**Estimating Agricultural Practices and their Impact on Biodiversity from Agricultural Statistics: A Proof-of-Concept Study on Food Labels in France**

Sarah HUET, Clélia SIRAMI, Abdoul DIALLO, Julie REGOLO, Valentin BELLASSEN

2024-08-26

# Abstract

Our method, BVIAS (Biodiversity Value Increment from Agricultural Statistics): - An objective, robust, and operational method to estimate agricultural practices and calculate their impact on biodiversity at the farm level in a representative sample of French farms. - Preliminary evaluation of the impact of 25 labeled products on biodiversity.

* Cultural practices in large-scale agriculture: only organic farming stands out from conventional methods.
* Nitrogen fertilization: 100% reduction in synthetic fertilizers, but with 5 times more organic fertilization, leading to a similar total nitrogen application per hectare as conventional methods.
* Pesticides: >96% reduction in pesticide use on large-scale farms.
* Livestock practices in dairy production: only organic farming and Comté (a French regional designation of origin) stand out.
* Organic: - More than 2 times more temporary grasslands compared to conventional methods, but no significant differences for permanent grasslands. - Higher share of main fodder crops, lower loading rate, and reduced maize silage in the ration.
* Comté: - 1.2 times more permanent grasslands than the average for French conventional farms in this region. - Compared to conventional farms in the Montagne region of Franche-Comté, only the share of temporary grasslands differs: >2 times more surface area.
* The different practices used in organic and Comté farming lead to a smaller impact per hectare but also lower yields, resulting in a similar impact per kilogram (see figure).
* Estimated practices are consistent with the requirements of specifications documents, and only those specifications that impose specific constraints to limit production impacts (i.e., organic farming and Comté) are associated with less impactful practices.
* Limiting the use of pesticides on crops and increasing the share of grasslands in livestock farming can reduce the impact per hectare of products on biodiversity but tend to decrease yields, compensating for differences in impact per kilogram.
* Only three crop cultural practices are estimated (soil tillage, nitrogen fertilization amount, and pesticide loading). However, before informing environmental labeling, the effects of agroecological infrastructure, crop heterogeneity, and the share of organic vs. synthetic fertilizers must be included in the BVIAS model.

# Introduction

Biodiversity erosion is likely the most important environmental crisis, along with climate change. If the impacts of current climate change trajectories are estimated to be several tens of percentage points of GDP (Rose et al., 2022), the sole disappearance of pollinators is valued at 1-2% of GDP and approximately four billion euros for a country like Germany (Lippert et al., 2021). The IPBES groups and prioritizes five determinants of biodiversity loss (IPBES, 2019): land use (30%), direct exploitation (23%), climate change (14%), pollution (14%), and invasive species (11%). Agriculture primarily intervenes through three of these five determinants (land use, climate change, and pollution) and, along with direct exploitation, is one of the two main economic sectors responsible for global biodiversity erosion (Maxwell et al., 2016; Tilman et al., 2017).

Environmental labeling on agricultural products is one of the policies that could reduce the impact of agriculture on biodiversity. Although the information provided to consumers seems to trigger only small changes in food choices in the short term (De Marchi et al., 2023; Dubois et al., 2021), environmental labeling opens up several indirect effects at long-term. It encourages producers to change their practices, and processors to modify product formulations to improve their score, and it can serve as a support for other policies (e.g.: minimum score requirement for public procurement, tax based on the score, …).

At the European level, the Commission published a proposal for a regulation in March 2023 requiring all companies that want to claim an environmental advantage to use the life cycle analysis framework, such as the EU Product and Organisation Environmental Footprint (PEF and PEO), to objectify the claim. France has taken an additional step with the “Climate and Resilience” law of 2021, which provides for mandatory environmental labeling on all food products after a planned five-year trial period. Following the EcoScore proposal by ADEME, which is expected to inspire the future government tool, several stakeholders criticize it for limiting itself to product life cycle analysis (Interbev, 2024). Their main argument is that life cycle analysis fails to account for the impact of food products on biodiversity. The scientific council of the trial emphasizes that life cycle analysis takes into account three of the five main determinants of biodiversity loss, but recognizes the usefulness of complementing life cycle analysis in certain areas (Soler et al., 2021). Given this controversy, it appears urgent to propose a method that is objective, robust, and operational for calculating the impact of food products on biodiversity. This is what this section aims to achieve.

According to us (**com1?**), environmental labeling must be based on a biodiversity indicator that meets five main requirements ([Table 1](#tbl-methods)):

* *An explicit and operational definition of biodiversity.* The term “biodiversity” is very polysemous. Therefore, it is important to explicitly define an operational definition adapted to the context (Santana, 2014). This definition must also maintain an intuitive link with the main issues related to the erosion of biodiversity such as species or ecosystem disappearance (and a fortiori those that provide important services like pollinators).
* *Taking into account the main determinants of biodiversity loss linked to agriculture*, namely land use, climate change, and pollution.
* *Based on measured and representative data for parcels, either on biodiversity or practice intensity*, in order to estimate the impact of actual practices rather than potential ones on biodiversity.
* *Enabling an evaluation of every food product.* Environmental labeling must be made mandatory and applicable to all products based on available data today, differentiating both between different products (e.g. lentils versus chicken) and different production modes for the same product (e.g. conventional wheat versus organic wheat).
* *Rely on the validation of the estimated impact based on in situ biodiversity measurements.* There are always two ways to evaluate an impact: on-site measurement and modeling. In the second case, a critical criterion for robustness is the validation of the model, at least for the predicted variables for which we have on-site biodiversity measurements (e.g. biodiversity per unit area).

***The literature review in Chapter 2*** shows that we can distinguish three main types of methods for evaluating the impact of food products on biodiversity: in situ observations of biodiversity by counting species in ecosystems, modeling the impact of agricultural practices on biodiversity, and modeling the impact of label requirements on biodiversity. The suitability of these three methods with the requirements of environmental labeling is summarized in the next three paragraphs and synthesized in [Table 1](#tbl-methods).

*In situ observations* clearly meet the criteria for data and validation. However, they are limited in both space and time, making it difficult to estimate the impact on all food products. With considerable effort, comprehensive meta-analyses that study multiple taxonomic groups allow estimating a mean effect per type of product and differentiating some production modes. For example, Tuck et al. (2014) distinguish between organic and conventional agriculture for five agroecosystems and estimate that species diversity is on average 30% higher in organic agriculture. Species diversity is a relatively explicit definition of biodiversity and maintains an intuitive link with the main issues related to biodiversity erosion as long as we stay within the same agroecosystem. However, this link stretches when comparing different ecosystems or agroecosystems because it involves comparing completely different species assemblages (Santana, 2014; Sarkar, 2002). Finally, in situ observations have the major disadvantage of not considering the amount of anthropized surface area. Since biodiversity is expressed per unit surface area in these studies, they attribute the same impact to two identical productions (e.g., wheat), even if one occupies twice as much surface area as the other. This is a paradox difficult to manage in an environmental labeling framework because two tons of wheat have the same impact as one ton of wheat, provided that the amount of inputs per hectare is the same.

*Modeling based on agricultural practice data* is used in life cycle assessments (LCAs). Crenna et al. (2019) shows that the impact of the European food system on biodiversity is mainly caused by animal products (70-75% of total impact), and more specifically by pork (19-23%) and beef (21-25%). Read et al. (2022) found that adopting a flexitarian diet, as recommended by the EAT-Lancet commission (Willett et al., 2019), could reduce the risk of species extinction caused by American food consumption by 30%, and up to 45% if food waste is reduced. The models used in these studies (e.g., (Chaudhary et al., 2015; Goedkoop et al., 2008)) only account for differences in practices within a single production unit in a limited way (typically three levels of “intensity” without considering the effects of landscape infrastructure, plot size, etc.). As a result, there is very low sensitivity to differences in practices per unit surface area (Wermeille et al., 2024). To address this, Lindner et al. (2019) proposed a model that takes into account 14 agricultural practices, including agroecosystem type (prairie vs crop vs forest). By using a simplified version of the model to adapt to the limitations of the Agribalyse database life cycle inventory data, Lindner et al. (2022) found that organic agriculture can reduce the biodiversity impact per kilogram of wheat (-33%) or liter of milk (-27%), but increases it for a kilogram of chicken (+33%). In all cases, the predictions from these models are only poorly validated when compared to in situ observations of biodiversity.

*Modelling from specifications*, currently limited to grey literature, proposes an evaluation of the potential impact of restrictions set out in label guidelines. Alliot et al. 2021 conclude that life cycle assessments associated with organic agriculture (AB, Demeter, Nature and Progrès) strongly limit biodiversity damage (score between 3/5 and 4/5), while AOP Comté and Bleu Blanc Cœur do so moderately (2/5), and other labels (HVE, Zéro Pesticides, Label Rouge, etc.) hardly do so at all. This approach has the advantage of being applicable to any label, but ignores actual practices in place. For example, the guidelines for Comté, which limits mineral fertilization to 50 kgN ha-1, does not allow for knowing the quantities actually used, nor a fortiori the potential induced effects on a more diverse cultural landscape or the ratio between organic and mineral nitrogen. Furthermore, this approach suffers from the same limitations as in situ observations, namely the lack of consideration of land ownership, and the same limitations as other models, namely the absence of validation.

see [Table 1](#tbl-methods)

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| Table 1: **Exigences de l’affichage environnemental et méthodes existantes.** Le code couleur donne le jugement des auteurs sur le degré d’adéquation du type de méthode avec chaque critère (exigence remplie, partiellement remplie ou pas remplie), en prenant appui sur l’exemple cité en haut de tableau.   | x1 | x2 | x3 | x4 | x5 | | --- | --- | --- | --- | --- | |  | Observations in situ (ex. Tuck et al., 2014) | Modélisation à partir de données sur les pratiques agricoles (ex. @lindner\_bringing\_2022) | Modélisation à partir de cahiers des charges (ex. Alliot et al., 2021) | BVIAS (cette étude) | | Définition explicite et opérationnelle de la biodiversité | Diversité spécifique (d’autres études présentent une pluralité d'indicateurs dont l’abondance, la diversité, la présence d’espèces rares/endémiques, …). Absence de lien systématique avec la sixième crise d’extinction. | Dégradation de l’état naturel (ou risque d’extinction d’espèces pour d’autres études) | Définition implicite | Dégradation de l’état naturel | | Prise en compte des principaux déterminants de pertes de biodiversité liés à l'agriculture |  |  |  |  | | Occupation des sols | Prise en compte des effets paysagers. Pas de prise en compte des rendements. | Pas de prise en compte des effets paysagers. Prise en compte des rendements | Prise en compte des effets paysagers. Pas de prise en compte des rendements. | Prise en compte des effets paysagers et des rendements | | Changement climatique | Non pris en compte | Non pris en compte par @lindner\_bringing\_2022, mais pris en compte par d’autres modèles | Non pris en compte | Non pris en compte | | Pollution | Prise en compte intrinsèque de toutes les pollutions | Prise en compte des principales pollutions sans taille d’effet | Prise en compte des principales pollutions sans taille d’effet | Prise en compte des principales pollutions avec taille d’effet | | Reposer sur des données mesurées, sur la biodiversité ou sur les pratiques, au niveau des exploitations | Oui (biodiversité), mais sans garantie sur la représentativité des parcelles (taille d’échantillon souvent faible, difficulté à couvrir l’ensemble des productions) | Oui (pratiques), mais souvent incomplètes et sans garantie sur la représentativité (inventaires de cycle de vie) | Non (cahier des charges) | Oui (pratiques, échantillon fourni et représentatif : RICA, RA, RPG) | | Permettre une estimation par défaut sur tout produit alimentaire | Non (trop peu de mesures pour différentier chaque produit) | Différencie les principaux produits, et le label bio | Différencie de nombreux labels, mais pas les produits entre eux | Différencie les principaux produits, et les labels suffisamment représentés | | Validation sur la base de mesures in situ de biodiversité | Oui (intrinsèquement) | Non | Non | Oui (ordres de grandeur consensuels dans la littérature) | |

Finally, for all three type of methods, it is currently difficult to assess the representativeness of the results proposed for a given product or label. In situ measurements, such as life cycle inventories, are generally carried out on a limited number of farms without explicitation of their representativity. This limitation risks becoming increasingly critical as environmental labeling may induce pressure on technical institutes, main suppliers of life cycle inventories, to choose flattering examples for their sector. The increasing availability of data collected for public statistics and agricultural policies now allows us to avoid this risk and increase sample sizes. Thus, some studies have already paired RICA (Réseau d’information comptable agricole) and INAO (Institut national de l’origine et de la qualité) data to evaluate the effectiveness of labeled farms. Jeanneaux et al. (2018) shows that certain labeled sectors do not generate higher profitability, as the product premium is entirely compensated by lower technical efficiency (e.g., Label Rouge or AB poultry meat). Sengel et al. (2022) estimates that dairy farms with geographical indications earn a 30% higher income per unit of work compared to conventional farms. This difference, driven particularly by Comtoise designations, increases to 40% after restricting the comparison to farms with similar structure and location using a “matching” procedure.

Our study proposes an objective, robust, and operational method for calculating the impact of food products on biodiversity. This method is applied to the main French agricultural productions, distinguishing the main trackable labels for environmental labeling (organic agriculture, Label Rouge, and geographical indications). It draws inspiration from the BVI model (Lindner et al. (2019)), but allows us to overcome the three main limitations raised during its application to environmental labeling (Lindner et al. (2022)). By relying on agricultural statistics data (e.g., RICA, Agricultural Census), it accesses large sample sizes and farm characteristics that enable objective selection of counterfactuals for labeled farms using a “matching” procedure. By mobilizing parcel maps (Graphical Parcel Register or RPG) and wooded elements (BD Hedges), it allows us to take into account landscape effects. Finally, by validating the predicted impact differences against established order-of-magnitude estimates from in situ biodiversity measurements in the literature, it reinforces confidence in the robustness of estimated impacts.

# Modelling the impact of crop practices on biodiversity

## The BVI model

The model selected for estimating the impact of agricultural practices on biodiversity is the BVI model as chosen initially by ADEME for environmental labeling of food products (Lindner et al. (2022)). This model considers biodiversity at the parcel and semi-natural spaces (ESN) adjacent to it, and takes into account soil occupation (grassland vs. crop), landscape effects, and the intensity of farming practices. We estimate seven different parameters that have a major impact on biodiversity within each category of soil occupation: soil tillage, nitrogen fertilizer application (quantity and quality), use of plant protection agents, hedge density, agricultural plot size, and cultural diversity.

The BVI method introduces a normalized biodiversity value that focuses on naturalness as an objective. To be able to aggregate the impact of these practices on this normalized biodiversity value and include them as input parameters in the BVI model (Lindner et al. (2022)), their intensity values are normalized within the interval [0,1], with the minimum intensity corresponding to 0 and the maximum corresponding to 1. To exclude potentially values aberrantes, the 95th percentile of positive values is fixed as (Lindner et al. (2019), Lindner et al. (2022); Equation 1 to 3).

# Comments

18/04/24 Clelia: Est-ce que c’est que “nous”? J’avais l’impression qu’il y avait déjà certains critères bien identifiés dans la littérature (point 1 et 2) ou le cahier des charges pour l’affichage environnemental (point 4)

25/04/24 Valentin: Si tu les as sous la main, c’est sûr que c’est mieux, mais pas moi

Lindner, Jan Paul, Horst Fehrenbach, Lisa Winter, Judith Bloemer, and Eva Knuepffer. 2019. “Valuing Biodiversity in Life Cycle Impact Assessment.” *Sustainability* 11 (20): 5628. <https://doi.org/10.3390/su11205628>.

Lindner, Jan Paul, Peter Koch, Horst Fehrenbach, and Silvana Buerck. 2022. “Bringing the Biodiversity Value Increment Method to Agribalyse.” ADEME.