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What are ecosystem services?

ON TRANSFORMATIVE TABLES AND THE SEARCH FOR SUPPLY AND DEMAND

Kewan Mertens
CSI - Centre de sociologie de l'innovation, i3 UMR CNRS
Mines ParisTech, PSL Research University
kewan.mertens@minesparis.psl.eu

Kato Van Ruymbeke
Department of Earth and Environmental sciences, KU Leuven

Liesbet Vranken
Department of Earth and Environmental sciences, KU Leuven

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ABSTRACT :

This article contributes to exposing inner workings of academic research on Ecosystem Services (ES) and their indicators. A self-reflexive study in a lab of environmental economics for more than two years reveals how previous research on agroecological practices in Europe is reinterpreted in order to identify the delivery of ES. We document the difficulties encountered in the transformation process.

We show that ES are operationalized through table-concepts. Two tables are used: the first one to extract data from their initial context and purify them from concepts and concerns in environmental sciences; and the second one to subsequently recomplexify these data into a new context of supply and demand. At the end of this process, the newly generated data have little to do with the scientific context from which they are originally derived. We describe the resistances to these transformations as well as the various strategies we employed to address the difficulties we encountered.

By carefully tracing the transformations in our study we show the particular nature of ES, how they selectively rely on concepts from both environmental sciences and economics, and the way they hierarchize and hybridize some of these concepts. While some of our findings may be specific to the context of our study, which has concentrated on European, anthropogenic and agricultural environments, we believe that they provide a unique insight into the nature of ES.

KEYWORDS :

economization; environment; agriculture; ecology; literature review; self-reflexive; archive; database

Introduction

This manuscript studies an alleged moment in the expansion and hybridization of economic reasoning. It investigates the operationalization of Ecosystem Services (ES) in an indicator that matches the supply of and demand for benefits of various agroecological practices in Europe[1]. While ES are frequently alleged to contribute to an economization of the environment (Gómez-Baggethun and Ruiz-Pérez 2011; McElwee 2017; Shapiro-Garza et al. 2020), our case displays none of the features that are traditionally associated with the field of economics: here are no markets, monetary valuations, abstract models or laboratory experiments. The research we describe does not even draw on the typical assumptions on self-interested individuals. Yet, ultimately, the indicator we observe aligns with a reasoning in terms of supply and demand, thereby potentially carving out of a domain for an economic understanding of the environment.

Current work is the product of a self-reflexive attempt to keep open the archives of our research (Bowker and Star 1999; Waterton 2010). The curious in-betweenness of ES, situated between environmental sciences and environmental economics, has pushed us to carefully attend to their construction process and subsequent operationalization. We are ourselves researchers originating from both environmental sciences and environmental economics. Yet, the questions that guided us in current study are typical of Science and Technology Studies (STS) (Latour 1987, 1993a): how are the translations made from one discipline to the other? What in this process is gained and what is lost? And, ultimately, what is the knowledge field that is constructed by ES?

The latter question, we believe, provides a partial response to the recent observation "that research on the making of economics has, so far, somewhat [been] neglected" (Asdal and Cointe 2022). According to Hirschman & Popp Berman (2014) one of the pathways through which economists "establish certain domains as under their own jurisdiction" is the establishment of cognitive infrastructures, which consist of devices tailored for policy making (Hirschman and Popp Berman 2014) and economic styles of reasoning (Hacking 1992). We study the construction of a calculative space for economic reasoning, a process which Miller & Power (2013) in their review of accounting research have called the territorialization of economics. We show how objects from environmental science and ecology are transformed and used to build a field dominated by economic ideas, such as decision-relevance, trade-offs and efficiency (Fourcade 2009; Miller and Power 2013). This *purification* and transformation of concepts from environmental science and ecology comes with a *hybridization* with some principles in economics.

[1] According to the Millennium Ecosystem Assessment (MEA 2005) "Ecosystem Services are the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling."

To be sure, economics has a long-standing interest in the natural environment. For the early physiocrats, Marx and classical economists, land was a source of use values and an important factor of production (Gómez-Baggethun et al. 2010). Agricultural economics and scientific forestry have, for their part, always remained concerned with biomass productivity (Perman et al. 2003) and research in those domains has led to important innovations such as discounting in mainstream economics (Doganova 2018). While the marginalist revolution of neoclassical economics has somewhat reduced the interest for the environment in the first half of the 20th century, the emergence of environmental and resource economics in the fifties, as well as ecological economics in the eighties, has re-established the environment and its resources as full-fledged subjects of economic analysis (Gómez-Baggethun et al. 2010; Missemer 2018; Perman et al. 2003; Røpke 2004). Within Environmental and Ecological Economics[2] a large array of methods and concepts have been developed to measure and internalize use and non-use values of the environment. Likewise, two concepts that grasp the environment in economic terms, natural capital and ES, are now more than four decades old and widely used[3] (Åkerman * 2005; Gómez-Baggethun et al. 2010). The concept of ES in particular, originally coined in ecology and environmental sciences, benefits from a strong institutional environment and an exponential use in scientific articles and policy documents (Chaudhary et al. 2015; Costanza et al. 2017).

While some have claimed that the concept of ES entails a Kuhnian paradigm shift (Potschin and Haines-Young 2011), the concept nevertheless remains highly debated (Masood 2018; Schröter et al. 2014) and its definition and metrology are distinctly unestablished (McElwee 2017; Rodriguez, Devictor, and Maris 2018). It has been claimed that the ES themselves, because of their complexity, resist standardization (McElwee 2017). McElwee (2017) has therefore argued that there is a need for "a detailed examination of how different types of ES are defined, measured, and made commensurate".

This is what our current STS study is about. We investigate what ES are and do. Not out there in the wild[4], but there where they are being studied and manipulated. Indeed, we conducted

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[2] While Environmental Economics developed from neoclassical welfare economics (Perman et al. 2003), Ecological Economics is more heterodox because it treats the economy as a subsystem of a finite biophysical environment, more frequently has an explicit concern for matters of sustainability and justice, and hosts a quite large array of methodological pluralism (Farley and Kish 2021).

[3] In fact, the notion of natural capital is much older, but it has been rediscovered in the eighties, after which its popularity has rapidly increased (Missemer 2018). Likewise, while the concept of ES has been coined in 1981 (Ehrlich and Ehrlich 1981) and popularized in the nineties (Costanza et al. 1997, 2017) many of its components were already valued and transacted on markets before the concept was being used (Gómez-Baggethun et al. 2010). In the 19th century a whole research field of "economic ornithology" attempted to measure the economic benefits of birds and can therefore be understood as an early precursor of the field of ES (Evenden 1995; Kronenberg 2014).

[4] The concept of "economization" is often associated with performativity but we do not study the performativity of ES. Research on the performativity of economics understands economization as the process by which economic concepts and methods put into effect the reality they represent, thereby re-organizing sociotechnical entities and practices such as markets (Çalişkan and Callon 2010; Mitchell 2007). This has generated a wealth of studies, covering a wide range of facets of economization. These include processes of measurement and classification (Robertson 2012), commensuration (MacKenzie

an old-school laboratory study (Latour 1987) on environmental economics. We have studied our own work: the development of a synthetic indicator of the environmental performance of different farming systems in Europe. This work has forced us to operationalize the relatively abstract concept of ES. Similar to observations made in Latour's study on soil scientists and foresters (Latour 1993a), several successive steps of translation from one discipline to another have been necessary for this operationalization. In our research these ES have taken the form of what we call *table-concepts*, material semiotic devices which have subsequently directed our research efforts. Our self-reflexive inquiry offers a unique insight in the capacity of ES to generate calculative spaces of their own.

We adopt an approach in which both the researchers and their texts are seen as actors in the research process. As researchers, we are bound by texts: we read and write texts, act upon and through texts, but are equally acted upon by and through these texts (Asdal and Cointe 2022). We show how elements from texts in environmental science and ecology are purified from their disciplinary ballast and reassembled into something new, to be governed according to economic principles of supply and demand, rational decision making and efficiency (Fourcade 2009:235–41; Miller and Power 2013). We argue that this process of economizing concepts from environmental sciences is something more than the mere application of economic principles to the environment. The struggles, resistances and transformations we faced signal to us a hybridization of concepts from both environmental science and economics (see also Asdal & Huse (2023)). This, we argue, would not be possible if the work we did was not situated in a context of anthropogenic nature and supported by strong institutional incentives at the European level.

The table-concept: attending to the trans-formative work of ES

Imagine 11 researchers in seven research groups, distributed over several universities in Europe, collaborating to evaluate the environmental performance of ecological farm management practices. Most of these researchers identify as agricultural or environmental economists and are based in a department of life sciences or agronomy, while two are geographers and one is an economist based in a department of economics. They participate in a large European H2020 project[5] which aims to identify the potential benefits of ecological farming in the European Union (EU). One of their tasks is to construct an indicator of environmental performance. The indicator is constructed by means of a combination of

2009), monetization (Fourcade 2011), commodification (Holm and Nielsen 2007; Robertson 2006) and marketization (Ehrenstein 2018). We do not look at what ES do outside of our lab of environmental economics.

[5] This project is called LIFT, standing for "Low-Input Farming and Territories", and is coordinated by the French National Institute for Research on Agriculture, Food, and the Environment (INRAE). The indicator of environmental performance is just one of the deliverables of LIFT and should become one of the components of a multi-scale sustainability assessment of European farming systems.

stakeholder workshops and a Rapid Evidence Assessment (REA) of existing reviews on the environmental consequences of a diverse range of agricultural practices in Europe (see Figure 1). In the REA, a review of reviews, data from environmental consequences are extracted from 95 existing reviews on agricultural practices in Europe. These data are subsequently reassembled into a composite indicator of environmental performance, which is itself composed of 17 sub-indicators representing the different ES that can be provided by the agricultural practices. How has this work on the development of an indicator allowed us to identify what ES do?

Laboratory studies have taught STS scholars to pay attention to the material-semiotic work of research tools[6]. These tools are used to produce validated texts, in the form of a peer-reviewed paper or book, which transport the findings of research from one laboratory to another, and thereby contribute to creating what is commonly understood as scientific knowledge (Latour 1987). Some of these texts can be understood as immutable mobiles or combinations of *inscriptions* (Latour 1987), i.e. the outcome of a translation of objects into science, while others also function as *instructions* or instruments (Asdal and Cointe 2022), i.e. designed to coordinate and guide additional translations and transformations.

In our research the objects that are being manipulated and studied are inscriptions found in scientific reviews from environmental sciences and ecology. We are, moreover, handling many other texts, such as the grant agreement, milestones, or emails exchanged with colleagues in the project. These texts frequently act as instructions. Classification systems themselves can be understood as instructions (Bowker and Star 1999). The guidelines for a proper REA, classifications of agricultural practices and lists of ES thus act as written instructions that prepare the conditions for the development of the indicator.

In practice, such classification-instructions translate into tables. As will become clear in the following sections, ES have a very specific role in these tables, different from the other classification-instructions such as guidelines for REA and lists of agricultural practices. In fact, the tables act as the materializations of the ES concept. We therefore study these *ES table-concepts* as the material-semiotic devices which make the indicator possible[7]. A set of two table-concepts constitutes the laboratory equipment of our research. This set allows us to collaborate across disciplinary and institutional boundaries and at the same time constrains us. Just like in the case of economic models (Breslau and Yonay 1999), the table-concept is something the researcher interacts with. While a modeler wants the outcomes of his/her work to be received as the agency of the model, and not the modeler, here the aim is to produce results which are deriving from the agency of the table-concept. The table-concept is thus endorsed with a kind of "disciplinary agency" (Pickering 1995), forcing researchers that interact with it to produce accounts that are sufficiently ordered to claim some form of objectivity.

[6] Concerning economics, studies in STS have therefore investigated the work of models (Breslau and Yonay 1999), accounting tables (MacKenzie 2009), experiments in the lab (Mitchell 2005) and in the field (Abdelghafour 2022; Berndt 2015), business models (Doganova and Muniesa 2015), and so on.

[7] Table-concepts are semiotic because they hold meaning and can make things happen (Greimas and Courtés 1982). They are also material in that they contain things which can be manipulated and made to travel.

In current manuscript we attend to the trans-formative work of the ES table-concepts, i.e. their capacity to *transform* the inscriptions from environmental sciences and ecology into new inscriptions that *form* a fertile ground for further manipulation in a different academic field. To trace this work, its struggles and resistances, it was necessary to follow those working with the table-concepts very closely. This has been made possible by our participatory and self-reflexive approach.

A participatory and self-reflexive approach

As mentioned, several research groups are involved in the development of the indicator, but it has been up to a Belgian research group in environmental economics to coordinate the data collection and conduct the analyses needed for the development of the indicator. Following initial preparations early 2020, the three researchers from that group invited the eight remaining researchers, based in Scotland, Greece, Austria, Sweden, England and Poland, to participate in the data extraction during the summer of 2020. Each of these researchers received a few reviews and had to extract information from these reviews into a large Excel table. Data cleaning and analysis for the indicator development were subsequently conducted in Belgium in the fall of 2020. From that period onwards all meetings within the Belgian research group have been systematically recorded.

These meetings have been recorded with the explicit purpose to conduct current STS research in parallel with the development of the indicator. Since this STS study has likely influenced our work, it is necessary to elaborate on our positionality. The three authors of current STS research are also the main researchers involved in the development of the indicator of environmental performance. The third author of current study is the head of the research group that coordinated the development of the indicator. Professor in environmental economics, with a Master in both agricultural engineering and economics and a PhD in economics, she participated in writing the grant proposal for the H2020 project. The second author is a PhD student under her supervision. She was hired on the H2020 project and has conducted the majority of research activities for the development of the indicator. She has a bachelor in biology and a master in sustainability and climate change.

The first author of current manuscript initiated and conducted the STS study. After having finalized a PhD under the supervision of the third author in 2018, he was in the process of reconverting himself to a post-doc in STS and geography at the start of current STS research in 2020. Since he was still working in the research group of his former PhD supervisor at that time, he got indirectly involved in the H2020 project[8] and participated in the daily supervision of the PhD student. His motivation to conduct this STS study derives from his in-between position: knowing both the practices in environmental economics (Schröter et al. 2014) and the stringent critiques one can find in geography (Fletcher and Büscher 2017; Gómez-Baggethun and Ruiz-Pérez 2011), the objective of the first author has been to render reflections

[8] He had his own source of funding during the whole period of this research and thus remained independent of the H2020 project. Since 2021 he is not also working in that research group anymore.

on environmental economics more targeted and more effective. This is in line with the call by Bowker and Star (1999) to keep open the black box of classifications.

This study has thus been made possible by the long-term trust relation between the authors, as well as their curiosity and openness to debate and critique. It was agreed that the first author would conduct the analysis, based on project documents, emails and transcribed recordings in Nvivo, and subsequently write the scientific article. The second and third author have been involved in the final revision of the STS article in order to ensure precision in the reporting as well as trust and accountability all along. The current analysis thus cultivates the proximity and distance that is required to open up the "gaps in meaning" that are necessary for this kind of situated research (Rose 1997). The interdependence between the two research projects, indicator development and STS analysis, has become constitutive of these projects. As stated by one of the researchers, addressing the first author of current manuscript in a comment on a preliminary draft: "I was very aware of someone studying the work we were doing, and sometimes spent a lot of time, maybe more than I would have otherwise, thinking things through to ensure that I could justify my actions to you later on" (Researcher 1)[9].

Besides interviews with the second and third author of current manuscript, five other researchers involved in the project have been interviewed. During the interviews, a focus was put on what had been done during the research and why. Respondents received the interview guidelines a few days before the actual start of the interview. A substantial number of other documents has been collected as well: more than 30 official documents related to the H2020 project, including the grant agreement and relevant milestones and deliverables; internal communications and documents with instructions for the Rapid Evidence Assessment (REA); Excel tables with data extracted during the REA; as well as transcriptions of 13 recorded meetings of 1 hour or more; tens of notes of shorter meetings; transcriptions of 3 workshops with stakeholders; and, finally, feedback on drafts of reports and on scientific manuscripts related to the indicator (the first manuscript, out of two, is currently under review in *Ecosystem Services*). An initial draft of current STS paper has been shared with the 11 researchers involved in the indicator development and a meeting was organized, recorded and transcribed in order to validate and nuance the findings. To preserve a relative anonymity, quotes from discussions and interviews are labelled as Researcher 1, Researcher 3,… in order of appearance in the text, while documents are referred to as Doc1, Doc2,... Interventions of the first author of current manuscript have not been quoted, but whenever his standpoint is different from his co-authors this is made explicit in the text.

[9] It should be noted that the first author of current STS research is male, while the second and third author are female. During one of the discussions about this work the question was raised whether this STS research, whereby a former PhD student is allowed to "look over the shoulder" of his former supervisor to study her work, would have been possible if gender roles had been inversed. This question, unanswered, highlights the specificity of this self-reflexive laboratory study.

Two table-concepts: the cruncher and the validator

In a preliminary draft of a scientific paper on the indicator it is stated that the aim is to "evaluate the performance of conventional and ecological farm management practices against ES supply" (Doc 1, 2021) and that the approach is derived from "the cascade model which postulates that an ES may only be considered a service if human beneficiaries can be identified" (Doc 1). The argument is made that this cascade model (Potschin and Haines-Young 2011) applied to agriculture "may be interpreted as a social-ecological system in which humans are a part of – rather than separate from – nature" (Doc 1). The authors speak of ES delivery when ES demand overlaps spatially and temporally with supply.

The methodology for the development of the indicator, in principle, is quite straightforward (see Figure 1). Reviews on agricultural practices in Europe are scanned for evidence of the consequences of these practices for different ES. A large Excel table is used to collect and assemble very different types of data. During the Rapid Evidence Assessment (REA), both quantitative and qualitative information on environmental consequences is collected in this Excel table, together with an evaluation of the scientific papers' quality. This quality assessment is later used to introduce a weighting that accounts for a (supposedly) unequal reliability of available evidence. Since this table handles a large amount of information by combining different classification systems and standards (see further) we will call it "the cruncher". The cruncher is used to produce an overview of the potential supply of ES for each agricultural practice.

To assess the environmental performance of a certain practice in a specific locality, the regional demand for ES also needs to be assessed. A second table is used to attribute context-specific weights to the different ES. In this table, which we will call "the validator", stakeholders[10] are requested to prioritize ES for their case study areas. The region-specific environmental performance that is thus produced evaluates agricultural practices against their capacity to deliver ES which are in high demand locally. The combination of the cruncher and the validator produces the region-specific indicator of environmental performance.

[10] Participatory and multi-actor approaches are extremely valued by the evaluators of H2020 projects, "so if [stakeholder workshops are] not in there, you cannot pass" (Researcher 2). The research project therefore had detailed guidelines on the timing of workshops (yearly), the type of stakeholders that should be invited and the way workshops should be organized. While the disciplinary work of those guidelines and their inconsistencies in practice are very interesting, they are not relevant for our argument so we will not further elaborate them here.

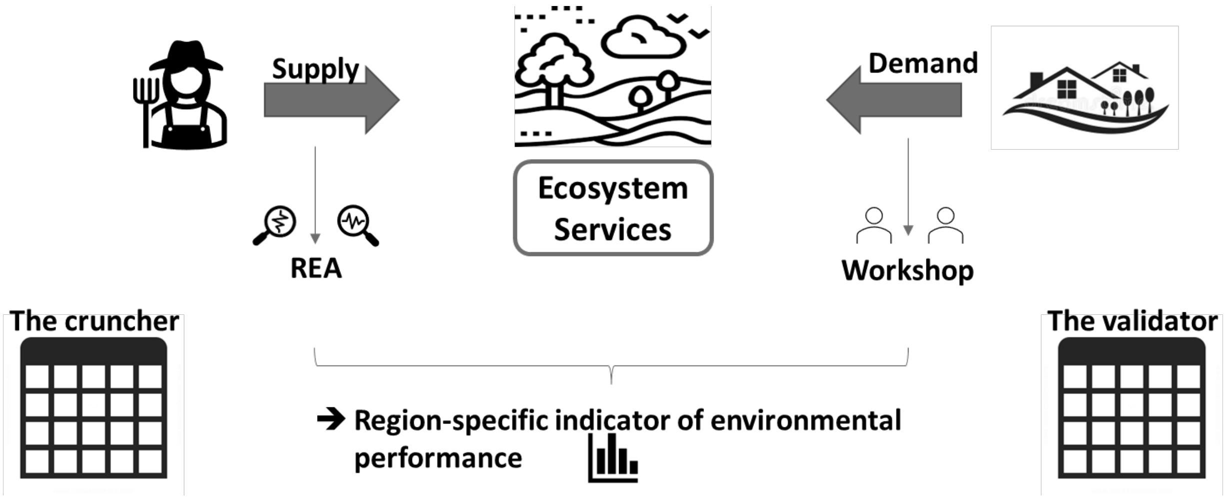

Figure 1: Schematic representation of the conceptual framework and work for the development of the indicator. The indicator is the outcome of the combined work of two tables, the cruncher which assembles the supply of ES through a Rapid Evidence Assessment (REA) of existing literature in environmental sciences, and the validator which constructs local demand through stakeholder workshops.

Unpacking the cruncher

The cruncher is used to conduct the REA. It combines at least three classificatory systems into two different sections (Figure 2). The first section is about the semiotic content of the reviews, *i.e.* what the reviews say about agricultural practices and their environmental consequences. The second section treats the reviews more as containers of information and evaluates the quality of these information carriers.

The first section of the cruncher draws on two classification systems: a typology of farming systems, constructed in a preceding work package of the H2020 project (Doc 2, deliverable D1.1), and an internationally recognized classification of ES. The former typology classifies farming systems according to their degree of uptake of agroecological practices, ranging from "agroecology" as the most ecological farming system cluster until "conventional, or standard farming, systems" as the least ecological system. While this typology "should not be considered as a rigid taxonomy" (Doc 3, deliverable D1.3) since "the relative ecological value of a practice compared with alternative practices is not straightforward to establish", it is used as the guiding document for classifying different agricultural practices into general categories. The Common International Classification of ES (CICES 2018) from the European Environmental Agency is subsequently used as a guiding document to classify different environmental consequences into the appropriate ES[11]. 17 ES are considered (CICES 2018). Space is foreseen in the table for both qualitative and quantitative evidence, as well as for comments and excerpts of the reviews in case the reviewers would feel the need to add context and nuance.

[11] In the grant agreement (Doc 5), the terms "public good" and "ES" are systematically used together. Researcher 2 explains that "the reason we actually use both terms is to satisfy researchers from different fields. I mean, ES emerged in ecology. Public goods is more from economic studies. But there's a large overlap between the two concepts." In practice, the concept of public good has been dropped relatively early in the process and it is around the concept of ES that research efforts have been directed. According to Researcher 3 "that is probably because ES encompasses both Public and Private Goods, and is therefore more general than Public Goods".

The second section of the cruncher consists of a list of 27 questions, in the form of checkboxes, to evaluate each of the reviews included in the REA. REA are conditioned by a set of criteria which define how to do a literature review. The gold standard is set by Cochrane reviews in medical sciences. This 'Cochrane' standard proposes an extremely protocolized, nearly mechanized, process to identify scientific evidence in literature (Cochrane 2022). Criteria are so rigorous because "in medicine systematic reviews save lives" (Researcher 3). While reviews in environmental sciences are generally less protocolized, we drew on Cochrane standards as a guideline for our own REA and as a way to evaluate the quality of the reviews under study. "Quality assessment is part of the procedure, the same way the abstract screening and full text screening and data extraction are" (Researcher 3). It is based on the premise that not all review papers are of the same quality. An assessment of confidence is therefore needed when conducting a REA. The quality criteria comprise checkboxes such as "all databases used in the search are listed", "the study includes the final reference list of excluded individual studies", "information on the effect sizes of each individual study is provided" and "sources of funding for the review are described" (Doc 4, Excel table). Together these questions, on the information carrier rather than its content, have been used to attribute a score to each of the linkages in the Excel table, based on the thus derived quality of its information source.

The cruncher is used to extract information from the reviews, reclassify this information in the form of linkages between a given set of agricultural practices and ES, and subsequently evaluate the strength of these linkages by looking at the number of observations, i.e. instances of a practice-ES linkage found in each review, and the quality of the papers they are derived from. A single score is constructed by counting the number of observations weighted for their quality[12]. The score supposedly indicates the strength of a linkage: it is a measure for the amount of certainty in scientific literature on the correlation between an agricultural practice and the provision of an ES. Most of the researchers in our study, except for the first author of current STS study who has some doubts, therefore consider this score to be useful for the governance of both research and agriculture: either there is scientific evidence of the benefits of a certain practice, and we can tell policymakers to subsidize it, or there is no scientific evidence and policy should stimulate further research. True, admits Researcher 2 in a discussion on this subject, "it would be short-sighted to say that there is no link if we do not find a link, but on the other hand, [if we do not find evidence] there is in fact no link on which to base policy". Note that this quite explicitly reflects the famous observation of Latour, that "nature" as we know it is only as strong as the scientific networks that are making it (Latour 1993b).

[12] The aggregation method stimulated some hesitation and discussion. Should we use a weighted average of the scores, i.e. an additive aggregation, or rather a geometric aggregation in order to give a lower weight to outliers? In other words, to what extent is consensus valued in scientific research? Regardless of these questions, in the end a weighted vote counting produced a single score for each practice-ES linkage. To maximize transparency, additional numbers were included in the final report so as to clarify whether a certain score would be derived from the large/low number of observations, or the high/low quality of the reviews contributing to this linkage.

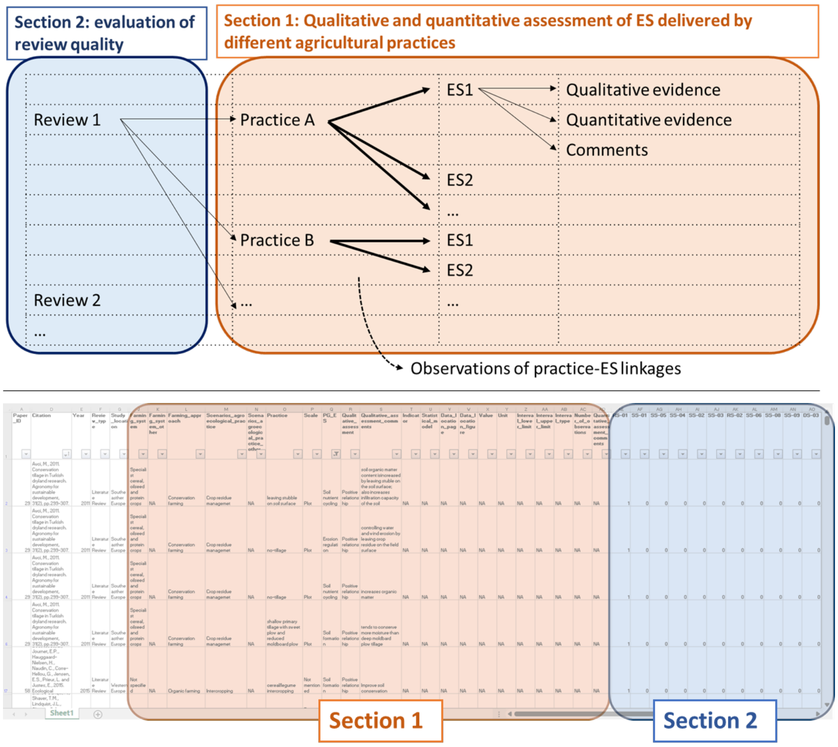

Figure 2: The cruncher, a table-concept ensemble that combines three classificatory systems to extract information from reviews, reclassify it in the form of practice-ES linkages and produces a score for each of these linkages. The score is an indicator of the strength of the available evidence on a certain practice-ES linkage. The three classification systems are (1) the list of agricultural practices, (2) ES and (3) the list of criteria to evaluate review quality. The upper part of the Figure is a schematic representation, while the lower part is a screenshot of a part of the table in Excel.

The validator

The cruncher, as we will see in the next sections, produces numbers which are fully detached and decontextualized. Except for the fact that data sources are limited to the European continent, the practice-ES linkages that are produced by the cruncher are free of all considerations regarding regional variations in climate, economy, or sociocultural context, as well as local variations in ecology, soil type, slope and other features of the biophysical environment. The second table-concept, the validator, is therefore used to recontextualize those data.

Three workshops with stakeholders are organized in three different regions (one in Belgium and two in the United Kingdom) in order to evaluate the local demand for ES. According to the perspective adopted in the research, agriculture has the potential to supply a bunch of ES, but their delivery depends on local demand. Stakeholders in the different regions are therefore invited to attribute scores to the different ES in order to measure their local importance. If such workshops would be organized in the whole of Europe, the argument goes, these tables of scored ES could be used to develop a region-specific indicator of potential environmental performance of agricultural practices.

The attribution of these scores is, however, not an easy process. The stakeholders in the workshops are farmers, farmer representatives or members of local interest groups and administration working on environmental and agricultural issues. They thus have experience with practice. Some stakeholders initially resist the process, arguing that it is all very theoretical, "far from truth", and that it is a "narrow-minded focus" that "misses out on many gradations" (Doc 6 transcript of third stakeholder workshop, 2021). Others question whether it is actually up to farmers to become provisioners of ES. After nevertheless reaching a consensus on the scores, doubts are also raised regarding the validity of these results. As put by one participant: "if I would do this again tomorrow, would I get the same results?"; and "I don't think [others] would get to the same results" (Doc 6). Detailed and practical concerns are the source of additional conceptual difficulties. Mulching (an agricultural practice consisting of covering the soil after harvest), as argued by one stakeholder, may be good for soil and biodiversity, but when it rains you can get a fusarium (a fungus) infection, which constitutes a risk. Besides this probabilistic and temporal dimension, some participants complain that the framework does not sufficiently take into account spatial issues and matters of scale: you need, for example, sufficient small landscape elements in a certain region to host a population of specific farmland birds, but the ES-table does not take this into account (Doc 6).

All these complaints have been carefully noted in the workshops' minutes. A report of one of the workshop concludes that "it was agreed upon that the delivery of certain ES from ecological farming practices will only be realized if set in favorable conditions" (Doc 7, 2021). But what to make of these resistances? Will they help us understand what the ES-table is about? As the following sections illustrate, many of the issues raised by the stakeholders are difficulties we struggled with ourselves and addressed through successive steps of translation. While these successive translations remain reversible, in theory at least, the outcome might nevertheless be far from the environmental sciences on which it originally builds. To understand the world that comes with the ES table-concept it is necessary to further dive into the practical work of the cruncher and the validator which we have introduced here.

Some difficulties in practice

The reviews considered in the REA are mostly situated in environmental sciences or agronomy. They refer to typical ecological and agronomic issues without making explicit reference to ES. The following sections highlight the difficulties faced in transcribing information contained in the reviews into the rigid framework proposed by the cruncher. It takes time to get rid of the disciplinary work of concepts in environmental sciences and agronomy and adopt the new framework proposed by ES.

Dropping context and nuance

To measure the ES delivered by certain agroecological practices, the 11 researchers who conduct the review of reviews have to identify the practices' environmental consequences. This leads to several difficulties. First, in order to identify consequences one needs an action and a baseline. While the baseline is taken to be the conventional counter-practice, it is not always clear in the reviews what this actually means. No-till farming can be compared to different practices involving tillage, for example, and biological pest control can be compared with the total absence of pest control or with a variety of chemical and mechanical interventions. In some way, the typology of farming systems that used in the cruncher is too coarse. Detailed practices studied in the review papers have to be categorized into broader groups of agricultural practices. For example, a detailed review on careful timing of autumn and spring grazing (Jefferson 2005) is thus categorized as "sustainable grazing", together with a study on the consequences of legume-based livestock systems (Rochon et al. 2004) and pig grazing in crop rotation (Webb et al. 2014).

Second, among all the detailed information provided in the review papers, it is necessary to identify which information about the environment is relevant. This often implied getting rid of much of the context and nuance. Regional and climatic information are systematically dropped. Technical details, warnings or conditionalities are also dropped, or when these warnings are too strong, results are labelled as "inconclusive". An observation such as "planting pasture grasses in area with Johnson grass infestation is most effective when grass is mowed combined with shallow tillage to bring the rhizomes to the surface to dry out during summer" (Travlos et al. 2019) thus leads to an observation that low input farming increases pest control. Whenever possible, nuances are conserved by extracting several observations from a single research paper. For example, the observation in Albrecht et al. (2016) that "uncultivated permanent set aside [land] tended to be associated with an initial increase in species diversity, followed by a decline" is interpreted as an inconclusive relation between agri-environmental schemes and biodiversity, while the observation in the same review that "wild flower strips provide habitat for agricultural fauna, but currently have little benefit to the rare arable flora as long as they do not target specific rare species in their mix" is interpreted as a positive relation between agri-environmental schemes and biodiversity.

The problems with the review papers is that those texts are not written with the REA in mind. This causes a third type of difficulties, because consequences, when identified, have to be classified into the appropriate ES. For example, when several chemical components are reported separately, such as levels of soil organic carbon, total nitrogen content, nitrogen use efficiency and microbial biomass, should they be classified as different observations of the same ES, or are they on the contrary, different proxies for different ES, such as "soil nutrient cycling", "freshwater purification" or even "carbon sequestration"? Should a study, such as Plexida et al. (2018), on the correlation between agrosilvopastoral systems and seven different taxonomic group be understood as one observation of a link between agroforestry and "biodiversity", or should the presence of some insects be linked to "pollination" instead?

Of course, these difficulties have not gone unnoticed. As Researcher 3 puts it, "it's all based on language and interpretation", and researchers' expert judgement is crucial in this process. To smoothen the process, extensive space is therefore foreseen in the Excel table to add comments and nuance. This proves useful in many cases: "Sometimes [when it got too hard] I ended up, like, copying the whole paragraph, putting it in the Excel file, just so if anyone wanted to double check how I'd read it, they had, like, the original thing without having to go into the paper" (Researcher 3). Extensive discussions during different meetings and the production of several documents with clear guidelines ultimately leads to a relatively neat table, with one line for each observed linkage between an agricultural practice and an ES. In this process, a lot of trust is put in the expert judgement of the various researchers involved. Both quantitative and qualitative assessments of the linkages are allowed, and extensive space is left for comments and reflections of the reviewers.

Aggregating numbers

A fourth difficulty relates to the units of the observations. The quantitative numbers in the reviews are expressed in all sorts of units. Other observations are expressed as a relative position (higher/lower) in comparison with a baseline. To be useful for the construction of an indicator this heterogenous set of qualitative and quantitative descriptions of consequences have to be transformed into a coherent table expressed in one and the same unit. After some deliberation, a measure with three categories is chosen: positive (+1), negative (-1), and no/inconclusive effect (0). This entails three important consequences: first, for each of the identified effects a value choice has to be made. This is straightforward in some cases: when a practice is associated with a higher soil stabilization, this counts as a positive effect on "erosion regulation". In some cases it is more complicated: should a positive correlation between a practice and the number of small mammals, including rodents, be treated as a negative consequence for "pest and disease control"? Second, while reducing the observations to simple numbers, data are stripped of all the remaining information, doubts and resistances which reviewers have been expressing in the comment section of the Excel table. Remaining information about context, or about conditionalities and correlation strength, as well as information allowing to make a distinction between the absence of an effect and doubts concerning its presence, all of this information is dropped. Third, the choice for three simple categories leads to the loss of a lot of quantitative information. For us, the researchers, this choice to drop a large amount of quantitative, biophysical data, is experienced as a sacrifice, as a concession to the requirement of some ES, such as the cultural ones, which cannot (yet) be expressed in quantitative units.

It is hard to overstate the importance that is attributed to a number. In several discussions and interviews the lack of quantitative indicators for some ES comes up as one of the main challenges. Numbers are easier to manipulate and aggregate into a single indicator. Numbers are also "a means to communicate a very complex message in a simple way" (Researcher 2). They are important because "policy makers think in numbers" (Researcher 2). Luckily, while dropping a large quantity of biophysical units, the cruncher manages to generate new numbers. It produces a list of linkages between agricultural practices and ES, each time with a simple assessment of this relation, a positive impact, negative impact, or no/inconclusive impact. Many of the practice-ES linkages are observed in several instances, since they can be observed in different reviews, or for different countries, or for different agricultural practices or environmental consequences, all aggregating into a same category of agricultural practice or ES. For each practice-ES linkage a single score is thus obtained by aggregating each of the observations of a linkage (positive, negative or inconclusive) after attributing a weighting factor to this observation in order to reflect the quality of the review from which it is derived.

A set of decontextualized numbers indicating the strength of a practice-ES linkages in scientific literature about European agriculture is thus obtained. As we have seen, this set of decontextualized numbers is strongly backed by a set of conceptual frameworks which have crystalized in the cruncher. It is additionally supported by the transparency and proceduralism which is demanded in H2020 project. While often perceived as a burden, the multiple bureaucratic procedures demanded by the grant agreement have allowed us to streamline collaborations across universities and disciplines and synthesize existing knowledge in Europe. Transparency and proceduralism are important to strengthen claims of validity and to stimulate a meaningful academic discussions about these numbers, since otherwise others "may be critical about some of these outputs" (Researcher 4). Or, as explained by Researcher 1, the clear guidelines assured that everyone was working in the same direction and extracted the same kind of information.

Yet, the score linking practices to ES nevertheless remains something particular: a detached number. All the cruncher does is to reframe and purify data obtained from review papers. Actually, a great deal of purification, from the dirty, complex and unpredictable dynamics on the agricultural fields to synthetic scientific evidence on environmental consequences, has already been realized before the REA. What the cruncher does merely results in a translation of existing scientific evidence into a set of practice-ES linkages. The second table-concept, the validator, recontextualizes the numbers. This is what makes the construction of an indicator possible. Together the two table-concepts, cruncher and validator, are generating a linkage between potential ES supply and local demand.

Changing concerns

While the validator is a very simple table at first sight, actually just a list of ES, it has been taking a great deal of thinking and discussion for the researchers to work it out. Just like abovementioned stakeholders did not easily accept the scoring exercise that was proposed with the validator, so have we, the researchers, initially been resisting it. The difficulties associated with the validator stem from the reasoning it puts forward, in terms of potential supply and demand, at the expense of concepts and associated concerns which are common in environmental science and agronomy.

Struggling with supply and demand

Self-evident as the fact that you have "the delivery of an ES when there is an overlap between supply and demand" (Doc 1, 2021) may now seem, quite some challenges are associated with this simple statement. Can we speak of a service when there is actually no explicit demand? As put by Researcher 3: "It's not like people can demand natural pest regulation if they don't know it. [Only once it fails, they realize] that it had been an important regulatory service provided by the system". Likewise, soil mulching has the potential to provide the ES of erosion prevention, but does not necessarily provide this service in flat environments[13]. Demand is thus partly driven by the environment, such as a steep slope demanding erosion prevention, as well as by local users benefiting from these effects. When local stakeholders are asked to identify this demand, we are in a situation of hypothetical demand, as if there would be a market for ES, but in the absence of anything resembling a market exchange. Or, as reformulated by Researcher 3, "the demand is very real. It's the market that is hypothetical". This does not mean that there *should* be a market for ES, but rather that a choice is made to think along

[13] While this example came up during a recorded conversation, it is actually not exactly true: mulching may provide erosion prevention, such as splash erosion, in flat environments (Findeling, Ruy, and Scopel 2003).

markets. We came to speak of agricultural practices *supplying potential* ES, while their *actual delivery* depends on how stakeholders assess local needs and thus identify potential demand.

While this reasoning in terms of supply and demand has been present in the H2020 project from the start[14], it has only come to dominate the conceptual framework of the indicator quite late in the process. "The more in-depth thinking about the distinction between supply and demand is something that we worked on in course of the project" (Researcher 2). Other researchers express a similar point. After reading a first draft of the manuscript that describes the REA and indicator of environmental performance, Researcher 5 stresses that "I did not have at all in mind what it was going to be".

Fading away of other concepts

Many other concepts, from both economics and environmental sciences, are referred to in the grant agreement and earlier deliverables, including public goods, trade-offs and synergies, externalities, scale and threshold effects, etc. With time many of these concepts and associated concerns have been marginalized or put aside.

In the original grant proposal, for example, trade-offs and synergies are central, associated with the idea of public goods. They grasp the intuition that choices regarding the attribution of agricultural subsidies have to be made in conditions of limited resources. The concepts of trade-off and synergy are particular because they are used in both environmental sciences and economics. Indeed, some agricultural practices and environmental benefits often go hand in hand, mutually reinforcing each other, while others are harder to combine. Hedgerows and flower strips can have mutually reinforcing effects on biodiversity and pollination, while it may be harder to combine soil nutrition and smell reduction when using organic fertilizer. While these kinds of synergies and tradeoffs are interpreted in a way which is different from the rational decision making the concepts imply in economics, they are close enough to make interdisciplinary dialogue possible.

A similar convergence is observed between agronomic concepts such as spill-over effects and territorial effects on the one hand and the economic concept of externality on the other. In the project documents these concepts are sometimes used interchangeably. They reflect the fact that many environmental dynamics are not confined to a plot level, but spill over to neighboring fields and their owners. A water harvesting ditch on one plot, for example, will likely be beneficial to all plots that are located downslope.

The problem with these concepts is that they often give rise to concerns that are more common in environmental sciences. Concerns regarding scale and threshold effects, for

[14] The grant agreement, for example, mentions that "First the task will investigate the environmental impact of ecological agriculture at case study level using a systematic analysis of existing literature on the provision of [Public Goods and Ecosystem Services (PG & ES)] by farms depending on the degree of their uptake of ecological approaches. […] Finally a quantitative monetary assessment of territorial PG & ES will be carried out to assess the demand (and thus value of) for PG & ES at territorial level". Another tasks may involve the "mapping of demand and supply of ES and ES bundles based on e.g. vegetation maps, land cover maps, socio-economic data" (Doc 5).

example: how to account for the fact that species need a certain amount of a certain habitat to survive in the long run[15]? Several meetings in the two first years of the project were entirely devoted to the challenge of incorporating scale and threshold effects in the indicator. At the end of the project little remains of those concerns. Likewise, concerns regarding multispecies dynamics (e.g. if there is a synergy between "cover crops" providing nectar in early spring to a specific type of solitary bee which also happens to be an important food to a bird species nesting in nearby small landscape elements) and seasonality (do we need to take into account the fact that toad crossings are only relevant in spring?) have faded away in the course of the project.

The point here is not merely that we are facing a simplification. Simplification and loss of nuance is an inherent aspect of constructing synthetic indicators (Lehtonen, Sébastien, and Bauler 2016). What we are experiencing is the fading away of certain concepts at the expense of others[16]. This fading away did not happen over one night, but through an iterative process, including writing down ideas and concerns, discussing them during meetings, re-diving into literature, re-discussing, taking decisions and accepting to let go previously important concepts.

Warnings-to-be-ignored

The move from environmental sciences to more economic concepts such as supply and demand has not been easy. To ease doubts along the way, two strategies are adopted: transparency and smoothening. As put by researcher 4 when talking about his concerns with the dataset, "being very transparent about the assumptions we make and also about the potential weaknesses that are involved with the approach is enough from my point of view to provide this information". This is combined with a continuous process of smoothening, leveling out the differences in order to make the transformation possible. For example, space is initially left in the Excel table to add nuance and vehiculate doubts. We have also regularly put up warnings: that it is just a framework and that one should not be "cherry picking" in the final results (Researcher 2). As researcher 3 signals: "the good thing is that […] someone could run [the analysis] with proper data from a proper database".

While everyone is genuinely convinced of the importance of these warnings and nuances, they are subsequently ignored for practical purposes: the abovementioned farm typology is used as a fixed taxonomy and the comments in the Excel table are not used in the subsequent stages. Rather than being an irregularity, we would like to argue that this pattern of warnings-to-be-ignored serves a specific purpose and is therefore a fundamental constituent of this kind of work: it is a way to smoothen a transformation which would otherwise not be possible. In

[15] These concerns were already present in the grant agreement, e.g. "[…] certain minimum size is needed before environmental benefits are realized" (Doc 5), and frequently came up during meetings.
[16] As noted by researcher 3 while reviewing a preliminary version of current paper, there are several other explanations for the lack of concern for threshold effects in the final output of the project: "thresholds and tipping points are very accepted concepts in systems ecology that very rarely pan out in empirical data", so that "the data coming from our very limited rapid review could not really feed into this."

the words of Researcher 6, during a discussion of the preliminary results of current STS analysis, this transformation is just a small step in a move "from idealism to pragmatism". Notable for this transformation is the shift in concerns. While being less concerned by "detailed" concepts from environmental sciences, Researcher 2 has "gained a much deeper understanding of ES" and learned "to make a choice between many details [about context and biophysical aspects] and pragmatic decisions" (Researcher 2). This "deeper understanding" has led Researcher 2 to attribute a great importance to the concept of *potential* supply and demand of ES, rather than just supply and demand, since this grasps the fact that ES delivery only happens when these potential supply and demand coincide spatially and temporally.

Purification, aggregation and re-complexification

We are witnessing the attempt to create a new object: the ES indicator. This ES indicator could theoretically become a black box with one output, an overview of best performing agricultural practices, and two inputs. While the 'inputs' seem typical of environmental sciences and agronomy, i.e. agricultural practices and environmental conditions, they enter the black box in a language of supply and demand stripped from many concerns of environmental sciences. A de-contextualization and re-contextualization has happened (Figure 3).

The de-contextualization happens through the formation of a database, the Excel file, from which information about local conditions, specific nuances, conditionalities,… are slowly stripped. The inscription of observations from environmental sciences into categories of ES also requires adjustments, slight reinterpretations and transformations of the data . Note that it is not the environment, with plants, animals and ecologies, which is gotten rid of here, but concepts from environmental sciences, ecology and agronomy. As such, the reviews included in the REA, with synthesized and purified environmental knowledge, had already done a great deal of the de-contextualizing work. The more advanced this purification and the closer their concepts are to the ones we use, the easier our work. As researcher 2 highlights: "it has been easier for reviews which were already talking in terms of ES".

The re-introduction of nuance and subsequent re-contextualization happens in two moments: first, the aggregation and quality weighting produce quantitative averages and measures of variability, thereby providing information about the data-generating process and increasing transparency. Second, the workshop with stakeholders firmly recontextualizes the data in a specific region and in a narrative of supply and demand.

What happens here is not merely a re-combination of heterogenous data into an indicator composed of ES, nor is it merely the translation of data from one framework to another. A real transformation has happened: the data that are generated at the end of the workshop have little to do with the ones they are derived from. In this process, our interdisciplinary background has been both a challenge and an opportunity. A challenge because our sensitivity to the concepts of environmental sciences entailed the permanent risk of being trapped by resistances to further decontextualization. An advantage, on the other hand, because the credibility of the indicator rests on the linkage it manages to maintain with the environmental sciences. The Excel file with the original papers, added as supplementary material to the preliminary draft of a scientific paper (Doc 1, 2021) and the academic profile of the researchers involved in the transformation ensure that a connection with environmental sciences is maintained. This bond is essential for the legitimacy of the indicator as a tool to evaluate environmental performance of agricultural practices.

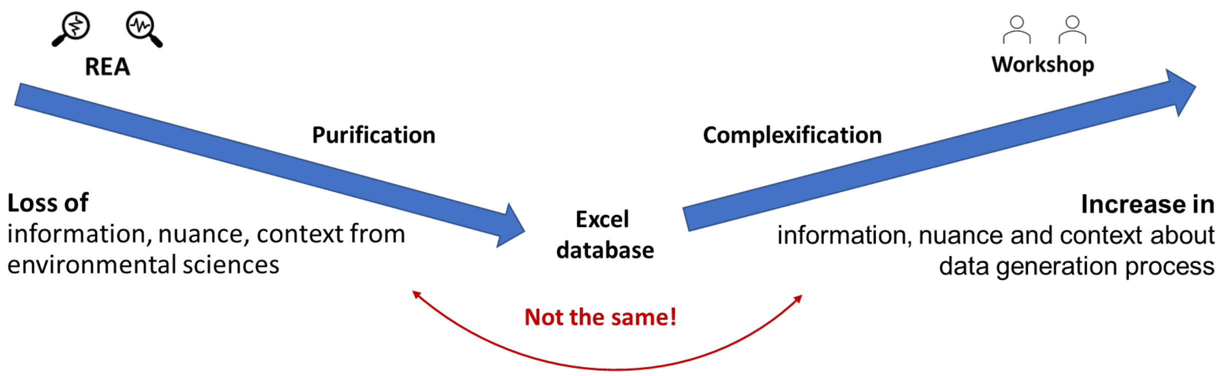

Figure 3: Overview of de-contextualization and re-contextualization process. While the quantitative data produced in the indicator contain a lot of information, are attached to local territories in Belgium and the UK and produce numbers which are nuanced by measure of variance and supplementary information, it is important to realize that much of this rich information is totally different from the information, nuance and context provided in the original review papers. A purification and re-complexification have happened.

But what are ES? Trans-formation and hybridization

Can we conclude? Not yet. The following paragraphs attempt to provide an answer to the question as to what ES actually are. Based on the interviews conducted for this STS study, ES are "a reframing more than anything else" (Researcher 3). They are used "to provide sound policy advice" in order to provide "a scientific background on what [agricultural practices] to support or not" (Researcher 2). They also allow to make accessible and useful all the knowledge that is already there. As put by Researcher 3: "we probably have all of the environmental evidence or most of what we need, but we just haven't bothered synthesizing it in". In the end, ES have the potential to "make people aware of how valuable nature is" (Researcher 1). While people who have a spiritual connection with nature "won't be served by the ES concept" (Researcher 1), most people, "including myself […], have distanced ourselves from nature in such a degree that we kind of take for granted what it provides for us" (Researcher 1). In that sense, "our work is valuable in that […] it positions humans and nature as more closely intertwined" (Researcher 1). ES would thus be "a way to send the message, or to communicate with a certain group of people that otherwise might not receive the message in a different way" (Researcher 1).

In previous paragraphs we have shown that the concept of ES is not merely a rhetorical device. Understood as a table-concept we have seen how it provides the means to purify information from environmental sciences, detach data from the context in which they have been generated and subsequently recontextualize numbers with new information and nuance. The ES table-concepts are thus transformative. Besides, they also act as coordination devices, boundary objects (Star and Griesemer 1989) that travel across disciplines and space within the H2020 project. The ES table-concepts moreover commensurate (Espeland and Stevens 1998), since they render information from very different origins comparable. By bringing in concerns which are more attuned to economics, in particular that of matching potential supply and potential demand in order to obtain the optimal delivery of services, ES may contribute to bringing the environment under the jurisdiction of economics (Hirschman and Popp Berman 2014). In this sense ES thus economize environmental sciences. But what do they do to economics? To provide an answer to this question we need to once again dive into the ES table-concepts. This time we will follow just one ES, soil formation, across the two table-concepts.

In the cruncher, soil formation is linked to agricultural practices. It appears to be improved by practices such as mulching, crop rotation and intercropping, while tillage and soil compaction with machinery tend to reduce it. The environmental consequences, which are extracted from the reviewed reviews and become "soil formation" in the cruncher, are composed of all sorts of variables, including several attributes of soil structure (such as different measures of aggregate stability, porosity, bulk density and water infiltration rate), chemical composition (including the percentage of soil organic matter, pH and the availability of various forms of nitrogen, carbon, phosphorous and kalium), microbial and fungal biomass and soil depth. These different attributes have different temporalities since, for example, aggregate stability can improve after a few years of no till agriculture, while some attributes of soil compaction can remain unchanged for more than 10 years (Blanco-Canqui et al. 2015). The attributes (and their temporalities) moreover vary with climate, topography and soil type. Dynamic effects between different practices are also to be expected. Finally, since there are some overlaps between the attributes of "soil formation" and those associated with "nutrient cycling", "water regulation" and "carbon sequestration", soil formation can be linked to a certain agricultural practice alongside with other ES.

In the validator, soil formation is none of all these variables and considerations. It has been purified of all abovementioned concerns and is now one of the 17 ES supplied by different agricultural practices. Demand for soil formation depends on region-specific assessments during stakeholder workshops. Its relation to other ES can be one of correlation, complementarity or substitutability. For the case of "erosion prevention" the relation with "soil formation" is even all of those at once: the need for soil formation is largest in areas with eroded soils, so that the presence of demands for both services are strongly correlated, while many erosion prevention measures equally enhance soil formation, leading to complementarity, and the presence of adequate erosion prevention may lead to a reduced need for additional soil formation. Demands for soil formation depend on the past usage of the soil, i.e. whether it has been degraded or not, as well as current practices (arable crops may have different requirements than cattle farming) and climatic and topographic conditions. If the framework is to be used for policy making, the idea is that agricultural subsidies should be targeted at those practices which deliver the services which are most demanded. To some extent soil formation thus competes with other ES, since its region-specific importance is compared with the demand for other ES.

In order to exist as something else than a concept, ES need both table-concepts: the cruncher maintains a selected number of elements from environmental sciences, while the validator structures things in terms of supply and demand. The indicator of environmental performance brings these two table-concepts together. Notice how, for soil formation at least, demand is frequently expressed in terms of the environment itself, as well as human practices. In the anthropogenic nature that is studied in our research, i.e. a nature shaped by agricultural practices, the needs or demands for ES are not understood in purely human terms: it is the steep slope that is in need for erosion prevention and the degraded soil that necessitates soil formation. Of course, this is driven by the presence of human activities on these soils. Yet, at the discursive level at least, we are in a situation which is different from the usual economic understanding of demand, since it is not driven by solely human consumers of goods and services, but also by non-human elements such as topography. In this vein, the stakeholders in our workshops could be understood as human representatives of region-specific human and non-human needs for ES.

The argument is that the ES table-concepts, applied in a context of strongly anthropogenic environments and in the absence of markets, might thus be contributing to an understanding of demand which is less anthropocentric than what we may usually expect in economics. While the environment has always been a source of supply to the economy and is sometimes understood as a boundary or a limit to it, to our knowledge it has not frequently been understood *as a source of demands* to the economy. Yet in our research we could envision maps of demand for the ES "soil formation" in agriculture based on environmental factors such as topography and precipitation alone. This can be explained in two different ways: an hybridization of economics by concepts from environmental sciences is happening, or a metaphor from economics, supply and demand, is being used in a discipline which has actually little to do with economics. In both cases, the economization of environmental science by the ES table-concepts is only partial and incomplete. In both cases, also, a new type of agency is attributed to the environment, which has become a source of demands for ES, in addition to its usual function as a source of supply.

Conclusion

Drawing on laboratory studies in Science and Technology Studies (STS), this paper attends to the transformative work of tables of Ecosystem Services (ES) before they leave the research lab. By following our own work as environmental economists in constructing an indicator of environmental performance we introduce the self-reflexivity that is demanded by Bowker and Star (1999) in the development and use of classification systems. Our work thus contributes to preventing the blackboxing and invisibilization that may accompany the operationalization of ES.

Introducing table-concepts as the practical material-semiotic expression of the ES concept, we show how the operationalization of ES necessitates a purification of data from their initial context and concerns in environmental sciences and subsequently a recontextualization of these data into a new conceptual and sociophysical environment. By showing how we have faced resistance to these processes, from ourselves as well as the concepts from environmental sciences and the people involved in stakeholder workshops, we illustrate the constructed nature of ES. Warnings-to-be-ignored and insistence on transparency are used to smoothen out resistances and make the transformation process possible. We also show that in this process some concepts and concerns typical from environmental sciences are lost and replaced by concepts, supply and demand, that are more frequently associated with economics.

Towards the end of the article we insist on the nature of ES. We show that the operationalization of the concept necessitates to maintain ties to environmental sciences and to construct supply and demand. Both these ties and the demand are constructed in very specific ways, proper to ES and unconventional to environmental sciences as well as economics: a specific representation of the environment seems to become an actor in the definition of demand. While further research on this topic is needed, our study might thus be enacting ES as a way to endow the environment with a new form of agency in reasonings that draw on the concept of supply and demand.

References

Abdelghafour, Nassima. 2022. "Produire Des Données Au Village. Le Cas d'une Expérimentation Contrôlée Randomisée En Afrique de l'Est." *Sociologie Du Travail* 64(3). doi: 10.4000/sdt.41465.

Åkerman *, Maria. 2005. "What Does 'Natural Capital' Do? The Role of Metaphor in Economic Understanding of the Environment." *Environmental Education Research* 11(1):37–52. doi: 10.1080/1350462042000328730.

Albrecht, H., J. Cambecèdes, M. Lang, and M. Wagner. 2016. "Management Options for the Conservation of Rare Arable Plants in Europe." *Botany Letters* 163(4):389–415. doi: 10.1080/23818107.2016.1237886.

Asdal, Kristin, and Béatrice Cointe. 2022. "Writing Good Economics: How Texts 'on the Move' Perform the Lab and Discipline of Experimental Economics." *Social Studies of Science* 52(3):376–98. doi: 10.1177/03063127221079600.

Asdal, Kristin, and Tone Huse. 2023. *Nature Made Economy - Cod, Capital and the Great Transformation of the Ocean*. London: The MIT Press.

Berndt, Christian. 2015. "Behavioural Economics, Experimentalism and the Marketization of Development." *Economy and Society* 44(4):567–91. doi: 10.1080/03085147.2015.1043794.

Blanco-Canqui, Humberto, Tim M. Shaver, John L. Lindquist, Charles A. Shapiro, Roger W. Elmore, Charles A. Francis, and Gary W. Hergert. 2015. "Cover Crops and Ecosystem Services: Insights from Studies in Temperate Soils." *Agronomy Journal* 107(6):2449–74. doi: 10.2134/agronj15.0086.

Bowker, Geoffrey C., and Susan Leigh Star. 1999. *Sorting Things out: Classification and Its Consequences*. Cambridge MA: MIT press.

Breslau, Daniel, and Yuval Yonay. 1999. "Beyond Metaphor: Mathematical Models in Economics as Empirical Research." *Science in Context* 12(2):317–32. doi: 10.1017/s0269889700003446.

Çalişkan, Koray, and Michel Callon. 2010. "Economization, Part 2: A Research Programme for the Study of Markets." *Economy and Society* 39(1):1–32. doi: 10.1080/03085140903424519.

Chaudhary, Sunita, Andrew McGregor, Donna Houston, and Nakul Chettri. 2015. "The Evolution of Ecosystem Services: A Time Series and Discourse-Centered Analysis." *Environmental Science and Policy* 54:25–34. doi: 10.1016/j.envsci.2015.04.025.

CICES. 2018. "Revision Highlights." Retrieved (https://cices.eu/revision-highlights/).

Cochrane. 2022. "About Cochrane Reviews | Cochrane Library." Retrieved (https://www.cochranelibrary.com/about/about-cochrane-reviews).

Costanza, Robert, Ralph D'Arge, Rudolf De Groot, Stephen Farber, Monica Grasso, Bruce Hannon, Karin Limburg, Shahid Naeem, Robert V. O'Neill, Jose Paruelo, Robert G. Raskin, Paul Sutton, and Marjan Van Den Belt. 1997. "The Value of the World's Ecosystem Services and Natural Capital." *Nature* 387(6630):253–60. doi: 10.1038/387253a0.

Costanza, Robert, Rudolf de Groot, Leon Braat, Ida Kubiszewski, Lorenzo Fioramonti, Paul Sutton, Steve Farber, and Monica Grasso. 2017. "Twenty Years of Ecosystem Services: How Far Have We Come and How Far Do We Still Need to Go?" *Ecosystem Services* 28:1–16. doi: 10.1016/j.ecoser.2017.09.008.

Doganova, Liliana. 2018. "Discounting and the Making of the Future: On Uncertainty in Forest Management and Drug Development." Pp. 278–97 in *Uncertain Futures: Imaginaries, Narratives, and Calculation in the Economy*, edited by J. Beckert and R. Bronk.

Doganova, Liliana, and Fabian Muniesa. 2015. "Capitalization Devices: Business Models and the Renewal of Markets." Pp. 109–25 in *Making Things Valuable*, edited by M. Kornberger, L. Justesen, J. Mouritsen, and A. K. Madsen. Oxford: OUP.

Ehrenstein, Véra. 2018. "The Friction of the Mundane: On the Problematic Marketization of the Carbon Stored by Trees in the Tropics." *Journal of Cultural Economy* 11(5):404–19. doi: 10.1080/17530350.2018.1461675.

Ehrlich, Paul, and Anne Ehrlich. 1981. *Extinction. The Cause and Consequences of the Disappearance of Species.* New York: Random House.

Espeland, Wendy Nelson, and Mitchell L. Stevens. 1998. "Commensuration as a Social Process." *Annual Review of Sociology* 24:313–43. doi: 10.1146/annurev.soc.24.1.313.

Evenden, Matthew D. 1995. "The Laborers of Nature: Economic Ornithology and the Role of Birds as Agents of Biological Pest Control in North American Agriculture, ca. 1880–1930." *Forest and Conservation History* 39(4):172–83. doi: 10.2307/3983958.

Farley, Joshua, and Kaitlin Kish. 2021. "Ecological Economics: The next 30 Years." *Ecological Economics* 190(August). doi: 10.1016/j.ecolecon.2021.107211.

Findeling, A., S. Ruy, and E. Scopel. 2003. "Modeling the Effects of a Partial Residue Mulch on Runoff Using a Physically Based Approach." *Journal of Hydrology* 275(1–2):49–66. doi: 10.1016/S0022-1694(03)00021-0.

Fletcher, Robert, and Bram Büscher. 2017. "The PES Conceit: Revisiting the Relationship between Payments for Environmental Services and Neoliberal Conservation." *Ecological Economics* 132:224–31. doi: 10.1016/j.ecolecon.2016.11.002.

Fourcade, Marion. 2009. *Economists and Societies: Discipline and Profession in the United States, Britain, and France, 1890s to 1990s*. New Jersey: Princeton University press.

Fourcade, Marion. 2011. "Cents and Sensibility: Economic Valuation and the Nature of 'Nature.'" *American Journal of Sociology* 116(6):1721–77. doi: 10.1086/659640.

Gómez-Baggethun, Erik, Rudolf de Groot, Pedro L. Lomas, and Carlos Montes. 2010. "The History of Ecosystem Services in Economic Theory and Practice: From Early Notions to Markets and Payment Schemes." *Ecological Economics* 69(6):1209–18. doi: 10.1016/j.ecolecon.2009.11.007.

Gómez-Baggethun, Erik, and Manuel Ruiz-Pérez. 2011. "Economic Valuation and the Commodification of Ecosystem Services." *Progress in Physical Geography* 35(5):613–28. doi: 10.1177/0309133311421708.

Greimas, A. J., and J. Courtés. 1982. *Semiotics and Language. An Analytical Dictionary*. Translated. Indiana University Press.

Hacking, Ian. 1992. "Statistical Language, Statistical Truth and Statistical Reason: The Self-Authentification of a Style of Scientific Reasoning." Pp. 130–57 in *The social dimension of Science*, edited by E. McMullin. University of Notre Dame Press.

Hirschman, Daniel, and Elizabeth Popp Berman. 2014. "Do Economists Make Policies? On the Political Effects of Economics." *Socio-Economic Review* 12(4):779–811. doi: 10.1093/ser/mwu017.

Holm, Petter, and Kåre Nolde Nielsen. 2007. "Framing Fish, Making Markets: The Construction of Individual Transferable Quotas (ITQs)." *Sociological Review* 55(SUPPL. 2):173–95. doi: 10.1111/j.1467-954X.2007.00735.x.

Jefferson, R. G. 2005. "The Conservation Management of Upland Hay Meadows in Britain: A Review." *Grass and Forage Science* 60(4):322–31. doi: 10.1111/j.1365-2494.2005.00489.x.

Kronenberg, Jakub. 2014. "What Can the Current Debate on Ecosystem Services Learn from the Past? Lessons from Economic Ornithology." *Geoforum* 55:164–77. doi: 10.1016/j.geoforum.2014.06.011.

Latour, Bruno. 1987. *Science in Action*. Cambridge: Harvard University Press.

Latour, Bruno. 1993a. "Le « pédofil » de Boa Vista – Montage Photo-Philosophique." *Raison Pratique* 4:171–225.

Latour, Bruno. 1993b. *We Have Never Been Modern (Translated by Catherine Porter)*. Cambridge, Massachusetts: Harvard University Press.

Lehtonen, Markku, Léa Sébastien, and Tom Bauler. 2016. "The Multiple Roles of Sustainability Indicators in Informational Governance: Between Intended Use and Unanticipated Influence." *Current Opinion in Environmental Sustainability* 18:1–9. doi: 10.1016/j.cosust.2015.05.009.

MacKenzie, Donald. 2009. "Making Things the Same: Gases, Emission Rights and the Politics of Carbon Markets." *Accounting, Organizations and Society* 34(3–4):440–55. doi: 10.1016/j.aos.2008.02.004.

Masood, Ehsan. 2018. "Battle over Biodiversity." *Nature* 560(7719):423–25.

McCracken, Grant. 1988. *The Long Interview*. SAGE publications.

McElwee, Pamela. 2017. "The Metrics of Making Ecosystem Services." *Environment and Society: Advances in Research* 8(1):96–124. doi: 10.3167/ares.2017.080105.

MEA. 2005. *Millenium Ecosystem Report - Ecosystems and Human Well-Being: Synthesis*. Island Press, Washington DC.

Miller, Peter, and Michael Power. 2013. "Accounting, Organizing, and Economizing: Connecting Accounting Research and Organization Theory." *Academy of Management Annals* 7(1):557–605. doi: 10.5465/19416520.2013.783668.

Missemer, Antoine. 2018. "Natural Capital as an Economic Concept, History and Contemporary Issues." *Ecological Economics* 143:90–96. doi: 10.1016/j.ecolecon.2017.07.011.

Mitchell, Timothy. 2005. "The Work of Economics: How a Discipline Makes Its World." *European Journal of Sociology* 46(2):297–320.

Mitchell, Timothy. 2007. "The Properties of Markets." Pp. 244–75 in *Do economists make markets? On the performativity of economics*.

Perman, Roger, Yue Ma, James McGilvray, and Michael Common. 2003. *Natural Resource and Environmental Economics (Handbook)*. 3rd ed. Pearson.

Pickering, Andrew. 1995. *The Mangle of Practice. Time, Agency and Science*. University of Chicago Press.

Plexida, Sofia, Alexandra Solomou, Kostas Poirazidis, and Athanasios Sfougaris. 2018. "Factors Affecting Biodiversity in Agrosylvopastoral Ecosystems with in the Mediterranean Basin: A Systematic Review." *Journal of Arid Environments* 151(December 2017):125–33. doi: 10.1016/j.jaridenv.2017.11.017.

Potschin, Marion B., and Roy H. Haines-Young. 2011. "Ecosystem Services: Exploring a Geographical Perspective." *Progress in Physical Geography* 35(5):575–94. doi: 10.1177/0309133311423172.

Prescott, Francis J. 2011. "Validating a Long Qualitative Interview Schedule." *Working Papers in Language Pedagogy* 5:16–38.

Robertson, Morgan. 2006. "The Nature That Capital Can See: Science, State, and Market in the Commodification of Ecosystem Services." *Environment and Planning D: Society and Space* 24(3):367–87. doi: 10.1068/d3304.

Robertson, Morgan. 2012. "Measurement and Alienation: Making a World of Ecosystem Services." *Transactions of the Institute of British Geographers* 37(3):386–401. doi: 10.1111/j.1475-5661.2011.00476.x.

Rochon, J. J., C. J. Doyle, J. M. Greef, A. Hopkins, G. Molle, M. Sitzia, D. Scholefield, and C. J. Smith. 2004. "Grazing Legumes in Europe: A Review of Their Status, Management, Benefits, Research Needs and Future Prospects." *Grass and Forage Science* 59(3):197–214. doi: 10.1111/j.1365-2494.2004.00423.x.

Rodriguez, Laura, Vincent Devictor, and Virginie Maris. 2018. "L'articulation Entre Savoirs et Actions Dans Trois Dispositifs Environnementaux : Conservation, Évaluation d'impact et Restauration." *VertigO* (Volume 18 numéro 2). doi: 10.4000/vertigo.20879.

Røpke, Inge. 2004. "The Early History of Modern Ecological Economics." *Ecological Economics* 50(3–4):293–314. doi: 10.1016/j.ecolecon.2004.02.012.

Rose, Gillian. 1997. "Situating Knowledges: Positionality, Reflexivities and Other Tactics." *Progress in Human Geography* 21(3):305–20. doi: 10.1191/030913297673302122.

Schröter, Matthias, Emma H. van der Zanden, Alexander P. E. van Oudenhoven, Roy P. Remme, Hector M. Serna-Chavez, Rudolf S. de Groot, and Paul Opdam. 2014. "Ecosystem Services as a Contested Concept: A Synthesis of Critique and Counter-Arguments." *Conservation Letters* 7(6):514–23. doi: 10.1111/conl.12091.

Shapiro-Garza, Elizabeth, Pamela McElwee, Gert Van Hecken, and Esteve Corbera. 2020. "Beyond Market Logics: Payments for Ecosystem Services as Alternative Development Practices in the Global South." *Development and Change* 51(1):3–25. doi: 10.1111/dech.12546.

Star, Susan Leigh, and James R. Griesemer. 1989. "Institutional Ecology, 'translations' and Boundary Objects Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39." *Social Science Quarterly* 19:387–420.

Travlos, Ilias S., Jose M. Montull, Gabor Kukorelli, Goran Malidza, M. N. Dogan, Nikolina Cheimona, Nikolaos Antonopoulos, Panagiotis J. Kanatas, Stavros Zannopoulos, and Gerasimos Peteinatos. 2019. "Key Aspects on the Biology, Ecology and Impacts of Johnsongrass [Sorghum Halepense (L.) Pers] and the Role of Glyphosate and Non-Chemical Alternative Practices for the Management of This Weed in Europe." *Agronomy* 9(11):1–12. doi: 10.3390/agronomy9110717.

Waterton, Claire. 2010. "Experimenting with the Archive: Sts-Ers as Analysts and Co-Constructors of Databases and Other Archival Forms." *Science Technology and Human Values* 35(5):645–76. doi: 10.1177/0162243909340265.

Webb, J., Mark Broomfield, Stephanie Jones, and Brian Donovan. 2014. "Ammonia and Odour Emissions from UK Pig Farms and Nitrogen Leaching from Outdoor Pig Production. A Review." *Science of the Total Environment* 470–471:865–75. doi: 10.1016/j.scitotenv.2013.09.091.