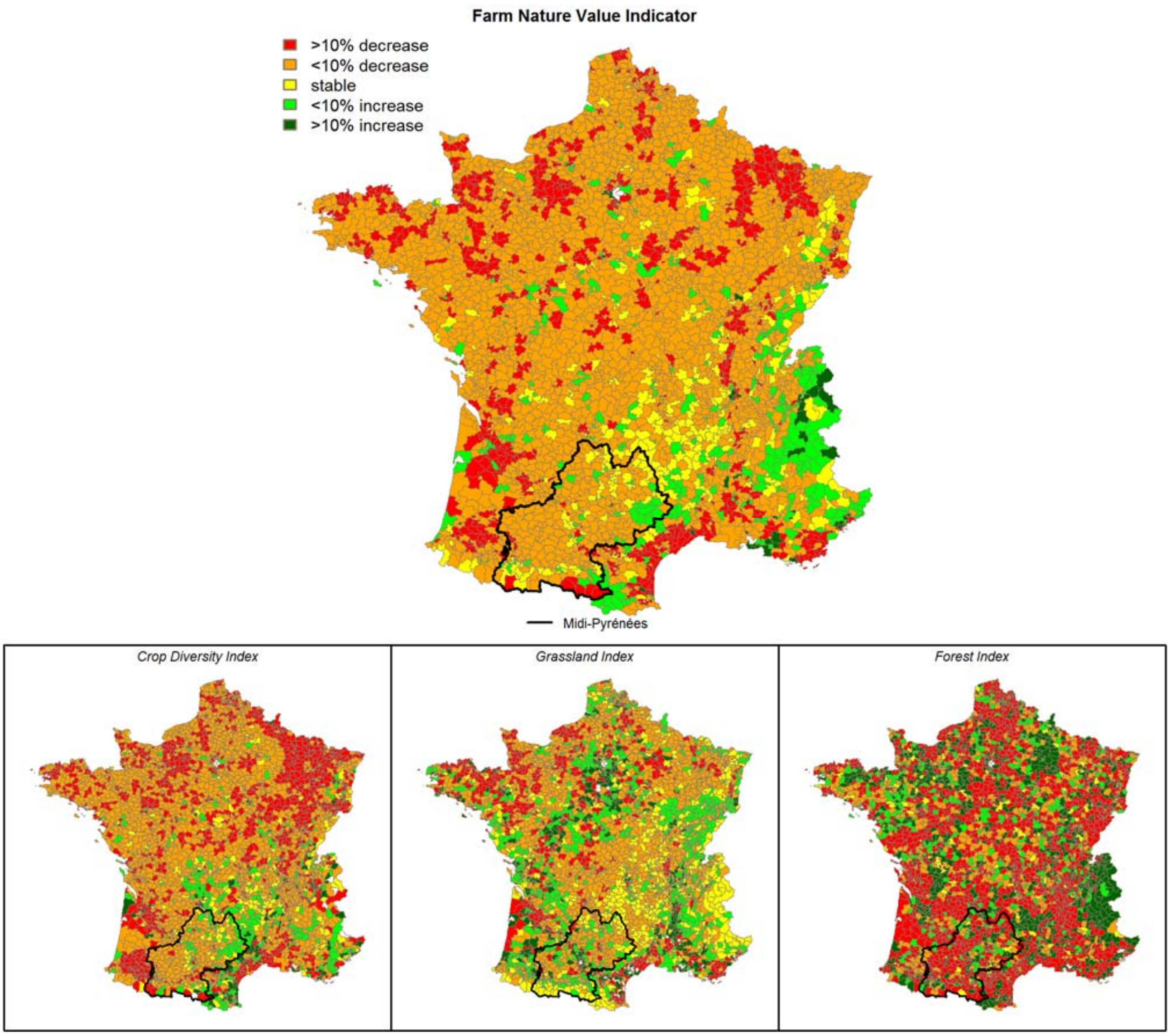

Figure 1: Percentage change of FNVI, and component indices, at LAU1 level over the period 2007-2010

The spatial pattern of FNVI (Appendix B) is obvious and reflects to some extent the pattern of agricultural production (and conditions of production) in France. Broadly speaking, mountainous and hilly areas are in dark green, grassland dominated areas in light green, areas characterised by intensive forms of agriculture in orange and red, and intermediate areas in yellow. However, such a clear-cut pattern is not observed when considering the change in the indicator and indices over the period (Figure 1), although the FNVI and its component indices look spatially clustered.

As shown in Table 3, the FNVI declined over the period (2007-2010) by more than 6% on average, while this decline is a bit lower (less than 4%) for the Midi-Pyrénées NUTS2 region. In France, this change stems from the CDI which decreased by almost 7%, while the GI remained steady on average and FI increased by more than 7%. In Midi-Pyrénées the change in FNVI is implied by a decrease in both CDI and FI.

Table 3: Descriptive statistics on the change in FNVI (and components) change

	FRANCE					MIDI-PYRÉNÉES				
	na[1]	**min**	**mean**	**max**	**std. dev.**	**na**[1]	**min**	**mean**	**max**	**std. dev.**
Change in crop diversity index (*evol_cdi*)	15	0.261	0.931	1.814	0.096	0	0.261	0.961	1.656	0.085
Change in grassland index (*evol_gi*)	32	0.000	1.002	10.609	0.426	2	0.415	1.058	9.792	0.655
Change in forest index (*evol_fi*)	13	0.000	1.073	31.454	1.360	1	0.067	0.957	13.257	0.792
Change in farm nature value indicator (*evol_fnvi*)	6	0.093	0.936	2.576	0.091	0	0.610	0.963	1.108	0.050

[1] 'na' stands for 'non available'

4.2. Correlation analyses

In order to first explore the relationship between the indices and FNVI on the one hand, and the AESs indicators (proxying for the uptake rate) on the other hand, various correlation analyses are conducted.

An assessment of the correlations is done taking into account, first, the value of the indices (and of FNVI) at the beginning of the period and, second, the change in the indices (and in FNVI) over the studied period (Table 5). The first analysis helps in assessing whether AESs were successfully targeted with regard to the environmental issues at stake (proxied by the level of our indicators), while the second helps in analysing how the indicators proxying for the AESs participation and our impacts' indicators vary (with no assumptions made about a causality link).

Table 4: Spearman correlation analyses between uptakes of AESs and the indices (and FNVI) in terms of both absolute values at the beginning of the period and changes over the period

FRANCE				
		indic_214a_area	*indic_214d_area*	*indic_214i_area*
Crop diversity index CDI	2007	-0.43***	-0.11***	0.04**
	Change 2007-2010	0.20***	0.07***	-0.05***
Grassland index GI	2007	0.71***	0.07***	0.15***
	Change 2007-2010	0.04***	-0.04***	0.00
Forest index FI	2007	-0.05***	0.16***	0.03*
	Change 2007-2010	0.07***	-0.02	0.03*
Farm nature value indicator FNVI	2007	0.65***	0.047***	0.17***
	Change 2007-2010	0.38***	0.00	0.02
MIDI-PYRÉNÉES				
Crop diversity index CDI	2007	-0.54***	0.20***	-0.09
	Change 2007-2010	0.16***	0.05	0.17
Grassland index GI	2007	0.79***	-0.07	0.22***
	Change 2007-2010	0.11**	-0.06	-0.01
Forest index FI	2007	-0.07	0.05	0.12**
	Change 2007-2010	0.13**	-0.08	-0.02
Farm nature value indicator FNVI	2007	0.75***	-0.03	0.22***
	Change 2007-2010	0.34***	-0.01	0.03

Significance levels: "" = 0.1; "**" = 0.05; "***" = 0.01*

From Table 4 we note from Some strong negative correlations between CDI and grassland measures (*indic_214a_area*) on the one hand, and organic farming measures (*indic_214d_area*) on the other hand, although to a lesser extent for the latter and only in France. Therefore these measures were mainly targeting areas with a low CDI. The strongest positive correlations are found for GI with regards to grassland measures, underpinning the fact that these measures were properly targeted. Concerning the correlations associated with the composite indicator (the FNVI), these are strong when considering grassland measures (they are contracted in areas with a high value FNVI), moderate when considering water and biodiversity targeted measures (i.e. *indic_214i_area*), and close to null (even not significant in the case of Midi-Pyrénées) when considering organic farming measures. Moreover, correlations related to grassland measures are quite similar in Midi-Pyrénées compared with France. The same applies for correlations related to water and biodiversity targeted measures (at least when they are still significant in Midi-Pyrénées). But striking results arise from the correlations associated with organic farming measures: first, while all correlations are significant in France, only one remains so in the Midi-Pyrénées results; second, organic farming measures are mainly contracted in areas with low CDI values in France (negative correlation), while the opposite applies in Midi-Pyrénées.

Turning now to analysis of change in the indices/indicator, over the period (i.e. 2007-2010) it is notable that, among the various measures, only grassland measures are correlated (positively) with the change in FNVI. It is interesting to analyse the cases of observed correlations between grassland measures and CDI (in both France and Midi-Pyrénées), between grassland measures and FI in France, or between organic farming measures and CDI in France. In these cases, the measures were mainly contracted in areas with low values of the considered indices; despite this fact the change in indices over the period is positively correlated with the measures' uptake. This, of course, does not prove any causality link but it is worthwhile exploring these situations further. Contrasting cases are also found where a measure was contracted in areas with mostly a high index value, but the change in index over the period is negatively correlated with the measure uptake. This is noted for the correlation between organic farming measures and GI, and the correlation between water and biodiversity targeted measures and CDI, in France. Finally, a different situation is observed, namely the correlations between water and biodiversity targeted measures and the composite indicator FNVI, in both France and Midi-Pyrénées. While it should be pointed out that these measures are mostly targeted in areas with a high FNVI value at the beginning of the period, the correlation is no longer valid when the change in FNVI is concerned.

All these various correlations need to be further investigated and the causality links should be identified once spatial effects are considered. Spatial analysis and econometrics are indeed proper tools for addressing these issues and identifying the respective determinants of the changes in the FNVI (and its component indices).

4.3. Spatial correlations and model specifications

Spatial autocorrelations of change in indices and in the FNVI over the period are explored through Moran's I statistics (Table 5). Such an analysis is complementary to the previous steps (exploratory mapping, descriptive statistics, and Spearman's correlation) as it helps in identifying spatial autocorrelations and justifies spatial analytic approaches.

Table 5: Moran's I statistics of the indices and composite indicator

	FRANCE	MIDI-PYRÉNÉES
Change in crop diversity index (*evol_cdi*)	0.247***	0.107***
Change in grassland index (*evol_gi*)	0.794***	0.112***
Change in forest index (*evol_fi*)	0.170***	0.135***
Change in farm nature value indicator (*evol_fnvi*)	0.217***	0.210***

*Significance levels: "***" = 0.01*

The important result from Table 5 is that highly significant positive spatial autocorrelations are found for each of our variables of interest, meaning that for each index (and the composite indicator) the value observed in a specific LAU1 region is correlated to the value observed in the neighbouring LAU1 regions. The magnitude of this correlation varies across the scale of interest and the index considered, although the spatial autocorrelation of the change in the composite indicator is similar whether considering France as a whole or Midi-Pyrénées NUTS2 region. At the global level (i.e. France), a higher Moran's I value is observed for the change in grassland index reflecting that this index is quite spatially clustered. The change in crop diversity index is also spatially clustered, but to a lesser extent. When focusing on Midi-Pyrénées, it is noted that Moran's I statistics are quite similar across all indices and exhibit relatively low values (although all are significant).

Following the process of identifying suitable model specifications, Moran's I test on residuals as well as LM tests are conducted on OLS regressions, where the various indices (and the composite indicators) are regressed against the independent variables presented in Table 2. Results of these tests are tabulated below (Table 6).

Table 6: Diagnosis on model specifications

		FRANCE	MIDI-PYRÉNÉES
evol_cdi	Moran's I test	0.146***	0.021
	LM error	220.14***	0.37
	Robust LM error	24.89***	2.05
	LM lag	206.08***	1.07
	Robust LM lag	10.83***	2.75*
evol_gi	Moran's I test	0.061***	0.058**
	LM error	37.95***	2.84*
	Robust LM error	3.68*	0.00
	LM lag	43.70***	3.06*
	Robust LM lag	9.43***	0.22
evol_fi	Moran's I test	0.144***	0.063***
	LM error	215.07***	3.42*
	Robust LM error	6.78***	3.23*
	LM lag	230.67***	4.53**
	Robust LM lag	22.38***	4.33**
evol_fnvi	Moran's I test	0.113***	0.056**
	LM error	132.99***	2.70
	Robust LM error	17.75***	2.34
	LM lag	121.22***	4.86**
	Robust LM lag	5.97**	4.50**

Significance levels: "" = 0.1; "**" = 0.05; "***" = 0.01*

Based on Moran's I and LM tests run on OLS regressions, and applying the decision rule on model specifications as described in Section 3.3, various models (summarised in Table 7) are to be estimated depending on the endogenous variable and the scale of interest.

Table 7: Decision on model specifications

	FRANCE	**MIDI-PYRÉNÉES**
evol_cdi	SAC model	OLS
evol_gi	SAC model	SAR model
evol_fi	SAC model	SAR model
evol_fnvi	SAC model	SAR model

An interesting issue arises from the fact that, for some endogenous variables, models' specifications vary depending on the scale of interest; SAC specifications for France, and SAR specifications for Midi-Pyrénées (except for the change in CDI, for which an OLS model is sufficient). The scale of interest therefore does matter and has a great influence on the type of model to be estimated.

4.4. Spatial econometric analyses

Since the respective changes in the indices and FNVI over the period are not convergent (Table 3), their respective determinants are analysed here. There is no correlation between any of the three individual indices (less than 3%, non-significant correlation). But, due to the way the change in FNVI is constructed, it is significantly correlated with each of them; most highly correlated with the change in CDI (40% for France and 63% for Midi-Pyrénées) and less highly correlated with the changes in GI (23% for France and 14% for Midi-Pyrénées) and in FI (18% for France and 19% for Midi-Pyrénées). Hence the change in CDI has a higher weighting than the other two indices in the change in FNVI.

4.4.1. On the crop diversity index

Comparing France to Midi-Pyrénées, the first important result is that, while in France estimating a SAC model is necessary, an OLS model in Midi-Pyrénées is proven satisfactory since no spatial effect is reported. Comparisons are therefore based on the results from the SAC model for France, and from the OLS model in Midi-Pyrénées (Table 8). Indeed, as revealed by the LM tests, specifying a spatial model for France is relevant, and the lower value of the Akaike Information Criterion (AIC) in the SAC model (in comparison to the OLS model) confirms that it best fits our data.

Table 8: Change in crop diversity index 2007-2010 (evol_cdi)

	FRANCE						**MIDI-PYRÉNÉES**	
	OLS		**SAC model**				**OLS**	
	Coefficients		Coefficients		*Total impacts*		Coefficients	
Intercept	0.9373	***	1.1031	***	-		1.0087	***
sh_grassl_2000	0.0503	***	0.0527	***	*0.0444*	***	0.0503	
log_lab06	0.0067	**	0.0038		*0.0032*		-0.0024	
rainf_2004_2006	0.0000	***	0.0000		*0.0000*		-0.0001	*
d_mecha_rdp1	0.0370	***	0.0159	**	*0.0134*	**	0.0240	*
d_aes_rdp1	0.0310	***	0.0246	**	*0.0208*	**	-0.0258	
d_aesDiv_rdp1	-0.0209	***	-0.0205	***	*-0.0173*	***	-0.0484	***
d_youngF_rdp1	0.0167		0.0025		*0.0021*		0.0334	

d_afforest_rdp1	-0.0048	-0.0005	*-0.0004*	0.0055
d_train_rdp1	-0.0009	-0.0088 *	*-0.0074* *	0.0027
d_LFA_rdp1	0.0348 ***	0.0247 ***	*0.0208* ***	-0.0184
d_markproc_rdp1	-0.0097 **	-0.0036	*-0.0031*	-0.0079
d_retir_rdp1	-0.0020	-0.0030	*-0.0025*	0.0181
PredS_121_benef	-0.0522 ***	-0.0198	*-0.0167*	0.0245
PredS_214a_area	-0.0407 ***	-0.0282 ***	*-0.0237* ***	-0.0467 *
PredS_214d_area	0.0189	-0.0085	*-0.0071*	0.0692 **
PredS_214i_area	-0.0302 ***	-0.0305 ***	*-0.0257* ***	0.0022
PredS_axis3_benef	0.0314 ***	0.0624 ***	*0.0526* ***	-0.0478
R2	*0.11*			*0.13*
N	*3683*	*3683*		*327*
rho (ρ)		*-0.19* ***		
lambda (λ)		*0.51* ***		
AIC	*-7185*	*-7382*		

Significance levels: "*" = 0.1 ; "**" = 0.05 ; "***" = 0.01

For France, many of the explanatory variables are significant. The increase in CDI is higher in regions characterised by the highest share of permanent meadow in 2000. These are regions dominated by grazing livestock farming. The 2007-2010 change in CDI is very significantly affected by RDP1 measures. Machinery investment aids (*d_mecha_rdp1*) and farm contracts that combined investment aids and AESs (*d_aes_rdp1*) have a positive delayed effect. Crop diversity also increases in regions that benefited from LFA payments (*d_LFA_rdp1*), while it decreases in regions where crop diversification and training RDP1 measures (*d_aesDiv_rdp1* and *d_train_rdp1*, respectively) were contracted. In addition, all RDP2 measures have significant effects, except for the conversion to organic farming (*PredS_214d_area*) and the investment aids for machinery and farm building modernisation (*PredS_121_benef*). This contrasts with the RDP1 investment aids. Measures designed to target an extensive use of grasslands (*PredS_214a_area*) and local AESs targeting water or biodiversity protection in designated areas (*PredS_214i_area*) have negative effects on crop diversification in arable farmland. Only Axis3 measures (*PredS_axis3i_benef*) report a positive impact.

In Midi-Pyrénées, only five explanatory variables are significant. The first is the rainfall variable (*rainf_2004_2006*) that negatively influences the change in CDI. The RDP1 machinery investment aids (*d_mecha_rdp1*) has a positive delayed effect, while the RDP1 measure for crop diversification (*d_aesDiv_rdp1*) has a highly significant negative delayed effect (as for France as a whole). As observed for France, the RDP2 measures supporting an extensive use of grasslands (*PredS_214a_area*) have negative effects. The RDP2 measure for the conversion to organic farming (*PredS_214d_area*) positively influences crop diversity in the Midi-Pyrénées context, while no additional effect is detected at the national level. Targeted AESs (*PredS_214i_area*) and Axis3 measures (*PredS_axis3_benef*) have no effect on the change in CDI in Midi-Pyrénées in contrast to France as the whole.

Relying on the results of the OLS model in France would be misleading as some variables, significant within the OLS, are not significant when the spatial model is considered. The opposite applies for only one variable which is not significant in the OLS, and significant in the spatial model. Moreover, comparing OLS and the SAC model shows that the OLS estimates are highly biased, as absolute values might be underestimated (e.g. by 50% in the case of *PreS_axis3_benef*) or overestimated (e.g. by more than 100% in the case of *d_mecha_rdp1*). One of the major advantages of spatial regression models is their ability to quantify spatial spillover effects. In the present case, the spatial lag (ρ) is negative, indicating that there is a negative spatial autocorrelation among regions. As such, directly interpreting SAC coefficients, and not the average total impacts correcting the coefficients for the spatial lag, would give biased information (overestimated, in the present case).

4.4.2. <u>On the grassland index</u>

As regards the change in GI, accounting for spatial effects in model specifications is justified in both France and Midi-Pyrénées cases (SAC model for France, SAR model for Midi-Pyrénées) (Table 9). Spatial autocorrelation in the error term (λ) in the case of France is significant, indicating that the specification of the model probably lacks relevant explanatory variables. This is not surprising given the low R-squared value of the OLS model. Nevertheless, comparing the AIC between OLS and the SAC reveals that the latter fits the data better.

Table 9: Change in grassland index 2007-2010 (evol_gi)

	FRANCE			MIDI-PYRÉNÉES		
	OLS	**SAC model**		**OLS**	**SAR model**	
	Coefficients	Coefficients	*Total impacts*	Coefficients	Coefficients	*Total impacts*
Intercept	1.1744 ***	0.5544 ***	-	2.0799 ***	1.8664 ***	-
sh_grassl_2000	0.0444	0.0256	*0.0579*	0.3469	0.3238	*0.3958*
log_lab06	0.0069	0.0044	*0.0101*	0.2150 ***	0.1965 **	*0.2402 ** *
rainf_2004_2006	0.0000	0.0000	*0.0000*	0.0000	0.0000	*0.0000*
d_mecha_rdp1	0.0588 **	0.0399 **	*0.0904 ** *	-0.0130	-0.0077	*-0.0094*
d_aes_rdp1	0.0023	-0.0043	*-0.0097*	0.4892 **	0.5426 **	*0.6631 ** *
d_aesDiv_rdp1	0.0453 **	0.0315 **	*0.0715 ** *	-0.0441	-0.0341	*-0.0417*
d_youngF_rdp1	0.0218	0.0155	*0.0350*	-1.2765 ***	-1.2857 ***	*-1.5713 *** *
d_afforest_rdp1	-0.0175	-0.0183	*-0.0414*	-0.1819 **	-0.1683 **	*-0.2057 ** *
d_train_rdp1	0.0510 **	0.0531 **	*0.1204 ** *	0.0047	0.0045	*0.0055*
d_LFA_rdp1	0.0034	0.0054	*0.0123*	-0.2888 *	-0.2867 *	*-0.3504 * *
d_markproc_rdp1	0.0220	0.0230	*0.0520*	-0.0582	-0.0650	*-0.0794*
d_retir_rdp1	0.0247	0.0208	*0.0472*	-0.2029 **	-0.1799 **	*-0.2199 ** *
PredS_121_benef	-0.1398 **	-0.1065 **	*-0.2415 ** *	-0.3760	-0.4086	*-0.4994*
PredS_214a_area	-0.1402 ***	-0.0759 ***	*-0.1721 *** *	-0.5814 ***	-0.5026 ***	*-0.6142 *** *
PredS_214d_area	0.0963 *	0.0492	*0.1115*	0.0310	0.0289	*0.0353*
PredS_214i_area	-0.1226 ***	-0.0589 **	*-0.1336 ** *	-0.1032	-0.0900	*-0.1100*
PredS_axis3_benef	-0.0047	-0.0221	*-0.0500*	0.2457	0.2609	*0.3188*
R2	*0.02*			*0.24*		
N	*3659*	*3659*		*325*	*325*	
rho (ρ)		*0.56 ** *			*0.18 * *	
lambda (λ)		*-0.52 *** *				
AIC	*4092*	*4027*		*596*	*594*	

Significance levels: "*" = 0.1 ; "**" = 0.05 ; "***" = 0.01

Considering the application for France, all significant RDP1 measures (i.e. *d_mecha_rdp1*, *d_aesDiv_rdp1*, and *d_train_rdp1*) positively influence the change in GI between 2007 and 2010. By contrast, all significant RDP2 measures (i.e. *PredS_121_benef*, *PredS_214a_area*, and *PredS_214i_benef*) have a negative effect. As expected, the most significant explanatory variable is the RDP2 grassland premium (*PredS_214a_area*), but its negative effect is unexpected and contradicts its stated policy objective of preventing the conversion of grassland into other agricultural land uses. The contract specification of the grassland premium may explain this surprising result. The grassland premium supports the total area in grassland and includes both permanent and temporary meadows. Although the grassland premium is properly targeted (Table 4), it still fails to generate an increase in the permanent meadow share. To a certain extent the conversion of permanent into temporary grassland is possible. Hence our result means that more beneficiaries than non-beneficiaries carried out such a conversion during the studied period. While all significant RDP1 measures have a positive impact on the evolution of GI, the analysis reveals that all significant RDP2 measures support the decrease in the index.

Except for the RDP2 grassland measure, all other determinants of the change in GI differ across France and Midi-Pyrénées. In Midi-Pyrénées, significant RDP1 measures are more numerous. The GI increases more where the available farm labour in 2006 (*log_lab06*) was higher and where farm contracts that combined investments aids and AESs (*d_aes_rdp1*) were entered into. The RDP1 measure supporting the setting up of young farmers (*d_youngF_rdp1*), afforestation measure (*d_afforest_rdp1*), LFA payments (*d_LFA_rdp1*) and early retirement scheme (*d_retir_rdp1*) have negative delayed effects on the change in GI. Compared to France as a whole, the negative effect of the grassland premium (*PredS_214a_area*) is much larger.

As in the case of modelling the change in CDI, relying on the results of OLS models would lead to a misinterpretation of the results. Moreover, the presence of a significant positive spatial lag must be given serious attention. Due to its magnitude in France, for instance, highly significant differences are observed between the estimated coefficients of the spatial model and average total impacts (i.e. accounting for the spatial lag). Ignoring the spillover effects would result in underestimating the impacts of the explanatory variables. In the case of France, the total impacts are more than twice as high as the direct impacts given by the estimate coefficients (e.g. -0.0759 vs. -0.1721 for the case of *PredS_214a_area*).

4.4.3. On the forest index

As regards the models addressing the change in FI, the LM tests presented in Section 4.3 reveal that spatial models are to be preferred to OLS. However, in the case of Midi-Pyrénées the spatial effect estimated through the SAR model is not significant (Table 10). An SAC model has also been tested and none of the spatial parameters (ρ and λ) are significant. In France, both spatial ρ and λ parameters are significant which confirms that specifying an SAC model is more relevant than OLS. However, the OLS R-squared is relatively low which might explain the strong spatial correlation in the error term: spatial effects which are not captured through the explanatory variables are captured in the error term as spatial autocorrelation. In spite of this, and based on the AIC, the SAC model fits our data better than the OLS model.

Table 10: Change in forest index 2007-2010 (evol_fi)

	FRANCE			**MIDI-PYRÉNÉES**	
	OLS	**SAC model**		**OLS**	**SAR model**
	Coefficients	Coefficients	*Total impacts*	Coefficients	Coefficients
Intercept	1.6524 ***	0.8757 ***	-	0.3961	0.3819
sh_grassl_2000	0.3248 **	0.1373 *	*0.5872 **	-0.1115	-0.0899
log_lab06	-0.0316	-0.0417	*-0.1783*	-0.0076	-0.0007
rainf_2004_2006	0.0004 ***	0.0001	*0.0005*	0.0004	0.0003
d_mecha_rdp1	0.3433 ***	0.1066 **	*0.4559 ***	0.0801	0.0786
d_aes_rdp1	-0.2046	-0.2415 **	*-1.0328 ***	-0.0226	-0.0261
d_aesDiv_rdp1	0.0830	0.0364	*0.1558*	0.0432	0.0440
d_youngF_rdp1	-0.0997	-0.1269	*-0.5426*	0.1922	0.1921
d_afforest_rdp1	-0.0216	-0.0260	*-0.1112*	-0.0736	-0.0582

d_train_rdp1	0.0401	0.0487	*0.2083*	0.3645 **	0.3586 **
d_LFA_rdp1	-0.1566 **	-0.0757 *	*-0.3236* *	0.2588	0.2420
d_markproc_rdp1	0.0239	0.0025	*0.0108*	-0.0597	-0.0570
d_retir_rdp1	-0.1148 **	-0.0793 *	*-0.3392* *	0.1099	0.1115
PredS_121_benef	-0.6821 ***	-0.2567 *	*-1.0976* *	0.0709	0.0481
PredS_214a_area	0.0879	0.0148	*0.0634*	-0.2148	-0.1885
PredS_214d_area	-0.0492	0.1054	*0.4508*	-0.3397	-0.3343
PredS_214i_area	0.1018	0.0789	*0.3373*	0.3273	0.2938
PredS_axis3_benef	0.3004 *	0.0901	*0.3853*	-0.3669	-0.3599
R2	*0.04*			*0.06*	
N	*3678*	*3678*		*326*	*326*
rho (ρ)		*0.77* ***			*0.06*
lambda (λ)		*-0.79* ***			
AIC	*12533*	*12236*		*789*	*789*

Significance levels: “*” = 0.1 ; “**” = 0.05 ; “***” = 0.01

For France as a whole, the increase in the change in FI between 2007 and 2010 mostly occurs in regions with a high share of permanent grasslands within the UAA in 2000 (*sh_grassl_2000*), capturing in some sense land abandonment in those areas. The RDP1 investment aids for machinery (*d_mecha_rdp1*) influence this increase and have a strong positive effect. This measure is targeted towards mountain areas where the share of grassland and the risk of land abandonment are higher. Farm contracts that combine investment aids and AESs (*d_aes_rdp1*) have a very strong negative delayed effect. The LFA payments (*d_LFA_rdp1*), as well as the early retirement scheme (*d_retir_rdp1*), also have a negative effect, which is in line with expectations, given that both are designed to favour farming continuation and prevent land abandonment. Regarding RDP2 measures, only investment aids for modernisation (*PredS_121_benef*) have a significant effect. This is negative in contrast to the RDP1 investments aids (*d_mecha_rdp1*).

In the Midi-Pyrénées context, only the RDP1 training measure (*d_train_rdp1*) has a positive and significant effect. Therefore, no convergent picture of the determinants of the FI index arises from these regressions.

In France, the spatial lag is strong leading to a high underestimation of the effects if one takes into account the SAC coefficients and not the total impacts. In fact, the impacts considering the spillover effect are more than four times stronger than the direct impacts.

4.4.4. On the farm nature value index

On the modelling of the evolution of FNVI, and similarly to the modelling of single indices, OLS goodness of fit (based on the R-squared) is better for Midi-Pyrénées than for France (Table 11). Compared to the OLS models, relying on a spatial effect in the specification is relevant based on the AIC. A spatial effect is notable in both situations, although the signs of the respective spatial lags (ρ) are opposite – and with a higher magnitude in the case of Midi-Pyrénées. For France, the policy measures have an overall negative spillover effect (although very moderate) meaning that any increase in a given LAU1 region has a negative effect on neighbouring LAU1 regions. However, the main spatial effect in the case of France is the correlation of errors, which mainly stems from omitted variables in the spatial specification, which is somewhat relevant with a lower OLS R-squared.

Table 11: Change in the overall farm nature value index 2007-2010 (evol_fnvi)

	FRANCE			MIDI-PYRÉNÉES		
	OLS	**SAC model**		**OLS**	**SAR model**	
	Coefficients	Coefficients	*Total impacts*	Coefficients	Coefficients	*Total impacts*
Intercept	0.9327 ***	0.9907 ***	-	0.9631 ***	0.7674 ***	-
sh_grassl_2000	0.0566 ***	0.0794 ***	*0.0733 ****	0.0425 **	0.0393 **	*0.0494 ***
log_lab06	0.0043	0.0059 *	*0.0055 **	-0.0047	-0.0041	*-0.0051*
rainf_2004_2006	0.0000 ***	0.0000 *	*0.0000 **	0.0000	0.0000	*0.0000*
d_mecha_rdp1	0.0318 ***	0.0207 ***	*0.0191 ****	0.0144 *	0.0120	*0.0151*
d_aes_rdp1	0.0252 ***	0.0217 **	*0.0200 ***	-0.0245	-0.0242	*-0.0304*
d_aesDiv_rdp1	-0.0033	-0.0012	*-0.0011*	-0.0340 ***	-0.0289 ***	*-0.0363 ****
d_youngF_rdp1	0.0145	0.0145	*0.0134*	0.0529 **	0.0521 **	*0.0655 ***
d_afforest_rdp1	-0.0049	-0.0059	*-0.0055*	-0.0078	-0.0073	*-0.0092*
d_train_rdp1	0.0033	-0.0029	*-0.0026*	-0.0041	-0.0053	*-0.0067*
d_LFA_rdp1	0.0272 ***	0.0190 ***	*0.0176 ****	0.0093	0.0056	*0.0071*
d_markproc_rdp1	-0.0041	-0.0001	*-0.0001*	-0.0049	-0.0054	*-0.0067*
d_retir_rdp1	0.0012	0.0004	*0.0004*	0.0033	0.0045	*0.0057*
PredS_121_benef	-0.0654 ***	-0.0536 ***	*-0.0495 ****	0.0159	0.0179	*0.0225*
PredS_214a_area	0.0005	0.0048	*0.0044*	-0.0321 **	-0.0299 **	*-0.0376 ***
PredS_214d_area	-0.0505 ***	-0.0622 ***	*-0.0574 ****	0.0340 **	0.0290 **	*0.0365 ***
PredS_214i_area	0.0310 ***	0.0264 ***	*0.0244 ****	0.0141	0.0110	*0.0138*
PredS_axis3_benef	-0.0032	0.0100	*0.0093*	-0.0176	-0.0118	*-0.0148*
R2	*0.13*			*0.21*		
N	*3685*	*3685*		*327*	*327*	
rho (ρ)		*-0.08 ***			*0.20 ***	
lambda (λ)		*0.35 ****				
AIC	*-7711*	*-7825*		*-1077*	*-1080*	

Significance levels: "*" = 0.1 ; "**" = 0.05 ; "***" = 0.01

The regressions of the change in FNVI between 2007 and 2010 (*evol_fnvi*) provide robust results. The significant spatial effects do not modify the sign of the estimated influences of the various policy measures. However, taking into account the spatial effects shows that the OLS estimates are significantly biased. For France, absolute values might be underestimated by 25% (such as the effect of the share of permanent grassland in year 2000 (*sh_grassl_2000*)) or overestimated by more the 50% (such as the effect of RDP1 LFA payments (*d_LFA_rdp1*)). Furthermore, as supported by the example of the farm labour at the beginning of the period (*log_lab06*), relying on the OLS model is also misleading as it does not reveal truly significant variables. The spatial spillover effect of explanatory variables is significantly negative but moderate in value. It means that a change of explanatory variables favouring FNVI in a region will slightly impede an FNVI increase in neighbouring regions. In contrast, the FNVI increase due to unknown factors has a positive spillover effect on neighbouring regions.

For France, the FNVI increases more in areas with a higher share of permanent grasslands in 2000. It increases more where more agricultural labour was available in 2007. Very significant RDP1 measures are investment aids for machinery (*d_mecha_rdp1*) and LFA payments (*d_LFA_rdp1*), with positive impacts on the change in FNVI. RDP1 farm contracts that combined investment aids and AESs (*d_aes_rdp1*) also have a positive delayed effect. Regarding RDP2 measures, the grassland measures (*PredS_214a_area*) have no significant impact despite what was estimated for CDI and GI change. The same applies for the Axis3 measures (*PredS_axis3_benef*) that were highly significant towards the change in CDI. By contrast, the conversion to organic farming (*PredS_214d_area*) has a highly significant negative effect on the change in FNVI (although it had no significant effect in any of the three single indices). Investment aids for modernisation (*PredS_121_benef*) have a negative effect, in contrast to the RDP1 investment aids. Local AESs on water or biodiversity protection in targeted areas (*PredS_214i_area*) have a positive effect despite their negative effect on the change in CDI and GI. Thus for the whole of France, it is striking that policy effects on FNVI change cannot be deduced by policy effects on the changes of single FNVI components. Among other examples, local AESs targeting water or biodiversity protection in designated areas (*PREDS_214i_area*) have significant negative effects on CDI and GI changes and a large positive but not significant effect on FI change, resulting in a significant positive effect on FNVI change. Even more surprising is the significant negative effect of the conversion to organic farming (*PREDS_214d_area*) on FNVI change although absolutely no significant effect is estimated on any of the three FNVI components. It means that the policy effects on FNVI change are highly dependent on the various combinations of policy effects on FNVI components at the regional level.

In Midi-Pyrénées the FNVI increases more in areas with a higher share of permanent grassland in 2000, as is observed for France as a whole. Fewer policy measures have a significant impact. The RDP1 AES for crop diversification (*d_aesDiv_rdp1*) and the RDP2 grassland premium (*PredS_214a_area*) both have a negative impact, in accordance with their respective effects on change in CDI and GI. The conversion to organic farming (*PredS_214d_area*) has a positive impact, according to its effect on CDI change. The RDP1 measure for the setting up of young farmers has a positive delayed impact, while it has a strong negative impact on GI. As regards the FNVI results for Midi-Pyrénées, policy effects on CDI clearly overrule most policy effects on other FNVI components. Among the eight significant variables in the GI and FI regressions, only the negative impact of the RDP2 grassland premium (*PREDS_214a_area*) holds for FNVI. It also holds for CDI. The RDP1 measure for the setting up of young farmers (*d_youngF_rdp1*), which has a strong significant negative effect on GI change, has a significant positive effect on FNVI. Again, though less strikingly than in France, the local combination of policy effects on the individual FNVI components brings unexpected results on the composite indicator.

To summarise, given our available explanatory variables, best regressions for each dependent variable are achieved for Midi-Pyrénées where the variability explained by the OLS regression (R-squared) reaches 21% for FNVI, 13% for CDI, 24% for GI and 6% for FI. For France, the corresponding figures are 13% for FNVI, 11% for CDI, 2% for GI and 4% for FI. However, all regressions for France, and most regressions for Midi-Pyrénées, are characterised by significant spatial effects. These are more significant and larger for the whole of France than they are within Midi-Pyrénées. For Midi-Pyrénées, a significant but moderate positive spatial lag (ρ) is found for GI and FNVI. In contrast, the spatial lag effect of explanatory variables for France is moderately negative for CDI and FNVI, indicating a competition effect among neighbouring areas, and strongly positive for GI and FI, indicating a spillover effect among neighbouring areas. In all regressions for France, this spatial lag is accompanied by a significant and strong spatial correlation of errors (λ) in the opposite direction (i.e. positive for CDI and FNVI, negative for GI and FI). Significant spatial correlation of the error terms indicates that some characteristics of the regions are not accounted for through the explanatory variables. In Midi-Pyrénées, the LM tests clearly point to spatial lag models, where applicable. Simultaneous autoregressive models were also run, as tests, to check for spatial correlations of errors, and none reported a significant λ.

A first striking result is the contrast between the results for France and Midi-Pyrénées. Clearly, the explanatory variables, especially the uptake of rural development measures, have contrasting effects on farm nature indices according to the implicit geographical reference.

A second striking general result is the number of unexpected effects of rural development measures that sometimes directly contradict their stated environmental objectives. For instance, the RDP2 grassland premium has a negative effect on the increase in the grassland share within the UAA (*evol_gi*). Eligible farms are farms with a high grassland share and low animal density. Hence the grassland premium contracts are mostly found in regions with a high grassland share, and these are probably regions with a more frequent conversion of grassland into annual crops or forest. Thus, the grassland premium somehow fails to protect permanent grassland areas from declining. This counterintuitive result may be rooted in the prescriptions of the grassland premium. Both temporary meadows and permanent grasslands are eligible for the grassland premium as soon as the farm livestock density falls within a certain range. Although the contract excludes the conversion from permanent to temporary grassland, such a conversion is possible in between two contracts. Since 2008, the new grassland premium contract allows for an increased animal density (from 1.4 to 1.8 livestock units per hectare) in certain situations, providing an incentive to convert. Second, in 2010 the conditions for receiving first pillar CAP payments were modified and specific prescriptions related to the management of permanent grassland areas (e.g. with regard to sales of permanent grass plots, and ploughing up) were introduced. That policy shock had been anticipated by farmers, and such anticipation may additionally explain a decrease in permanent grassland areas to the benefit of temporary grassland areas (Faïq et al., 2013).

From a general viewpoint, it can be noted that, with or without specifying the spatial effects, more parameters of our models are significant for France than for Midi-Pyrénées despite lower R-squared. This obviously results from the higher number of observations in France that increases the precision of the estimates.

5. Discussion

Analyses presented above bring a number of very interesting results. First, the impacts of policy measures differ according to the scale of analysis, which defines the implicit reference of changes in the FNVI over time. For instance, payments for water and biodiversity protection have a positive effect in France on the change in FNVI but no significant effect in Midi-Pyrénées. By contrast, the grassland premium measure has no significant effect on France although a negative one is observed while considering Midi-Pyrénées. In the same vein, the negative effect the conversion to organic farming has on the change in FNVI in France as a whole contrasts with the positive impact it has when focusing on Midi-Pyrénées. This negative impact is counterintuitive, and worth further investigation. In France, the area of permanent grassland converted into organic farming was nearly 70% higher, over the period, than the area of cereals, oilseed, and protein crops converted into organic (at the Midi-Pyrénées level, the percentage is 12%) (Agence Bio, 2010). Given that organic grasslands have a lower fodder productivity per hectare, farmers frequently convert some arable land into grassland to meet the herd's needs. Regarding our indices, this means that such a conversion decreases the value of CDI, and increases the value of GI. Although not significant, the signs associated with the impact of conversion to organic on the change in CDI and in GI are consistent (i.e. negative and positive, respectively). This suggests that the negative sign of the change in FNVI arises from a spatial combination of the FNVI components and the higher weighting given to CDI (in comparison to GI and FI) within the composite FNVI. Therefore, one recommendation for further research would be to disaggregate the conversion to organic farming policy based on the farming system it addresses (e.g. annual field crop, permanent crops, etc.), since the observed effects might not be the same. Moreover, and more broadly, it is also important to keep in mind the way FNVI is constructed, since, due to data limitations, landscape features and pesticide use are not considered in the indicator. It would therefore be misleading to interpret the results as true impacts on biodiversity per se.

Second, RDP1 measures have delayed effects. Hence, taking into account that RDP2 might also have delayed effects, the actual impacts of current measures might be missed to a large extent by the present analysis; it is based on uptake and impact indicator variation in the first half of the RDP2 period only.

Third, these results show that RDP2 measures generally do not improve farm nature value. Most of them have significant negative effects, while other measures (such as RDP1 investment aid, AES, or LFA measures) have positive delayed effects. This is less obvious when the focus is placed at the NUTS2 level as for Midi-Pyrénées. Bearing in mind the fact that uptake rates are low, this result might mean that these measures are implemented in regions where the impact indicator (and indices) decreases most. Accepting that our strategy for controlling for endogeneity is robust, farmers make use of RDP2 payments to carry out farm adaptations that mainly accelerate the decline of our FNVI. Regarding FNVI components, afforested areas and crop diversification indices increase most where the permanent grassland share was the highest in 2000. The grassland premium supports both temporary and permanent grassland areas, and has no significant influence on FNVI at the national scale. However, it significantly discourages crop diversification and permanent grassland. This means that beneficiaries convert permanent into temporary grassland and reduce their number of arable crops more than non-beneficiaries do. In contrast, the measure related to the conversion into organic farming has no significant effects on the different FNVI components, while a quite significant effect of this measure is observed on the FNVI, which suggests there are effects due to spatial combinations of the different FNVI components.

Finally, from a methodological viewpoint, testing for the existence of any spatial effect and then specifying the appropriate spatial model is of high importance when analysing the effects of policies. Indeed, not accounting for spatial effects leads to severe biases in the estimators – downwards or upwards depending on the measures. Estimates retrieved by models of spatial econometrics must be corrected for spatial effects in order to analyse total impacts on the indicator of interest.

6. Conclusions and recommendations

There are a number of challenges in assessing the impact of RD measures on the natural value of farming and forestry resource (Beaufoy and Cooper, 2009).

This paper has explored the possibility of measuring the impact of AESs and rural development measures by means of nature value indicators to measure the pressure from agricultural management on biodiversity. It has shown that it is indeed possible to relate rural development efforts to nature value indicators – albeit with some simplifications – and their different components.

Adapting Pointereau et al. (2010) indicators to LPIS data presents the important advantages of providing indicators (or single indices) computable on a yearly basis, which is particularly useful within policy monitoring or ongoing evaluations contexts. An improvement in the modelling will be provided by the LPIS, which by 2018 will include a layer on Ecological Focus Areas, which are one of the measures of the so-called CAP Greening. Such a layer will provide some information on semi-natural vegetation in the UAA of farms receiving CAP subsidies, and will certainly help fine-tune the FNVI proposed in our approach. Alternatively, the share of semi-natural vegetation could be provided by the use of remote sensing, or through the computation of the difference between the total area occupied by farms (excluding tracks, building and housing areas) and the cropped UAA: the larger that difference, the larger the area under semi-natural vegetation is likely to be.

The methodology proposed is a good starting point for further research on policy impact assessment as regards farms' contribution to biodiversity. Nevertheless, empirical analyses have shown that the specifications of the models suffer from omitted variables when the national scale is considered. Hence, a recommendation would be to favour modelling the effects at a regional scale unless the data availability is sufficient to account for all spatial effects.

Finally, the presented study focuses on biodiversity, which is just one of the environmental targets. The areas of intervention in the current CAP programming period have a wide focus on improving the state of the environment, which include improved soil and water management. The proposed conceptual approach shows that information regarding the AES effectiveness on ecosystem services supply can be obtained even when measurements of the investigated variable are not available. This is feasible when adequate proxies, that have a demonstrated link with the variable to be assessed, are available. In the analysed case it is the link between some characteristics of farming land-uses and practices and their impact on biodiversity. In the case of soil erosion it could be, for instance, the link between a change in crop mix and the relative change in soil erosion risk. But the objectives of RDP are much larger than the provision of ecosystem services. As such, one can imagine applying the proposed tool to assess the impacts of RD measures on other indicators relevant within the CMEF context. Moreover, for a general viewpoint there is a potential need for the data set to be augmented with all relevant determinant variables in order to properly assess the additional effect of policy measures of interest. Being a common EU framework for monitoring the effects of RDPs, the CMEF is permanently in need of supplementary and complementary analyses. The present article makes a contribution to this. This type of analysis cannot provide a full assessment of AES effectiveness but, as demonstrated, can point out major discrepancies between the stated AES aims and the statistical impact of the measures. On the implementation of the CMEF by Member States, there is still a lot to achieve in terms of indicator definitions, adaptation and development of existing data bases, data availability, and methodologies to provide accurate evaluations of the benefits or negative impacts of RDPs, and to assess the extent to which the various RDP objectives are achieved.

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Appendix A. Descriptive statistics of explanatory variables

	FRANCE (n=3699)						MIDI-PYRÉNÉES (n=327)					
	na's[1]	**zeros**	**min.**	**mean**	**max.**	**std. dev.**	**na's[1]**	**zeros**	**min.**	**mean**	**max.**	**std. dev.**
sh_grassl_2000	0	25	0.000	0.323	1.000	0.282	0	0	0.000	0.341	0.997	0.290
log_lab06	0	0	1.600	5.031	7.747	0.897	0	0	1.617	5.005	6.713	0.854
rainf_2004_2006	0	0	388.7	825.1	1884.0	199.4	0	0	597.1	814.9	1368.0	161.7
PredS_121_benef	0	0	0.005	0.902	1.000	0.191	0	0	0.001	0.922	1.000	0.200
PredS_214a_area	0	0	0.000	0.716	1.000	0.365	0	0	0.000	0.883	1.000	0.273
PredS_214d_area	0	0	0.000	0.480	0.986	0.251	0	0	0.000	0.508	0.996	0.323
PredS_214i_area	0	0	0.000	0.600	1.000	0.284	0	0	0.000	0.428	1.000	0.300
PredS_axis3_benef	0	0	0.000	0.204	0.890	0.165	0	0	0.000	0.125	0.706	0.135
d_mecha_rdp1	0 : 3234 1 : 465						0 : 234 1 : 93					
d_aes_rdp1	0 : 125 1 : 3574						0 : 11 1 : 316					
d_aesDiv_rdp1	0 : 2909 1 : 790						0 : 277 1 : 50					
d_youngF_rdp1	0 : 103 1 : 3596						0 : 6 1 : 321					
d_afforest_rdp1	0 : 589 1 : 3110						0 : 80 1 : 247					
d_train_rdp1	0 : 3294 1 : 405						0 : 290 1 : 37					
d_LFA_rdp1	0 : 1958 1 : 1741						0 : 33 1 : 294					
d_markproc_rdp1	0 : 2801 1 : 898						0 : 252 1 : 75					
d_retir_rdp1	0 : 1169 1 : 2530						0 : 80 1 : 247					

[1] 'na' stands for 'non available'

Appendix B. Mapping of FNVI and component indices, at LAU1 level, as in 2010