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# The spatial agglomeration of low-input farming intensity: implications for biodiversity conservation

Teillard F<sup>1,2</sup>, Allaire G<sup>3</sup>, Cahuzac E<sup>3</sup>, Leger F<sup>1,2</sup>, Maigne E<sup>3</sup>, Tichit M<sup>1,2</sup>

<sup>1</sup>INRA, UMR 1048 SADAPT, F-75231 Paris, France

<sup>2</sup>AgroParisTech, UMR 1048 SADAPT, F-75231 Paris, France ; teillard@agroparistech.fr

<sup>3</sup>INRA, US 0685 ODR, F-31326 Castenet-Tolosan, France

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## Introduction

Many studies have revealed the negative impacts of farming systems with high input use on biodiversity. Less attention has been paid to the distribution of farming intensity on large gradient. Such knowledge is however crucial for the design of more efficient conservation policies. Indeed, the lack of spatial targeting has been identified as an important cause of their low effectiveness (Whittingham, 2007). Zonal policies targeting the protection of agglomerated high nature value areas may be more effective (Kleijn 2003; Feehan, 2005). Conversely, policies may also achieve positive changes when targeting high intensity areas (Primddahl, 2003). The debate on both policies option is still open because farming intensity data are often missing on large gradients. Most studies addressing the spatial distribution of farming intensity focused on organic farming. However, low-input, extensively managed farmlands are also crucial for biodiversity. Biodiversity may also display a non-linear continuous response to the gradient of agricultural intensity. It is thus important to study the spatial distribution of intensity at a fine scale consistent with a fine tuning of public policies. It requires an intensity indicator able to reveal broad gradients, and relevant for the different farming systems. The intensity indicator should also be computable, cost effective and easy to interpret. Most intensity indicators in the literature are relevant for a single production type and focus on a single component of agricultural intensity (*e.g.* N input). They often need specific surveys for their computation at fine scale or they remain at large scales (80-180 km wide entities) when using existing surveys. Objective of this paper was to test the agglomeration of low-input farming intensity at a fine infra regional scale. Relying on national agricultural statistics, we developed a novel method to estimate the value of an intensity indicator relevant for the main French farming systems. Finally we discuss the consequences of its use for the design of efficient conservation policies.

## Materials and Methods

The FADN (Farm Accountancy Data Network) was used to develop an aggregated intensity indicator: the *Input Cost / ha* (“*IC/ha*” in €/ha). It was defined as the ratio between the main categories of input costs and the total utilized agricultural area (UAA) of the farm:

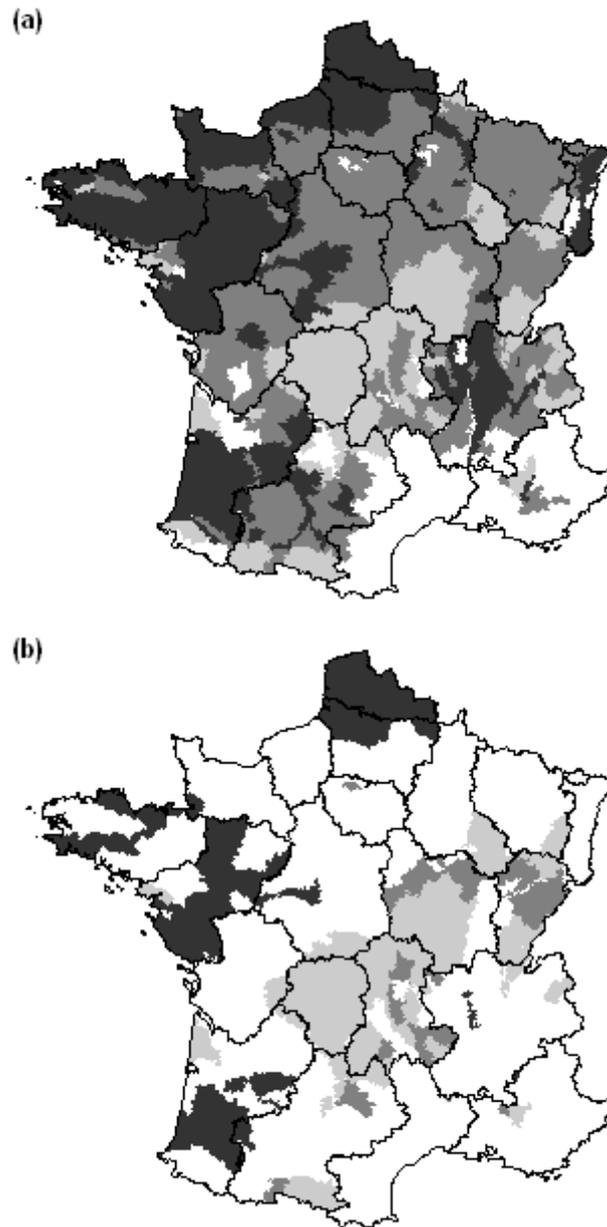
$$IC/ha = \frac{(\text{feed} + \text{fertilizers} + \text{fuel} + \text{seed} + \text{vet. prod.} + \text{electricity} + \text{pesticides}) \text{ costs}}{\text{Farm Utilized Agricultural Area}}$$

The use of costs rather than amounts made it possible to aggregate diverse categories of inputs, relevant for five farming systems: industrial crops, cereal crops, mixed farming, bovine dairy and bovine meat. With the FADN dataset, multinomial regression models were developed to predict the *IC/ha* indicator with *simple* variables (land uses, climatic, economic). Two other datasets (common agricultural policy declarations, agricultural social security) were used to compute the mean values of the same *simple* variables at the small

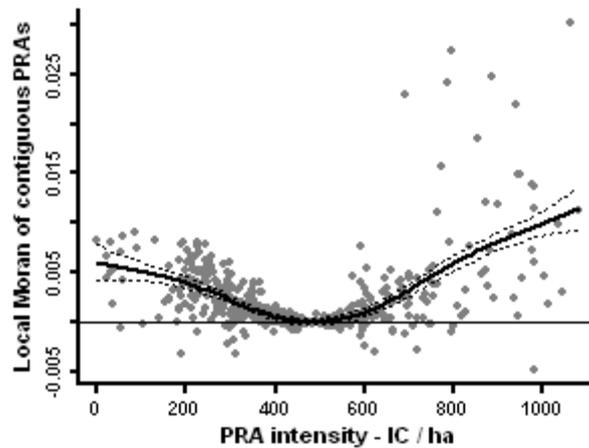
agricultural regions (“PRA”) scale (mean PRA width = 25 km). The models were then used to estimate the *IC/ha* value at the PRA scale from the *simple* variables. Validation procedure based on leave-one-out cross validation were used. The local Moran index was used to test for spatial agglomeration of PRAs with similar intensities. The local Moran measures spatial auto correlation. Positive values indicate spatial auto correlation *i.e.* clustering of PRAs with close *IC / ha* while negative values indicate more spatial dispersion of *IC/ha*. Significance of the spatial auto-correlation was tested with one-sided bootstrapping method on 1000 samples with replacement.

## Results and Discussion

The estimation method provided a continuous value of the intensity indicator – the *IC/ha* – at the fine scale of the PRA (Figure 1a). The *IC/ha* indicator revealed a broad gradient of intensity, PRAs *IC/ha* values ranging from 37 to 1582 €/ha (mean  $\pm$  sd: 452  $\pm$  194 €/ha). Because the *IC/ha* was a relevant intensity indicator for five important agricultural production types, it could be computed for 84% of the French PRAs. We revealed the precise location of low-input systems, with an *IC/ha* value lower than 300€/ha. They were mainly concentrated in a large area spreading in the centre of France. Other regions contained more isolated low input PRAs, mainly in the eastern part of France. PRAs with high input levels were concentrated in western and northern regions of France while the medium *IC/ha* values filled the remaining territory. Figure 2 shows that within the two intensity extremes, PRAs were agglomerated. There was a significant relationship between the *IC/ha* value of a PRA and its local Moran ( $p < 2e^{-16}$ , GAM with 5.8 d.f., explained deviance = 43.1%) *i.e.* the similarity with its contiguous neighbours *IC/ha*. The local Moran was positive for PRAs of the two intensity extremes, indicating that low-input PRAs were agglomerated, and PRAs with high *IC/ha* also. Conversely, PRAs with medium intensities showed weak local Moran, indicating more spatial dispersion. Figure 1b highlights the PRAs significantly agglomerated with contiguous neighbours of similar intensity (*IC/ha*). There was significant agglomeration of both low and high intensity PRAs. Most of the PRAs with low *IC/ha* in Figure 1a showed significant value of the local Moran agglomeration index. There was thus a large cluster of low input PRAs spreading across several regions in the centre/eastern France. Three main clusters with PRAs showing high, significantly auto-correlated intensity were found in south western, western and northern France. Both clusters of low and high intensity PRAs did not show consistency with administrative region borders. Therefore, spotting these clusters would not be possible with the regional averages provided by the standard agricultural statistics. Our approach could be helpful to design conservation policies targeted at an infra-regional scale consistent with the clustering of agricultural intensities. In order to improve the cost effectiveness of conservation policies, they may be targeted at the most suitable areas where environmental effects would be provided at lower costs than if conducted elsewhere (Uthes 2010). We suggest that protection policies for preventing extensive areas from intensification or abandonment may be targeted at the low-input clusters we revealed. Conversely, improvement policies for achieving positive changes should be targeted at the high-input clusters. As most of the datasets we used are available in other European countries, our approach could be generalized.



**Figure 1.** Maps of French PRAs agricultural intensity ( $IC/ha$ ) and agglomeration. Light grey: low  $IC/ha$  ( $<300\text{€}/ha$ ), medium grey: medium  $IC/ha$  ( $300\text{-}500\text{€}/ha$ ), dark grey: high  $IC/ha$  ( $>500\text{€}/ha$ ). Administrative regions borders are shown in black. **(a)**: data not available for PRAs in white (PRAs dominated by other production types than the five focus types). **(b)**: only the PRAs showing significant agglomeration with contiguous neighbours of similar intensity are plotted (PRAs in white means data not available or non significant agglomeration).



**Figure 2.** Relationship between the intensity (*IC/ha* value) of each PRAs and their local Moran index. Local Moran index indicates if a PRA is agglomerated with neighbours showing similar intensity (*IC/ha*) values. Each point stands for a PRA. A generalized additive model is used to determine the relation between *IC/ha* and local Moran (black curve), because this relation didn't seemed linear. 95% confidence intervals are shown in dotted lines.

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