Matière
à débattre & décider

Ecosystem services provided by agricultural areas

Evaluation and characterisation approaches

Anaïs Tibi and Olivier Therond

éditions Quæ

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Content

Preface

By responding to the request for evaluation of agroecosystem services in France, as part of the national EFESE program supported by the Ministry in charge of the Environment, the work coordinated by the Directorate of Collective Scientific Assessment, Foresight and Advanced Studies, of which this work presents a synthesis, has taken up several challenges.

The first challenge is to have, for more than two years, brought together around forty scientific experts from various disciplinary fields and institutional origins, and mobilised Inra's (now INRAE since 2020) skills in modeling agricultural ecosystems, data engineering and cartography. A summary of a report of nearly 1,000 pages, this work presents the conceptual and methodological advances, and the main results obtained by this multidisciplinary experts committee.

The second challenge is conceptual. The transposition of the notion of ecosystem service to the case of agricultural ecosystems, which are highly managed or even constructed, is not obvious. It therefore required developing an important and original conceptualisation, and making choices in a scientific field where debate is intense. The purposes of agriculture and the plural nature of agricultural practices have led the expert committee to differentiate goods and services, and to distinguish the practices those which build the ecosystem - the installation of planned biodiversity - from those which relate to the provision of exogenous inputs such as water, fertilisers and phytosanitary products and which regulate the potential for ecosystem services. In the same vein, proposals were made to clarify the oppositions between services, disservices, positive and negative externalities of agriculture.

A third challenge lies in the specification of services and the choice of biophysical and economic evaluation methods, the two essential dimensions of the notion of ecosystem service. This specification and this assessment — enriched by previous conceptual reflection, including particular attention to the links between services, benefits and beneficiaries, and an overview of the specificities of French agricultural ecosystems — required profound adaptations of the international typology of ecosystem services (Common International Classification of Ecosystem Services)[1] and a rich and profitable review of evaluation methods. A total of 14 services, which offer good coverage of the categories "regulatory services", "goods" and "cultural services", were studied. The use of the finest possible spatial resolution (down to the field), databases on soils, climate and cropping systems, and crop and meadow simulation models, results in an assessment based on both precise and complete throughout the national territory.

1. https://cices.eu/

A particular strength of this evaluation, beyond the information it provided to inform public decision-making, is to have fed back into the initial conceptual reflection around the relationship "agricultural practices – biodiversity – service – benefit". For example, a quantification at the national scale of the share of agricultural production enabled by input ecosystem services and that enabled by the provision of exogenous inputs was carried out. Likewise, this work offers an enlightening comparison of the maps of services provided by agricultural ecosystems and the negative impacts of agriculture relating to similar criteria, such as the regulation of water quality by immobilisation of mineral nitrogen (service) and the amount of leached nitrogen (negative impact). Similarly, the economic assessment prompted critical reflection from the authors on the conditions for applying the methods and the need for a solid biophysical evaluation upstream.

The consideration of service bundles, which is crucial for rethinking the management of agricultural ecosystems, emerged as an additional challenge. This work has given a unique place to the analysis of interactions between services, in which the central role of cultural sequences appears, and which makes it possible to identify major management levers.

The perspectives opened by this work are rich on the conceptual, methodological and cognitive levels. Understanding the role of livestock and the management methods of the agroecosystem in the provision of ecosystem services are of course central to these perspectives. Likewise, the relationship "planned biodiversity – associated biodiversity" and the key role of biodiversity in the provision of services must still be deepened and explained. The results of these investigations, which call for a renewal of approaches, are highly anticipated as the potential impacts are significant.

By meeting all the challenges mentioned above, the expert committee not only responded to the request of the Ministry in charge of the Environment, but it also shared its considerable work and its achievements with the French community gathered in the Inra unifying program on agricultural ecosystem services, which supported the project with great interest. Even more, these experts contributed to advancing the thinking of researchers who invest in the fundamental area of the links between agriculture, biodiversity and the concept of ecosystem service, at the interface between science and society. Before inviting the reader to delve into this work, we would like to thank the 71 members of the working group who contributed to this major project, providing a solid scientific foundation and paving the way for numerous future works on characterisation and assessment of ecosystem services.

Guy Richard, Françoise Lescourret
First Inra research programme on agricultural
and forest ecosystem services - EcoServ (2013-2019)

Main acronyms used

C: carbon

CH_4: methane

CICES: Common International Classification for Ecosystem Services

CO_2: carbon dioxyde

DOC: dissolved organic carbon

DEPE: directorate for Collective scientific assessment, Foresight and advanced Studies

EFESE: *Évaluation française des écosystèmes et des services écosystémiques* (French assessment of ecosystems and ecosystem services)

CSA: collective scientific assessment

GHG: greenhouse gas

LPIS: Land Parcel Identification System

MAES: Mapping and Assessment of Ecosystem and their Services

N: nitrogen

N_2: dinitrogen

N_2O: nitrous oxide

NO_3^-: nitrate

P: phosphorus

SAR: small agricultural region

ES: ecosystem service

PCU: pedo-climatic unit

Introduction

Context and scope of the question asked to Inra

Although the idea of "services provided by nature" appeared in the second half of the 19th century, the term "ecosystem services" first appeared in 1970, in a report known as the *Study of Critical Environmental Problems* (SCEP)[2]. Sponsored by the Massachusetts Institute of Technology, the SCEP was the first large-scale study seeking to draw attention to the global environmental impacts of human activities. In the early 2000s, the "ecosystem services" concept gained further recognition with the Millennium Ecosystem Assessment (MEA, 2005)[3], undertaken at the order of the UN Secretary General in 2000. The MEA sought to provide a scientific evaluation of the current and potential future threats to the ecosystems on which human life and wellbeing depend.

Following the MEA, in 2011 the European Union adopted a strategy intended to halt biodiversity loss by 2020. The "EU 2020 Biodiversity Strategy" is organised into six main targets, the second of which calls upon the EU Member States, with the support of the European Commission, to engage in the mapping and assessment of ecosystem conditions and ecosystem services for their respective national territories. In 2013, a dedicated working group was created – the Mapping and Assessment of Ecosystems and their Services (MAES) – the first responsibility of which was to develop of an analytical framework for Member States to employ for these assessments, in order to assure their completion in a coherent and uniform fashion.

Beginning in 2009, the French government has been engaged in advancing the MEA goals at the national level. The EFESE program (for *Evaluation Française des Ecosystèmes et des Service Ecosystémiques*)[4], launched in 2012 by the Ministry in charge of the Environment, seeks to create tools for ecosystem services assessment, for a range of different types of ecosystems, in order to improve public awareness of the value of biodiversity and to inform national and local processes for planning and development. Another objective of the EFESE program is to establish values for biodiversity within national accounting systems. The scope of this program includes all terrestrial and marine ecosystems for mainland France and its overseas territories, divided into six major ecosystem types, each of which is the focus of a thematic study:

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2. (1970) The Williamstown Study of Critical Environmental Problems, Bulletin of the Atomic Scientists, 26:8, 24-30, DOI: 10.1080/00963402.1970.11457855. https://mitpress.mit.edu/books/mans-impact-global-environment
3. Millennium Ecosystem Assessment, 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC. http://www.millenniumassessment.org/en/index.html
4. https://www.ecologique-solidaire.gouv.fr/levaluation-francaise-des-ecosystemes-et-des-services-ecosystemiques

forested ecosystems; agricultural ecosystems; urban ecosystems; wetlands; coastal and marine areas; and high-mountain and rocky areas.

In this context, in early 2014, the French Ministry in charge of the Environment requested Inra (which will become InraE in 2020) to complete the “agricultural ecosystems” portion of the EFESE program (hereinafter referred to as EFESE-AE). As this request is part of a program intended to support public decision-making, Inra has entrusted the carrying out of this work to its Directorate for Collective Scientific Assessment, Foresight and Advanced Studies (DEPE). The unifying research program led by Inra since 2013 on the services provided by agricultural and forest ecosystems has joined forces with MTES to support this operation.

The goal of EFESE-AE was to describe the underlying mechanisms for a range of ecosystem services based on available scientific knowledge, and then to propose methods for biophysical and economic assessment of these services at the national level, at the most detailed scale possible. It was also a matter of identifying issues that were poorly understood and for which additional work seemed a priority. Finally, this work was to contribute to building a sustainable information system for the evaluation of agricultural ecosystems and associated ecosystem services, managed by Inra, and made available to the scientific community. Accordingly, all the assessment methods proposed and implemented by the expert group during the time available for the study were designed to be fully traceable and reproducible.

Organisation of work conducted by Inra

Among the range of activities coordinated by the DEPE to inform public policies and debate, this work was organised in the form of a study, in compliance with guidelines established by Inra for the conduct of Collective Scientific Assessments (see Box 1). Approximately forty scientific experts and other scientific contributors from a variety of public institutions and with complementary disciplinary expertise (ecology, agronomy, hydrology, animal science, economics, etc.) were called upon to complete the work. Expertise in data management, a key component of EFESE-AE, was provided primarily by Inra. The working group was led by two scientific leads who directed the expert group from a scientific perspective, and a project leader responsible for the overall project management. A list of working group’s members may be found on the final page of this book.

First, the experts assembled and analysed the relevant international scientific literature in order to establish an analytical framework for the specification and assessment of ecosystem services from agricultural ecosystems; determine the list of services to address; and propose indicators to assess these services. Second, these indicators were quantified using data for France; and results were analysed and interpreted.

All the information produced is included in the extended scientific report[5], written by the experts and delivered in 2017. Then, a condensed report[6], based on the extended scientific report, was written with the coordination of the DEPE between May and October 2017. The present book is adapted from the condensed report.

This document is intended for a non-specialist public and seeks to provide an overall view of the study's findings. It may be considered as a reading guide to the extended report, which is the primary deliverable for the study. All the deliverables are available *via* the Inra web site[7]. NB: This book does not include the bibliographic references reviewed by the expert group, and which support the content presented here. An exhaustive list of these references may be found in the extended report.

This book presents the results of the work carried out by the working group between November 2014 and March 2017. Chapter 1 presents the analytical framework developed specifically for the study of services provided by agricultural ecosystems, an ecosystem type characterised by a high level of anthropisation. Chapter 2 addresses so-called "input" ecosystem services provided to farmers in their role as managers of these ecosystems. A first estimate of the contribution of input services to agricultural production is proposed in chapter 3. Chapter 4 presents regulating services provided by agricultural ecosystems to the society as a whole. It also discusses possible definitions of cultural services. Chapter 5 presents available methods of economic assessment and the challenges inherent in their application to the ecosystem services concept. Chapter 6 presents an integrated analysis of the various services covered in the preceding chapters, and suggests avenues for thinking about the management of ecosystem services. A concluding section presents, in a transversal fashion, the major directions for future research suggested by this work.

5. https://dx.doi.org/10.15454/prmv-wc85
6. https://dx.doi.org/10.15454/1h4z-tq90
7. https://www.inrae.fr/en/news/assessing-services-provided-agricultural-ecosystems-improve-their-management

Box 1. Scientific assessment to inform public decision-making

Created in 2010, Inra's (now INRAE since 2020) Directorate for Collective Scientific Assessment, Foresight and Advanced Studies (DEPE) has the mission of informing public decision-making on complex societal issues and, at the same time, promoting reflection on the Institute on its own scientific orientations. Through the three types of exercises that it most often carries out at the request of public authorities, the DEPE is at the interface between political decision-makers, stakeholders, scientific institutions and experts. The "agricultural ecosystems" component of the EFESE program was carried out by Inra by adopting the method and principles established by its DEPE for the conduct of Collective Scientific Assessment (CSA), of which the Advanced studies are derivatives.

The institutional activity known as CSA, undertaken by Inra since 2002 and governed by a French national charter signed in 2011, is defined as a process of knowledge gathering and analysis covering a wide range of disciplinary fields relevant to public policy. It identifies existing scientific knowledge, points of uncertainty, notable areas of scientific debate, and questions requiring further research. The CSA is not intended to provide specific recommendations or practical answers to the questions confronting decision makers. The DEPE also coordinates and carries out Advanced Studies, activities that extend a CSA project by assembly and treatment of available data (statistical analyses, calculations, simulations using existing proven computer models, meta-analyses, etc.) based on published scientific work. All such exercises lead to the production of an extended scientific report written by the experts, a condensed report and a summary report both written by the DEPE.

CSA and Advanced Studies are conducted in accordance with guidelines designed to guarantee the integrity and robustness of project outputs.[8] Core principles include: competence and diversity of contributing experts (identified by Inra from their publications); impartiality (experts are required to file conflict of interest declarations, which are reviewed by Inra's Ethics Oversight Committee); transparency with respect to the methodologies adopted; and traceability of the actions taken and means employed for the project.

8. https://dx.doi.org/10.17180/6x6d-wn26

1. A framework for assessing ecosystem services from agricultural ecosystems

The concept of ecosystem services (ES) has gained broad currency within both the scientific community and the public policy arena, particularly in the years since the publication of the Millennium Ecosystem Assessment (MEA, 2005). A considerable amount of research and other work undertaken since the late 2000s has sought to describe and specify interactions between nature and human wellbeing. They aim to clarify the concept of ES so as to operationalise its use for decision-making and policy making purposes. Nevertheless, multiple conceptual frameworks for ES exist; these frameworks are continually evolving and subject to ongoing debate. Persistent ambiguities with regard to both the biophysical and the socioeconomic factors involved make it difficult to compare research findings across different contexts.

The ecosystem services concept as applied to the functioning of agricultural ecosystems

Agricultural ecosystems: human-impacted ecosystems managed for the production of biomass

From the perspective of both ecological and agronomic sciences, the agroecosystem is made up of two interacting systems: an ecological (or biophysical) system and a socioeconomic system. In this book, the term "agricultural ecosystem" refers to the ecological system; or in other words, the soil and its vegetation cover, associated semi-natural features (hedgerows, isolated trees, wet areas, field margins, etc.) and animals living in or passing through the field (livestock on pasture, wild animal biodiversity). The socio-economic system includes people who manage the ecological system and intervene in it (farmers) as well as the artificial means used to produce food, fiber, or other agricultural products.

The agricultural ecosystem is designed and managed by humans for the primary purpose of producing biomass. The farmer influences the nature and functioning of the ecosystem through two types of practices:

- practices that determine the configuration of the agricultural ecosystem and therefore the nature and potential volume of agricultural outputs for a given climate. This includes the choice of plant and animal genotypes (species, varieties, breeds); sowing dates and density; crop rotations; and animal presence in the ecosystem (role of grazing in the livestock feeding strategy);

- biomass production management practices:
  - limiting abiotic stresses (e.g., through water and mineral element supply) or modifying the physico-chemical conditions of the soil (e.g., through tillage or liming);
  - reducing biotic stresses (e.g., through the use of pesticides);
  - exporting the plant biomass from the field (harvesting) or return it to the soil.

The composition and functioning of agricultural ecosystems are different from "semi-natural" ecosystems because of the interaction between two components of biodiversity: so-called "planned" biodiversity and "associated" biodiversity. Planned biodiversity includes the cultivated plant species (annual, semi-annual, or perennial) and livestock intentionally introduced into the ecosystem for agricultural production purposes. Associated biodiversity includes weed species present in the field, soil fauna (endogenous macro- and meso-fauna, soil microbial communities), and the aboveground and airborne macro- and meso-fauna moving through the field and its immediate environment. The structure and dynamics of associated biodiversity depend on the planned biodiversity (plant notably serving as a food source and habitat for animal biodiversity); on biomass management practices; and on the structure of adjacent ecosystems (e.g. the composition and configuration of semi-natural habitats or forested areas).

NB: In this book, the term "agricultural ecosystem" is frequently used in the singular form to designate the ecosystem type that is the focus of EFESE-AE. Nevertheless, this should be understood to refer to "the totality of agricultural ecosystems in all their diversity."

A framework for the description and assessment of ecosystem services

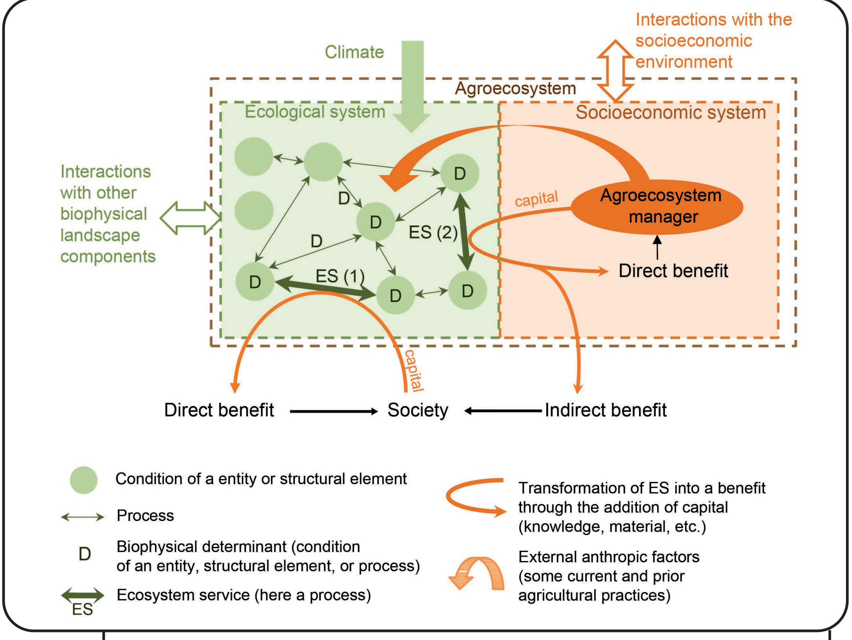
Many conceptual frameworks link the concepts of ecosystem structure and biophysical processes, ES and benefits along a chain (or cascade) that links ecosystem functioning to human well-being. An international literature review published in 2012 identified two major types of definitions: i) those in which ES are understood as biophysical components of ecosystems, from which benefits are derived – the definition adopted by the authors of the CICES[9]; and ii) those in which ES are understood as the benefits received by humans from ecosystems – the definition adopted in the MEA report.

Given the focus on agricultural ecosystems, EFESE-AE followed the CICES, choosing to understand ES as ecosystem "components" from which humans derive benefits that

9. The Common International Classification of Ecosystem Services (CICES) was introduced in 2009. CICES was developed within the context of work being done by the European Environment Agency and the United Nations Statistical Division seeking to revise and standardise the international system of environmental accounting (System of Environmental Economic Accounting – SEEA).

contribute to improving their well-being. This understanding clearly distinguishes the concepts presented in the following pages, and summarised in Figure 1-1.

Figure 1-1. Schematic representation of key concepts used in EFESE-AE



The figure illustrates the provision of two ES: (1) an ES provided directly to society; (2) an ES provided directly to the farmer, with society receiving an indirect benefit.

Benefits and beneficiaries of ecosystem services

ES are ecological processes or ecosystem structural elements from which humans derive benefits, whether actively, by mobilising material (energy, water, crop protection products) and/or cognitive capital (knowledge, including agricultural practices), or passively (for example, benefits received from ES of climate regulation). The benefits received from ES are no longer part of the ecosystem; they may be material (goods) or immaterial (socioeconomic services[10]) in nature. A single ES may be the source of multiple benefits.

10. The terms *goods* and *services* are used here in the national accounting sense, and refer to the totality of goods created by businesses, public agencies, or other organisations. A *service* in the national accounting sense is different from an ecosystem service as discussed in this study.

From a public policy perspective, identifying the specific benefits obtained from ES by different groups of individuals within society can help clarify the stakes involved and highlight associated action levers for ecosystem management. Two categories of beneficiaries were distinguished here: farmers, and society as a whole. As managers of agricultural ecosystems, farmers derive from certain ES specific benefits that contribute directly to agricultural production: it is thus considered that these ES provide a direct benefit to farmers. Society as a whole is a beneficiary of ES supplied by agricultural ecosystems, both directly (in the case of ES of global climate regulation, for example), and indirectly through farmers (for example, in the case of regulating ES that substitute for the use of chemical inputs that can contaminate the environment). In the second case, the way in which society benefits from ES depends on farmers' behavior.

We should note that as residents and citizens, farmers also belong to the second category of beneficiaries, society as a whole. Given the thematic focus of EFESE-AE, other categories of social actors were not considered.

Ecosystem services, biophysical determinants and external factors

Ecosystems are made up of an assemblage of biotic and abiotic entities and processes in interaction. The structure of the ecosystem is defined by the nature and the interrelationships of those entities (spatial pattern, functional interactions...). The structure of the ecosystem and the condition of its various entities determine ecological processes (e.g., population dynamics, competition among populations) and vice versa. For example, processes of predation or parasitism determine the condition and the structure of pest species communities, which in turn determine the nature of these processes and the degree of damage to crops.

ES are the sub-group of processes or entities from which humans receive direct benefit(s). The level of ES provision thus depends on the condition of ecosystem entities and on overall ecosystem functioning. In the analytical framework of EFESE-AE, the principal ecosystem entities and biophysical processes determining the level of ES provision are referred to as "biophysical determinants." For example, the ES of pollination corresponds to the process of pollen transfer between male and female flowers. The characteristics of pollinator communities (structure, composition, abundance) are major biophysical determinants for this ES. Note that only those processes involving living organisms are recognised as ES (as a corollary, biodiversity is a biophysical determinant of ES). Certain abiotic entities or processes (e.g., soil texture) can be considered to be biophysical determinants when their interactions with biotic entities or processes determine the level of ES.

In addition, certain processes external to the ecosystem, both natural (i.e., climate) and anthropic (human activities), can increase or decrease the level of ES provision, directly and/or through their effects on biophysical determinants. These are referred to as "external factors" in EFESE-AE. For example, the ES of nutrient supply to crop plants is influenced by phenomena connected to climate change as well as by fertilisation practices; these factors directly influence levels of soil organic matter, one of the key biophysical determinants for this ES.

In the case of agricultural ecosystems, agricultural practices can play various roles. Insofar as they define the nature of the agricultural ecosystem, ecosystem configuration practices help determine the level of ES provision. Biomass management practices are considered as external anthropic factors when they influence the level of ES provision. Such practices can exert an effect either through their historic influence on ecosystem conditions (e.g., effects of tillage practices on soil organic matter) or through their effect on ES expression within the assessment timeframe (e.g., crop protection practices, which, through their effects on pest species and their natural enemies, influence the level of ES for pest species regulation over the course of a year).

Ecosystem services, "dis-services" and impacts of agricultural practices

In the literature, the concept of "dis-services" is often used to refer to two distinct phenomena: 1) the negative effects of some biodiversity components or certain ecosystem processes on human well-being; 2) the negative impacts of human activities on the environment.

First of all, one needs to distinguish between the negative effects of some types of ecosystem functioning on human beings and situations of low ES provision. Negative effects of ecosystem functioning (dis-services of type 1) can include some effects of wild fauna in agroecosystems or in urban areas; or the release of pollen allergens by plants. A low effective level of ES corresponds to a situation in which a low level of benefit is received.

Furthermore, transposed to the case of agricultural ecosystems, dis-services of type 2 correspond essentially to material flows from agricultural ecosystems to other ecosystems as a result of agricultural practices. Thus, some biomass management practices (e.g., crop protection treatments, fertiliser applications) create pollution (e.g., pesticides, nitrates) that moves beyond the agricultural ecosystem and ultimately results in a reduction of human well-being. ES and the negative environmental impacts of human activities offer two different and complementary ways of looking at ecosystem functioning. For example, the conversion of N_2O (a greenhouse gas) into N_2 is an ES, whereas N_2O emissions resulting from nitrogenous fertiliser applications are an environmental impact.

When assessing ES and dis-services, it is important to keep in mind that a single ecological process may be considered an ES for one category of beneficiaries and a dis-service for another: the definition of ES and dis-services thus depends on the group of actors considered. For example, the regulation of wild ungulates by large predators may be an ES for foresters, but a dis-service for hunters or hikers. Dis-services were not examined in the study that gave rise to this book. Nevertheless, where useful and appropriate, indicators of the negative impacts of agricultural practices were developed and quantified in addition to levels of ES provision (e.g., fixed N vs. leached N; see Chapter 6).

Identifying and assessing ecosystem services from agricultural ecosystems

Typology of ES provided by agricultural ecosystems

In keeping with much of the international research and the EFESE program, EFESE-AE used the CICES classification (version 4.3[11]) as its reference typology for the identification of ES from agricultural ecosystems. CICES classifies ES into three major groups:

- "provisionning services," corresponding to the production of biomass, water, and energy by the ecosystem;
- "regulation and maintenance services," corresponding to ecological processes that help regulate phenenoma such as the climate, the frequency and magnitude of disease outbreaks, or various aspects of the water cycle (e.g., floods, water quality) and the movement of material by water (e.g., erosion);
- "cultural services," source of recreational, aesthetic, or spiritual benefits.

After selecting for analysis a group of ES supplied by agricultural ecosystems in France among the ES listed by CICES,[12] the expert group determined for each one, based on the international scientific literature: i) the nature of the ES, ii) the benefits received by society and (where applicable) by farmers; iii) the major biophysical determinants and external factors involved in ES provision. This work led the group to refine and adjust the classification of some of these ES, and thus to significantly revise the CICES typology (cf. Annex 2).

In particular, the status of agricultural production is widely debated in the scientific literature the international ES assessments. Agricultural production results from interactions between regulating ES and anthropic inputs (energy, irrigation, fertilisation, pesticides). Treating agricultural production as a "provisioning service" suggests that a higher level of this ES can result from an increased use of external inputs, not just from better ecosystem functioning. In order to distinguish between the respective roles of ecosystem functioning and external input supply in agricultural production, the concept of a "provisioning service" was not adopted in EFESE-AE. Instead, agricultural production was understood as an agricultural good, or in other words, as a benefit received by the farmer from interactions between certains regulating ES – called "input services" in EFESE-AE – and anthropic external inputs (see Chapter 3). In addition, the "water supply" ES as defined by the CICES were understood as water flow regulation ES (see Chapter 2).

The definition of so-called "cultural" services is likewise the focus of some debate. In practice, the majority of items identified in this category by the CICES correspond more closely to a typology of landscape uses and/or values (and thus benefits) than

11. The most recent version when this study was completed - https://cices.eu/resources/
12. ES marginal within the French context or supplied exclusively by other types of ecosystems (for example, regulation of salt water quality) were excluded from the scope of the study. In addition, some ES supplied by agricultural ecosystems could not be examined due to a lack of relevant expertise among the study team.

to ES in the sense adopted in EFESE-AE. As a result, only those services described as "recreational" in the CICES framework were examined here (cf. Chapter 4).

Table 1-1 presents the final list of ES examined within EFESE-AE. All the ES were the subject of a review of the scientific literature to propose an evaluation methodology. Where possible, the expert group used these methods to obtain a biophysical or even economic quantification of the ES. Where this was not possible, they identified the need for additional work and data that would enable them to be implemented.

Table 1-1. Final list of ES examined in EFESE-AE

ES Designation	Biophysical analysis	Economic analysis
Pollination of crop plants	Quantified	Assessed
Regulation of weed seeds	Partially quantified	Investigated
Regulation of insect pests	Partially quantified	Investigated
Soil stabilisation and erosion control	Quantified	Investigated
Soil structuration	Investigated	/
Storage and return of water to crop plants	Quantified	Assessed
Storage and return of blue water	Quantified	/
Supply of mineral N to crop plants	Quantified	Assessed
Supply of other nutrients to crop plants	Investigated	/
Natural attenuation of pesticides by soils	Investigated	/
Regulation of water quality with respect to N, P, and DOC	Partially quantified	Investigated
Global climate regulation by GHG attenuation and C sequestration	Quantified	Investigated
Recreational potential (outdoor activities, no sampling)	Partially quantified	/
Recreational potential (outdoor activities, with sampling)	Investigated	/

Some other ES strongly relevant for to agricultural ecosystems should be studied to supplement the work carried out in EFESE-AE. This is particularly the case for:

- regulation of crop and livestock diseases;
- decomposition and the recycling of dead matter and waste products;[13]
- local climate regulation (at the landscape or field level);
- regulation of air quality;
- regulation of flood.

13. Performed by necrophagous and coprophagous organisms, respectively; primarily insects (but also carrion-eating birds in the case of larger carcasses).