Project co-funded by the European Union and national funds of the participating countries

Interreg Balkan-Mediterranean BIOPROSPECT

Deliverable. 3.1.2	**Assessing the status and trends of forest services availability and distribution**

BIOPROSPECT: Conservation and sustainable capitalization of biodiversity in forested areas

Project title	Conservation and sustainable capitalization of biodiversity in forested areas (BIOPROSPECT)
Call identifier	Interreg V-B "Balkan-Mediterranean 2014-2020" Transnational Cooperation Programme
Project acronym	BIOPROSPECT
Starting date	October 20th, 2017
End date	October 19th, 2019
Funding scheme	European Regional Development Fund (ERDF),Pre-Accession Assistance (IPA) Fund / National Funds
Contract no.	BMP1/Z1/2336/2017
Deliverable no.	D.3.1.2
Partner	DUTH (LP1)
Deliverable name	Assessing the status and trends of forest services availability and distribution
Work Package	WP3
Date	

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Assessing the status and trends of forest services availability and distribution

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VERSION HISTORY

Version	Completion date	Modifications
V1	**29-6-2018**	

ABBREVIATIONS

Term	Explanation
ARIES	Artificial intelligence for ecosystem services
BD	Bird Directive
BISE	Biodiversity Information System for Europe
CICES	Common International Classification of Ecosystem Services
CLC	CORINE Land Cover
CORINE	Coordination of Information on the Environment
EC	European Commission
ES	Ecosystem Service
ESC	Ecosystem Capacity
ESTAT	Eurostat, Statistical office of the European Union
EU	European Union
EUNIS	European Nature Information System
FAO	Food and Agriculture Organisation of the United Nations
FES	Forest Ecosystem Services
HD	Habitats Directive
InVEST	Integrated Valuation of Environmental Services and Tradeoffs
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
LPIS	Land Parcel Identification System
MEA	Millennium Ecosystem Assessment
MAES	Mapping and Assessment of Ecosystems and their Services
MCPFE	Ministerial Conference on the Protection of Forests in Europe
MESEU	Mapping of Ecosystems and their Services in the EU
NEA	National Ecosystem Service Assessment
NEP	Net ecological production
NFI	National Forest Inventory

NGO	Non-Governmental Organisation
NPP	Net Primary Production
OPERA	Operational Potential of Ecosystem Research Applications
SEBI	Streamlining European Biodiversity Indicators
SEEA	System of Environmental Economic Accounts
TEEB	The Economics of Ecosystems and Biodiversity
UN	United Nations
UNEP	United Nations Environment Programme
WFD	Water Framework Directive
WISE	Water Information System for Europe
WWF	World Wide Fund for Nature

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Foreword

The main aims of the project BIOPROSPECT are to explore and document the bioprospects of forested protected areas and the ways of sustainable capitalization as a mean for their wise management and conservation, to encourage cooperation partnerships and networking among economic development planners and PA managers, to develop a cross-border bioprospect assessment methodological framework and economic valuation model in order to achieve outcomes which benefit both economic development and conservation.

BIOPROSPECT Work Package 3 aims to develop a tool box for the economic valuation and sustainable capitalization of biodiversity-ecosystem services. This will be achieved through the specific project objectives; to provide operational tools for the conservation of forest biodiversity through economic valuation and sustainable capitalization.

This report, (deliverable D3.2.1 under Task 3.2 in Work Package 3) approaches this objective by providing a manual for assessing the status and trends of forest services availability and distribution.

The starting point of this report is a comprehensive literature review, based on peer-reviewed scientific articles and overview of international trends and approaches to ecosystem services. The report presents a methodology for assessing the status and trends per service using the appropriate criteria and the interactions and trade-off between forest services. The D3.2.1 also targets to the creation of the appropriate protocol to be used for producing spatially defined maps of the most important ecosystem services of the national study areas.

Executive Summary

Deliverable 3.1.2 (D3.1.2), under Task 3.2 in Work Package 3 (WP 3) - Tool box for the economic valuation and sustainable capitalization of biodiversity-ecosystem services, approaches a manual for assessing the status and trends of forest services availability and distribution. This report presents methodology for assessing the status and trends per service using the appropriate criteria and the interactions and trade-off between forest services. It targets to the creation of the appropriate protocol to be used for producing spatially defined maps of the most important ecosystem services (ESs) of the national study areas.

The report is structured in seven main sections. Section 1. The Introduction (Section 1) provides information about the concept under which the project Bioprospect is implemented.

Section 2 as the starting point of the analysis is a comprehensive literature review, and overview of international trends and approaches to ESs. Definitions of terms are provided along with information policy framework and status of forest ES. In this section, the typology for classification of ecosystem, ES sand forest ESs is also analyzed, and National Ecosystem service assessments and projects on mapping ES are introduced

Section 3 is an overview of the methods used in assessing status and trends of forest services. Based on case studies and relevant literature and reports, we present theory and properties of recommended ecosystem services indicators reflecting provisioning, regulating and cultural services. Section 3 outlines the evolving role of remote sensing and geographic information systems within the assessment of ecosystem services. Moreover, ES tools are described, including model aspects and data issues for mapping ecosystem services.

Section 4 refers to the possibilities that spatial indicators and landscape metrics provide to ES s assessment.

The last part of the report (Section 4) offers a practical, step-by-step guidance on how to carry out an ES assessment process and produce spatially defined maps of the most important ESs of the national study areas. Furthermore, this section highlights the criteria for selecting these ESs and suggests a list of indicators for each service, with aim to assess forest services as developed in CICES.

The report closes illustrating the interactions between ecosystem services. The assessment of multiple ES in conjunction with the assessment of interactions and trade-offs between these ES is the basis for assessing the multifunctionality of ecosystems and providing the necessary information for making sound decisions about proper management of forest ecosystems.

Finally, for a more complete approach to the assessment of the status and trends of forest ES availability and distribution, a questionnaire was distributed among stakeholders and experts. The questionnaire investigates the significance of forestry ES and the appropriate indicators to assess and map ES.

Εκτεταμένη Ελληνική περίληψη

Ένας από τους κύριους στόχους του προγράμματος BIOPROSPECT είναι η διερεύνηση και η τεκμηρίωση των οικονομικών αξιών της βιοποικιλότητας και των οικοσυστημικών υπηρεσιών (Ο.Υ) δασικών περιοχών καθώς και των τρόπων βιώσιμης κεφαλαιοποίησής τους, ως μέσο για την αειφορική διαχείριση, ανάπτυξη και προστασία περιοχών.

Το παραδοτέο D3.1.2, το οποίο ανήκει στο Πακέτο εργασίας (WP 3) - Εργαλεία για την οικονομική αποτίμηση και τη βιώσιμη κεφαλαιοποίηση των Ο.Υ, αποτελεί ένα εγχειρίδιο για την αξιολόγηση της κατάστασης και των τάσεων της διαθεσιμότητας και κατανομής των δασικών Ο.Υ. Στην παρούσα έκθεση παρουσιάζεται μια μεθοδολογία για την αξιολόγηση της κατάστασης και των τάσεων ανά υπηρεσία με βάση τα κατάλληλα κριτήρια και τις αλληλεπιδράσεις μεταξύ δασικών υπηρεσιών. Επιπλέον, στόχος του D3.1.2 είναι η δημιουργία του κατάλληλου πρωτοκόλλου που θα χρησιμοποιηθεί για την παραγωγή χωρικά προσδιορισμένων χαρτών των πιο σημαντικών οικοσυστημικών υπηρεσιών των εθνικών περιοχών μελέτης.

Η έκθεση διαρθρώνεται σε επτά ενότητες. Η Ενότητα 1. παρέχει πληροφορίες σχετικά με το πλαίσιο εφαρμογής του έργου Bioprospect, ως απόρροια των προτεραιοτήτων της Ευρωπαϊκής Ένωσης (Στρατηγική της ΕΕ για τη βιοποικιλότητα έως το 2020), στις οποίες συμπεριλαμβάνεται και υπογραμμίζεται η σημασία της χαρτογράφησης των οικοσυστημάτων και των υπηρεσιών τους, καθώς και η προώθηση της ενσωμάτωσης των αξιών αυτών σε συστήματα λογιστικής και υποβολής αναφορών τόσο σε επίπεδο ΕΕ όσο και σε εθνικό έως το 2020.

Η Ενότητα 2 ως σημείο εκκίνησης της έκθεσης, είναι μια αναλυτική βιβλιογραφική ανασκόπηση και μια επισκόπηση των διεθνών τάσεων και προσεγγίσεων των Ο.Υ. Αναφέρονται ορισμοί βασικών εννοιών (πχ ecosystem services) και αναλύονται τυπολογίες ταξινόμησης των οικοσυστημάτων όσο και των υπηρεσιών τους. Παράλληλα, γίνεται περιγραφή των περιαστικών δασών και των υπηρεσιών τους.

Για την ταξινόμηση των Ο.Υ, τρία διεθνή συστήματα ταξινόμησης είναι διαθέσιμα: Millennium Ecosystem Assessment (MEA), The Economics of Ecosystems and Biodiversity (TEEB) και Common International Classification of Ecosystem Services (CICES). Ουσιαστικά, και τα τρία συστήματα συσχετίζονται σε μεγάλο βαθμό μεταξύ τους. Και οι τρεις ταξινομήσεις περιλαμβάνουν υπηρεσίες παροχής, υπηρεσίες ρύθμισης και πολιτιστικές υπηρεσίες. Κάθε κατάταξη έχει τα δικά της πλεονεκτήματα και μειονεκτήματα που οφείλονται στο συγκεκριμένο πλαίσιο όπου αναπτύχθηκαν.

Στην ίδια Ενότητα γίνεται σύντομη παρουσίαση άλλων εθνικών αξιολογήσεων Ο.Υ καθώς και σχετικών προγραμμάτων (OPERAs, ESMERALDA κ.α). Επίσης, παρουσιάζονται οι υφιστάμενες ή δυνητικές απειλές των δασικών εκτάσεων και οι ποσοστιαίες αλλαγές στις δασικές Ο.Υ, σύμφωνα με την αξιολόγηση (MAES, 2015).

Η Ενότητα 3 αποτελεί μια επισκόπηση των μεθόδων που χρησιμοποιούνται για την αξιολόγηση και χαρτογράφηση της κατάστασης και των τάσεων των δασικών Ο.Υ. Για τον ποσοτικό προσδιορισμό των τριών κύριων κατηγοριών Ο.Υ κατά CICES (προμηθευτικές, ρυθμιστικές και πολιτισμικές) και την χαρτογράφηση των Ο.Υ εφαρμόζονται δείκτες αξιολόγησης. Σε αυτή την ενότητα παρουσιάζονται η θεωρία και οι ιδιότητες των δεικτών αξιολόγησης των Ο.Υ, με βάση μελέτες περιπτώσεων και σχετικής βιβλιογραφίας και εκθέσεων. Οι δείκτες αξιολόγησης προτείνονται με βάση δύο κριτήρια: i) την διαθεσιμότητα δεδομένων και ii) την ικανότητα μετάδοσης πληροφοριών στη διαδικασία χάραξης πολιτική. Η δεύτερη έκθεση MAES συγκεντρώνει έναν μεγάλο αριθμό δεικτών που μπορούν να χρησιμοποιηθούν για τη χαρτογράφηση και την αξιολόγηση των Ο.Υ σε εθνικό επίπεδο σύμφωνα με το σύστημα CICES.

Στη συνέχεια της Ενότητας 3, περιγράφεται ο εξελισσόμενος ρόλος των συστημάτων τηλεπισκόπησης και γεωγραφικών πληροφοριών στην αξιολόγηση των υπηρεσιών οικοσυστήματος και γίνεται αναφορά σε σημαντικά εργαλεία, λογισμικά και μοντέλα για τη χαρτογράφηση των Ο.Υ.

Η Ενότητα 4 αναφέρεται στις δυνατότητες χωρικών δεικτών και χωρικής διάρθρωσης των τοπίων στην αξιολόγηση των Ο.Υ.

Στην Ενότητα 5 παρουσιάζεται ένας πρακτικός οδηγός για την διαδικασία αξιολόγησης των Ο.Υ., με σκοπό να εφαρμοστεί και από τους εταίρους στις περιοχές μελέτης τους, ώστε να παραχθούν χάρτες των πιο σημαντικών Ο.Υ. Επιπλέον, στην ενότητα αυτή υπογραμμίζονται τα κριτήρια επιλογής των σημαντικότερων Ο.Υ. και προτείνεται ένας κατάλογος δεικτών για κάθε υπηρεσία, με σκοπό την αξιολόγηση των δασικών Ο.Υ. όπως αναπτύσσονται στο CICES.

Η τελευταία Ενότητα εξετάζει τις αλληλεπιδράσεις και συσχετίσεις μεταξύ Ο.Υ. Η αξιολόγηση των πολλαπλών Ο.Υ σε συνδυασμό με την εκτίμηση αλληλεπιδράσεων και συσχετίσεων μεταξύ αυτών των υπηρεσιών, αποτελεί τη βάση για την αποτίμηση της πολυλειτουργικότητας των οικοσυστημάτων και την παροχή απαραίτητων πληροφοριών για τη λήψη ορθών αποφάσεων σχετικά με την κατάλληλη διαχείριση των δασικών οικοσυστημάτων και την επίτευξη μέγιστων κερδών.

Τέλος για την πληρέστερη προσέγγιση της εκτίμησης της κατάστασης και τάσεων διαθεσιμότητας και κατανομής δασικών Ο.Υ παραθέτεται ερωτηματολόγιο που απευθύνεται σε άμεσα εμπλεκόμενους (stakeholders) και εμπειρογνώμονες (expert judgment) και αφορά τη διερεύνηση της σημαντικότητας των δασικών Ο.Υ. προς μελέτη, τον προσδιορισμό κριτηρίων ανά Ο.Υ. και των κατάλληλων δεικτών που αποτυπώνουν την κατάσταση των υπηρεσιών. Οι απαντήσεις των ερωτώμενων θα καθορίσουν την επιλογή των οικοσυστηματικών υπηρεσιών, των κριτηρίων και των αντίστοιχων δεικτών.

1 INTRODUCTION

Healthy ecosystems provide a stream of goods and services vital to society, such as food, fibres, clean water, healthy soils, protection against floods and erosion. Unfortunately, many of Europe's ecosystems are now heavily degraded which drastically reduces their ability to deliver these valuable services. The problem is further exacerbated by the fact that these services are often public goods, and their economic value is not recognized by the markets; consequently, their true economic worth is not reflected in society's decision making and accounts

In May 2011, the European Commission and Council adopted the 'Communication for the Implementation of the Biodiversity Strategy to 2020' (EC, 2011), which also implies the time lines to meet the Aichi targets of the Convention of Biodiversity (EC, 2014a). The strategy is in line with the commitments made by EU leaders in March 2010 and the international commitments adopted by 193 countries, including the EU and all its Member States. The new biodiversity strategy is built around six measurable targets that focus on the main drivers of biodiversity loss. Each target is accompanied by a corresponding set of actions.

In addition to halting the loss of biodiversity, the new strategy also highlights, for the first time, the immense value of ecosystem services (ES) and the urgent need to maintain and restore these for the benefit of both nature and society. Action 5 states that 'Member States, with the assistance of the Commission, will map and assess the state of ecosystems and their services in their national territory by 2014, assess the economic value of such services, and promote the integration of these values into accounting and reporting systems at EU and national level by 2020 The second target focuses on maintaining and enhancing ESs, and restoring degraded ecosystems across the EU, in line with the global goal set in 2010 to restore at least 15% of degraded ecosystems.

The nationwide mapping and assessment of ES can be seen as part of a National Ecosystem Assessment (NEA) and is essential to understanding how ecosystems contribute to human well-being and to supporting decisions on policies which have an impact on natural resources (Burkhard and Maes 2017). In 2013, an EU initiative on Mapping and Assessment of Ecosystems and their Services (MAES) was launched, and a dedicated working group was established with member states, scientific experts and relevant stakeholders. ES maps are mandatory instruments for landscape planning, environmental resource management and land use optimization (Burkhard and Maes 2017).

The Goal of BIOPROSPECT project is to explore and document the economic value of forested areas and the ways of sustainable capitalization as a mean for their wise management and conservation. One of the specific objectives is to provide operational tools for the conservation of forest biodiversity through economic valuation and sustainable capitalization. The main aim of this report is to develop a manual for assessing the status and trends of forest services availability and distribution.

2 REVIEW AND ANALYSIS

2.1 Identification of sources of information

To detect the latest trends in ES research after completion of the MA we conducted an update comprehensive literature search. The literature search used databases provided by the three major publishers for scientific literature: Elsevier, Springer, and Wiley. Additionally, relevant literature was found using the Google search engine. We focus solely on peer- reviewed literature allowed us to capture the current trends in this scientific field and on 'recently' published papers (not older than year 2000). As far as the choice of the keywords for our literature search is concerned we are in line with other reviews on similar topics (cf. Egoh et al. (2012), 'Indicators for mapping ecosystem services. a review').

The literature review concentrated on recently published peer reviewed studies, but also considered comprehensive reports about mapping of ES and ecosystem capacities to deliver (specific) services (ESC) in Europe, the sub-global assessments of the MEA (2005), and national assessments. We also collect data and information from international organisations, projects reports. and web platforms for biodiversity and ES as:

- ✓ IPBES Intergovernmental Science-Policy Platform on Biodiversity and ESs: established to strengthen the science-policy interface for biodiversity and ESs for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development.
- ✓ JRC Reference Data and Service Initiative (RDSI) portal (http://rdsi-portal.jrc.it), the Commission's science and knowledge service
- ✓ HESP Hellenic Ecosystem Services Partnership: HESP, the Greek National Network of researchers, CSO Civil Society Organisations decision makers and professionals dedicated to the research into and application of Ecosystem Services in the Greek part of the Mediterranean Basin
- ✓ ESP-VT Ecosystem Services Partnership Visualization tool: ESP-VT is an interactive knowledge platform that allows users to share information on ESs maps, data, and mapping methods. ESP-VT is a joint initiative of the Ecosystem Service Partnership's Working Groups on Mapping and Modelling ecosystem services, developed and supported by the Joint Research Centre of the European Commission (JRC-EC) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia.
- ✓ BISE -Biodiversity Information System for Europe- BISE is single entry point for data and information on biodiversity supporting the implementation of the EU strategy and the Aichi targets in Europe. Bringing together facts and figures on biodiversity and ESs, it links to related policies, environmental data centers, assessments and research findings from various sources. It is being developed to strengthen the knowledge base in support of the implementation of the EU biodiversity strategy and the assessment of progress in achieving the 2020 targets.

The review aimed at achieving a reflection of the full variety of ES according to 'The Economics of Ecosystems and Biodiversity 2010' (TEEB), - Millenium Ecosystem services Assessment (MEA, 2005) and the Common International Classification of Ecosystem Services (CICES, 2010) standard classification.

2.2 Typology for classification of ecosystems

2.2.1 Definition

An ecosystem is usually defined as a complex of living organisms with their (abiotic) environment and their mutual relations. Ecosystems, in more scientific terms, are communities of interacting organisms and the physical and chemical non-living components of their environment, e.g. water, minerals, soil and climate. These biotic and abiotic components are linked together through food-webs, nutrient cycles and energy flows (Odum, 1971). Article 2 of the Convention on Biological Diversity defines an ecosystem as ‘a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit’ and a habitat as ‘the place or type of site where an organism or population naturally occurs’ (UN, 1992). Ecosystems are multi-functional, each system provides a series of services for human well-being either directly, e.g. as food, fibers or timber, or more indirectly by e.g. providing clean air and water.

In the last decades, a number of classifications have been developed, especially for habitats, both at pan-European and national levels. There are several classification systems accepted and used both locally and regionally, nationally and internationally. Some of this classification systems are more detailed, for example the CORINE typology (1991), the EUNIS classification and The Habitats Directive (1992, adopted in 1999 and 2002). The MAES approach plans to develop a system of ecosystem classification, in the sense that the ecosystem is defined as a complex of flora and fauna in relationship with the abiotic environment.

2.2.2 Corine Land Cover

The CORINE Land Cover (CLC) inventory was initiated in 1985 (reference year 1990). Updates have been produced in 2000, 2006, and 2012. It consists of an inventory of land cover in 44 classes. CLC uses a Minimum Mapping Unit (MMU) of 25 hectares (ha) for areal phenomena and a minimum width of 100 m for linear phenomena. The time series are complemented by change layers, which highlight changes in land cover with an MMU of 5 ha. Different MMUs mean that the change layer has higher resolution than the status layer. Due to differences in MMUs the difference between two status layers will not equal to the corresponding CLC-Changes layer. If you are interested in CLC-Changes between two neighbour surveys always use the CLC-Change layer.

The Eionet network National Reference Centres Land Cover (NRC/LC) is producing the national CLC databases, which are coordinated and integrated by EEA. CLC is produced by the majority of countries by visual interpretation of high resolution satellite imagery. In a few countries semi-automatic solutions are applied, using national in-situ data, satellite image processing, GIS integration and generalisation. The 2012 version of CLC is the first one embedding the CLC time series in the Copernicus programme, thus ensuring sustainable funding for the future.

The CORINE Biotope classification, aimed to identify and describe habitats of major importance for conservation within the European Community. It is a hierarchical classification system, designed to cover all types of habitats but with an emphasis on natural and semi-natural habitats, a limited coverage of marine habitat types. Although it is based on the phytosociological approach, it also includes other factors, such as geography, climate, soil, and captures several types of habitats without vegetal cover.

An objective of the CORINE program is to bring together all the attempts that have been made over the years at different levels (international, community, regional and national) to get as much information as possible about the environment and how it changes.

2.2.3 Habitats Directive

The first version of the Habitats Directive classification developed in Annex I of the Habitats Directive published in 1992 is a selection from CORINE Biotope classification (Evans, 2010), identifying

233 types of habitats of conservative interest, the European Environment Agency establishing a correspondence between habitats codes from Annex I and the CORINE classification. Habitats are listed in Annex I of the Habitats Directive and described in the Interpretation Handbook (European Commission 2007). Although the Interpretation Handbook provides more details than the list of habitats in Annex 1, there are still many problems when trying to identify the types of habitats on site, selecting sites, evaluating national lists for the proposed sites and monitoring them. Some of these problems arise from the flawed, sometimes overlapping, and definition of habitat types. This has led to differences in interpretation between different countries and regions.

The classification in Annex 1 of the Habitats Directive does not define ecosystems, this typology is still working with the term habitat, addressing in particular to natural and semi-natural habitats which requires the identification of a protection and conservation regime.

2.2.4 European Nature Information System (EUNIS)

EUNIS brings together data on species and habitats from several European databases and organisations (http://eunis.eea.europa.eu/index.jsp). It is part of the Biodiversity data centre of the European Environment Agency and aids implementation of EU biodiversity strategies and the General Union Environment Action Programme to 2020 – Living well, within the limits of our planet (EC, 2014). The EUNIS habitat classification covers both natural and artificial pan-European habitats and groups them into 11 broad categories:

A. Marine habitats
B. Coastal habitats
C. Inland surface waters
D. Mires, bogs and fens
E. Grasslands and lands dominated by forbs, mosses or lichens
F. Heathland, shrub and tundra
G. Woodland, forest and other wooded land H. Inland unvegetated or sparsely vegetated habitats
I. Regularly or recently cultivated agricultural, horticultural and domestic habitats
J. Constructed, industrial and other artificial habitats
X. Habitat complexes

This hierarchical classification, which was revised in 2012, divides the 11 broad habitat categories into 5282 distinct habitat types (http://www.eea.europa.eu/themes/biodiversity/eunis/eunis-habitat-classification).

2.2.5 MAES project

Following the EU 2010 Biodiversity Baseline, the fifth MAES report proposed ecosystem classification, based on a combination of Corine Land Cover classes for spatial explicit mapping adjusted with the European Nature Information System (EUNIS) habitat types where necessary. The proposed typology separates at level 1 three major ecosystems: terrestrial systems, fresh water and the marine environment and it distinguishes 12 main ecosystem types based on the higher levels of the EUNIS Habitat Classification, which is a European reference classification with cross linkages to the habitat types listed in Annex I of the Habitats Directive. The ecosystem types are proposed as basic units for ecosystem mapping at European scale and the main classes should allow for consistent assessments of state and services from local to national, regional and European scale (Maes et al., 2013).

The MAES typology was applied in six pilot studies covering forests, agriculture, fresh waters and marine systems. MAES typology worked well for forests, questions were raised about the appropriateness of combining arable land and permanent crops into a single category (i.e. cropland). The challenges of defining boundaries for freshwater systems was highlighted and several weaknesses with the marine typology were identified that require further refinement (Maes et al, 2014).

In order to optimize the decision support expert systems, a table of correspondence have been developed in order to achieve all the links between the main EUNIS classification systems, the Habitats Directive, CORINE Land Cover, and MAES (Table 2).

Table 1 Proposed MAES typology of European habitats and corresponding EUNIS habitat code. Adapted from Maes et al (2013

Habitat type	MAES Description	EUNIS code
Urban	Areas where most of the human population lives and it is also a class significantly affecting other ecosystem types. Urban areas represent mainly human habitats but they usually include significant areas for synanthropic species, which are associated with urban habitats. This class includes urban, industrial, commercial, and transport areas, urban green areas, mines, dumping and construction sites.	J
Cropland	Main food production area including both intensively managed ecosystems and multifunctional areas supporting many semi- and natural species along with food production (lower intensity management). It includes regularly or recently cultivated agricultural, horticultural and domestic habitats and agro-ecosystems with significant coverage of natural vegetation (agricultural mosaics).	I
Grassland	Dominated by grassy vegetation (including tall forbs, mosses and lichens) of two kinds – managed pastures and (semi-) natural (extensively managed) grasslands.	E
Woodland and forest	Dominated by woody vegetation of various age or they have succession climax vegetation types on most of the area supporting many ESs.	G
Heathland and shrub	Areas with vegetation dominated by shrubs or dwarf shrubs. They are mostly secondary ecosystems with unfavourable natural conditions. They include moors, heathland and sclerophyllous vegetation.	F
Sparsely or unvegetated land	All unvegetated or sparsely vegetated habitats (naturally unvegetated areas). Often these ecosystems have extreme natural conditions that might support particular species. They include bare rocks, glaciers and dunes, beaches and sand plains	B,H

Inland wetlands	Predominantly water-logged specific plant and animal communities supporting water regulation and peat-related processes. This class includes natural or modified mires, bogs and fens, as well as peat extraction sites.	D
Rivers and lakes	Permanent freshwater inland surface waters. This class includes water courses and water bodies.	C
Marine inlets and transitional waters	Ecosystems on the land-water interface under the influence of tides and with salinityhigher than 0.5 ‰. They include coastal wetlands, lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments.	X01-X03 A1-A5, A
Coastal areas	Coastal, shallow, marine systems that experience significant land-based influences. These systems undergo diurnal fluctuations in temperature, salinity and turbidity, and are subject to wave disturbance. Depth is up to 50-70 m.	A1-A5, A7
Shelf	Marine systems away from coastal influence, down to the shelf break. They experience more stable temperature and salinity regimes than coastal systems, and their seabed is below wave disturbance. Depth is up to 200 m.	A5, A7
Open ocean	Marine systems beyond the shelf break with very stable temperature and salinity regimes, in particular in the deep seabed. Depth is beyond 200 m.	A6, A7

X01: Estuaries; X02: Saline coastal lagoons; X03: Brackish coastal lagoons; A1: Littoral rock and other hard substrata; A2: Littoral sediment; A3: Infralittoral rock and other hard substrata; A4: Circalittoral rock and other hard substrata; A5: Sublittoral sediment; A6: Deep-sea bed; A7: Pelagic water column

Table 2 Correspondence between Corine Land Cover classes and EUNIS habitat code, MAES typology and ecosystem types. Source: Biodiversity Information System for Europe

ES	MAES_L2	EUNIS L1	EUNIS code	EUNIS name	CLC	CLC_Name
Feshwater	Rivers and Lakes	**C** Inland surface **waters**	C1	Surface standing waters	512	Water bodies
			C2	Surface running waters	511	Water courses
			C3	Littoral zone of inland surface waterbodies	331	Beaches, dunes, and sand plains
			C3	Littoral zone of inland surface waterbodies	411	Inland marshes

Terrestrial	Wetlands	**D Mires**, bogs and fens	D1	Raised and blanket bogs	412	Peatbogs
					412	Peatbogs
			D2	Valley mires, poor fens and transition mires	411	Inland marshes
					411	Inland marshes
			D3	Aapa, palsa and polygon mires	412	Peatbogs
					412	Peatbogs
			D4	Base-rich fens and calcareous spring mires	411	Inland marshes
					411	Inland marshes
			D5	Sedge and reedbeds, normally without free-standing water	411	Inland marshes
					411	Inland marshes
			D6	Inland saline and brackish marshes and reedbeds	411	Inland marshes
	Grassland	**E Grasslands** and land dominated by forbs, mosses or lichens	E1	Dry grasslands	231	Pastures
					321	Natural grassland
			E2	Mesic grasslands	231	Pastures
					242	Complex cultivation patterns
					243	Land principally occupied by agriculture, with significant areas of natural vegetation
					321	Natural grassland
			E3	Seasonally wet and wet grasslands	231	Pastures
					321	Natural grassland
			E4	Alpine and subalpine grasslands	231	Pastures
					321	Natural grassland
			E6	Inland salt steppes	421	Salt marshes
			E7	Sparsely wooded grasslands	231	Pastures
					244	Agro-forestry areas
	Heathland and shrub	**F Heathland**, scrub and tundra	F1	Tundra	333	Sparsely vegetated areas
			F2	Arctic, alpine and subalpine scrub	322	Moors and heathland
					333	Sparsely vegetated areas
			F3	Temperate and mediterranean-montane scrub	322	Moors and heathland
					322	Moors and heathland
			F4	Temperate shrub heathland	322	Moors and heathland
			F5	Maquis, arborescent matorral and	323	Sclerophyllous vegetation
					323	Sclerophyllous vegetation

			thermo-Mediterranean brushes		
		F6	Garrigue	323	Sclerophyllous vegetation
		F7	Spiny Mediterranean heaths (phrygana, hedgehog-heaths and related coastal cliff vegetation)	323	Sclerophyllous vegetation
		F8	Thermo-Atlantic xerophytic scrub	323	Sclerophyllous vegetation
		F9	Riverine and fen scrubs	322	Moors and heathland
		FA	Hedgerows		
		FB	Shrub plantations	221	Vineyards
				222	Fruit trees and berry plantations
Woodland and forest	G Woodland, **forest** and other wooded land	G1	Broadleaved deciduous woodland	HRL forest	JRC_forest: deciduous
				311	Broad-leaved forest
		G2	Broadleaved evergreen woodland	223	Olive groves
				311	Broad-leaved forest
		G3	Coniferous woodland	HRL forest	JRC_forest: coniferous
				312	Coniferous forest
		G4	Mixed deciduous and coniferous woodland	313	Mixed forest
		G5	Lines of trees, small anthropogenic woodlands, recently felled woodland, early-stage woodland and coppice	324	Transitional woodland shrub
Sparsely or unvegetated land	H Inland **unvegetated** or sparsely vegetated habitats	H1	Terrestrial underground caves, cave systems, passages and waterbodies		
		H2	Screes	331	Beaches, dunes, and sand plains
		H3	Inland cliffs, rock pavements and outcrops	332	Bare rock
				333	Sparsely vegetated areas

			H4	Snow or ice-dominated habitats	335	Glaciers and perpetual snow
			H5	Miscellaneous inland habitats with very sparse or no vegetation	333	Sparsely vegetated areas
					334	Burnt areas
			H6	Recent volcanic features		
	Cropland	I Regularly or recently cultivated **agricultural**, horticultural and domestic habitats	I1	Arable land and market gardens	211	Non-irrigated arable land
					212	Permanently irrigated land
					213	Rice fields
					241	Annual crops associated with permanent crops
					242	Complex cultivation patterns
					243	Land principally occupied by agriculture, with significant areas of natural vegetation
			I2	Cultivated areas of gardens and parks	141	Green urban areas
					142	Sport and leisure facilities

2.3 Ecosystem services

2.3.1 What are ecosystem services

The concept of ESs as developed for the Millennium Ecosystem Assessment (MA) is currently the most extensive, international, scientific concept dealing with the interaction between the world's ecosystems and human well-being.

A large variety of ES definitions and classification approaches have been proposed. These include Daily et al. (1997), Costanza et al. 1997 (de Groot et al., 2002), Millennium Ecosystem Assessment (MA, 2005), Wallace (2007), Boyd and Banzhaf (2007), Fisher and Turner (2008), Haines-Young and Potschin (2010a, 2010b, 2013), TEEB (2010), Staub et al. (2011),

Daily et al. (1997) defines ESs as “a wide range of conditions and processes through which natural ecosystems, and the species that are a part of them, help sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors” (p. 2)

Costanza et al. 1997 define “ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions” (p.253)

de Groot et al., 2002 define ecosystem functions as “the capacity of natural processes and components to provide goods and services that satisfy human needs, directly or indirectly.”

The **MA report** defines ESs in the following way: “Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services, such as nutrient cycling, that maintain the conditions for life on Earth” (p. 39).

Boyd and Banzhaf’s (2007) definition is as follows: “Final ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being” (p. 619).

Wallace (2007), defines ESs using the terminology from MA (2005)—as “the benefits people obtain from ecosystems” (p. v).

Fisher and Turner’s (2008) definition of ESs (which draws largely on Boyd and Banzhaf) is as follows: Ecosystem services are “the aspects of ecosystems utilized (actively or passively) to produce human well-being” (p. 1168).

In the proposal for CICES -**Haines-Young and Potschin (2010a, 2010b, 2013),** ecosystem goods and services are defined to be the contributions that ecosystems make to human well-being, and arise from the interaction of biotic and abiotic processes

The Economics of Ecosystems and Biodiversity **(TEEB, 2010),** which defines ES as, ‘the direct and indirect contributions of ecosystems to human well-being’ (TEEB, 2010)

In **Staub et al. (2011),** study, ESs “concentrates on those aspects of ecosystems that have a recognizable connection to (human) welfare, that is, are used or valued in some form or other by the human population” (p. 3). This approach follows Boyd and Banzhaf (2007) in considering only those goods and services that are directly enjoyed, consumed or used by humans as Final Ecosystem Goods and Services (FEGS).

Burkhard etal.,2012a define ESs as the contributions of ecosystem structure and function—in combination with other inputs—to human well- being

Despite differences in the exact definition of ESs in terms of whether only direct benefits are considered (Boydand Banzhaf,2007) or also indirect benefits or passively used aspects of ecosystems (Costanza et al.,1997; Fisher et al.,2009), most commentators agree that there is some kind of ‘pathway’ that goes from ecological structures and processes at one end through to the well-being of people at the other. This idea can be represented in terms of what we call the ‘cascade model’. Figure 1 illustrates the ESs ‘cascade model’ (Potschin and Haines-Young 2011, 2016) which sets out the way ESs connect ecological structures and processes to the benefits and values realized by society, and hence the way human well-being depends on the underpinning characteristics of living systems or biodiversity.

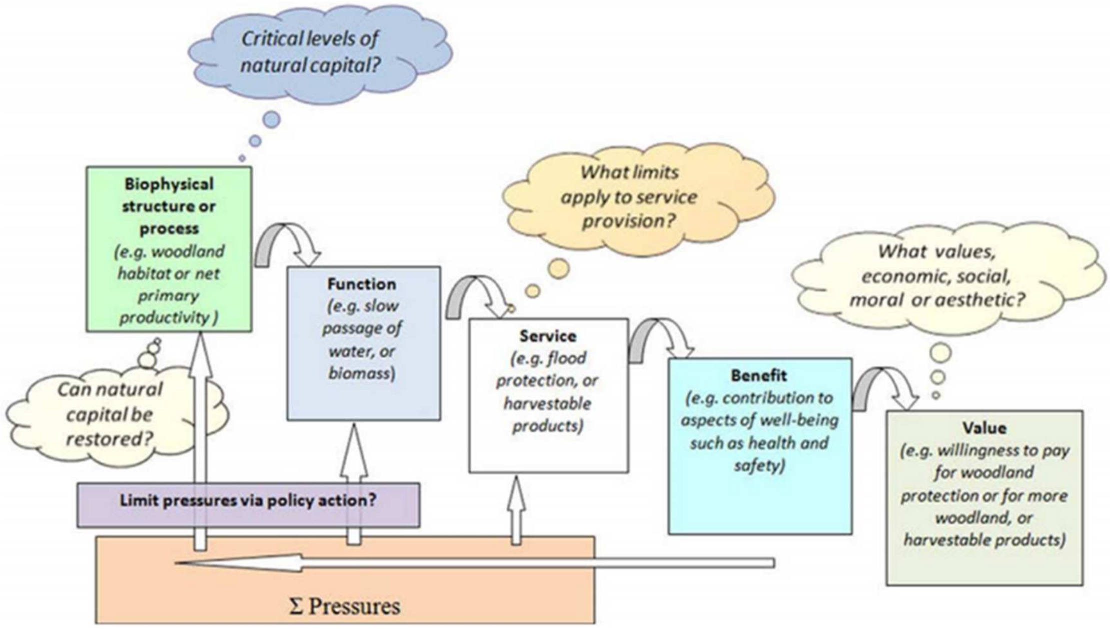

Figure 1 The ecosystem service cascade model initially proposed in (Haines-Young and Potschin, 2010) modified to separate benefits and values in (De Groot Rudolf et al., 2010)

2.3.2 Ecosystem services approach

The concept of an ecosystem provides a valuable framework for analyzing and acting on the linkages between people and their environment. For that reason, the ecosystem approach has been endorsed by the Convention on Biological Diversity (CBD) and the Millennium Ecosystem Assessment (MA) conceptual framework is entirely consistent with this approach.(MEA, 2005)

An ES approach helps to identify and classify the benefits that people derive from ecosystems. It also includes market and non-market, use and non-use, tangible and non-tangible benefits. It also explains consumers and producers of ES for maintenance and improvement of ecosystems for human well-being (Cork et al., 2007). The approach helps to describe and communicate benefits derived from natural and modified ecosystems to a wide range of stakeholders (Figure 2).

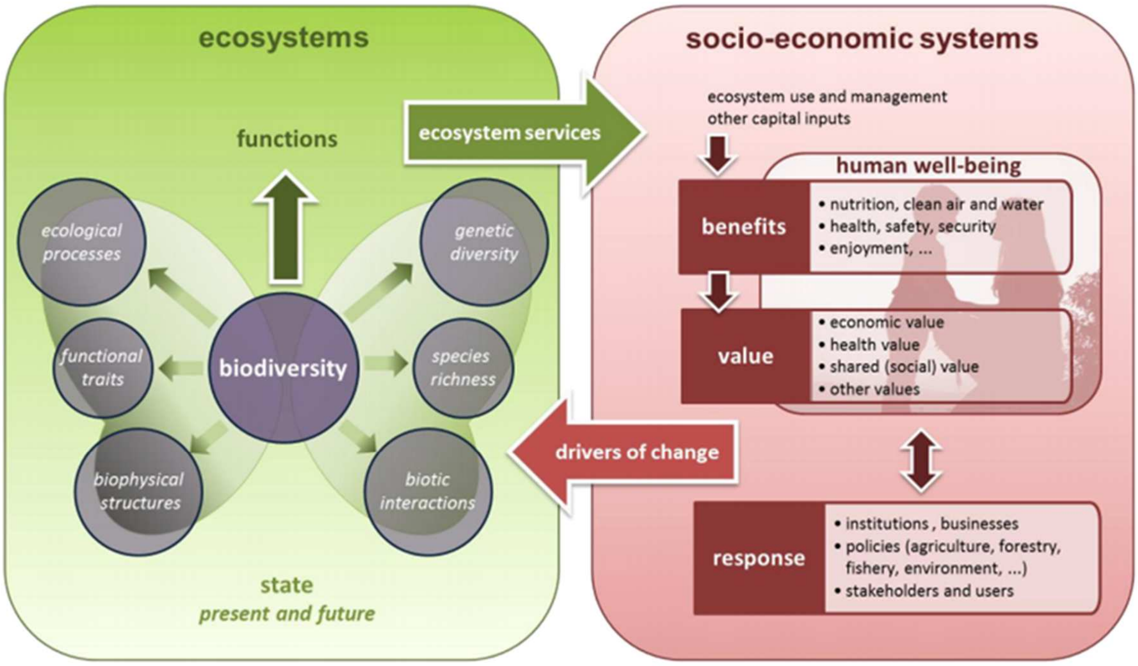

Figure 2 Conceptual framework for EU wide ecosystem assessment

Ecosystems directly contribute to human well-being via the provision of ESs. The benefits provided by ESs within systems are direct, such as food and raw materials, and indirect as the regulation of water supply and quality and nutrient cycling example. Underpinning these services is a suite of ecological functions that must be understood in a first step to valuing, managing and enhancing ES provision (Onil et al., 2013).

Making the link between function and service also enables us to identify threats to ESs from unsustainable management practices. Ecosystem functions result from the interactions between characteristics, structures and processes (Turner et al., 2000) constituting the physical, chemical, and biological exchanges and processes that contribute to the self-maintenance and self-renewal of an ecosystem (e.g. nutrient cycling and food-web interactions). Ecosystem functions involve interactions between biotic and abiotic system components in achieving any and all ecosystem outcomes (National Research Council, 2005). de Groot et al., (2002) illustrates the link between ecosystem function and human benefit by defining function as the capacity of natural processes and components to provide goods and services that generate human utility. Linking ecosystem function to human benefit should encourage ecosystem-based management because of the monetary or non-monetary benefits provided by functionally diverse systems (Willemen et al., 2010; Onil et al., 2013)

2.3.3 Typology for classification of ecosystem services

Any application of an ES-based approach starts with choosing the services to be assessed (and valued) from a list of services, i.e a classification system. Classification systems are usually based on a theoretical framework whose principles and concepts are reflected in the meaning and structure of the items presented (La Notte et al., 2017). The most renowned and used overarching classification systems are:

MEA - Millenium Ecosystem services Assessment (2005)

TEEB -The Economy of Ecology and Biodiversity (2008)

CICES - The Common International Classification of Ecosystem Services (2010)

2.3.3.1 Millennium Ecosystem Assessment classification system

The Millennium Ecosystem Assessment (2005) categorization provided a sound basis to launch ESs research and applications, but it does not constitute a proper taxonomy (La Notte et al., 2017)

The Millennium Ecosystem Assessment (2005) was the first large scale ecosystem assessment that has been adopted and further refined by TEEB and CICES. The MA organizes ESs into four well known groups:

1. provisioning services (e.g. food, fibers, fuel, genetic resources);
2. regulating services (e.g., water purification and regulation, climate regulation, extreme events and disease mitigation);
3. supporting services (e.g., primary production and nutrient cycling);
4. and cultural services (e.g., eco-tourism and recreation, aesthetic and spiritual values).

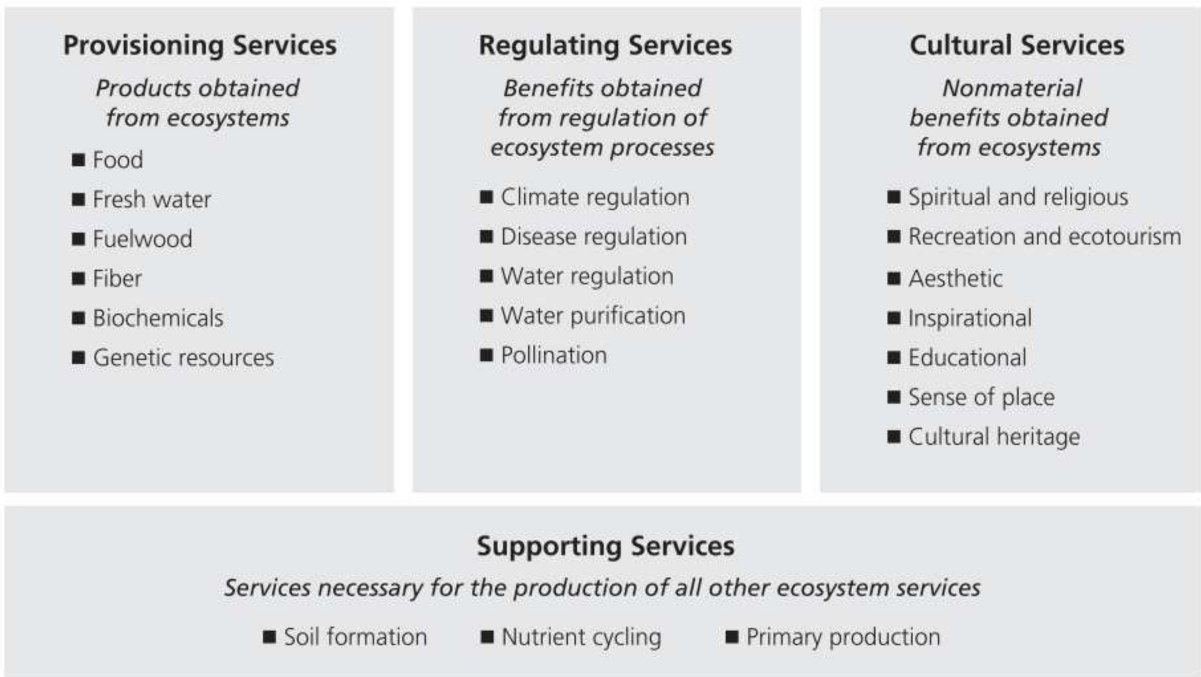

Figure 3 Ecosystem Services. Source: Millennium Ecosystem Assessment framework (2005)

2.3.3.2 TEEB classification system

The Economics of Ecosystems and their Biodiversity (TEEB) is a global initiative aiming at highlighting the economic benefits of biodiversity including the growing cost of biodiversity loss and ecosystem degradation. TEEB project, which followed on from the Millennium Ecosystem Assessment, proposes a typology of 22 ESs divided in 4 main categories. However the TEEB classification replaced ‘supporting services’ with ‘habitat or supporting services’, which comprise ‘habitats for species’ and ‘maintenance of genetic diversity’ (TEEB, 2010b), highlighting the importance of ecosystems to provide habitat for migratory species (e.g. as nurseries) and gene-pool protectors (e.g. natural habitats allowing natural selection processes to maintain the vitality of the gene pool). The availability of these services is directly dependent on the state of the habitat providing the service.(Maes et al., 2011).

1. provisioning services: the goods or products obtained from ecosystems
2. regulating services: the benefits obtained from an ecosystem's control of natural processes
3. habitat services: services supporting the provision of others by providing habitat
4. cultural services: the nonmaterial benefits obtained from ecosystems

Table 3 Ecosystem Service classification suggested in TEEB

Main service-types	
PROVISIONING SERVICES	
1	Food (e.g. fish, game, fruit)
2	Water (e.g. for drinking, irrigation, cooling)
3	Raw Materials (e.g. fibre, timber, fuel wood, fodder, fertilizer)
4	Genetic resources (e.g. for crop-improvement and medicinal purposes)
5	Medicinal resources (e.g. biochemical products, models & test-organisms)
6	Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion)
REGULATING SERVICES	
7	Air quality regulation (e.g. capturing (fine)dust, chemicals, etc)
8	Climate regulation (incl. C-sequestration, influence of veg. on rainfall, etc.)
9	Moderation of extreme events (e.g. storm protection and flood prevention)
10	Regulation of water flows (e.g. natural drainage, irrigation and drought prevention)
11	Waste treatment (esp. water purification)
12	Erosion prevention
13	Maintenance of soil fertility (incl. soil formation)
14	Pollination
15	Biological control (e.g. seed dispersal, pest and disease control)
HABITAT SERVICES	
16	Maintenance of life cycles of migratory species (incl. nursery service)
17	Maintenance of genetic diversity (esp. gene pool protection)
CULTURAL SERVICES	
18	Aesthetic information
19	Opportunities for recreation & tourism
20	Inspiration for culture, art and design
21	Spiritual experience
22	Information for cognitive development

2.3.3.3 Common International Classification of Ecosystem Services

The Common International Classification of Ecosystem Services offers a structure that links with the framework of the UN System of Environmental-Economic Accounts (SEEA 2003) (United Nations, 2003). CICES builds on the existing classifications but focusses on the ES dimension.

CICES has been developed to support the work of the European Environment Agency on environmental accounting and is linked with the UN System of Environmental Economic Accounts (SEEA). It therefore focuses on services that are used directly CICES groups services into 3 sections.

1. Provisioning services: Material and energetic outputs from ecosystems from which goods and products are derived
2. Regulating services: the ways that ecosystems can mediate the environment in which people live or depend on in some way and therefore benefit from them in terms of health or security.
3. Cultural services: all the non-material characteristics of ecosystems that contribute to, or are important for people's mental or intellectual well-being.

CICES is hierarchical in structure, splitting these major 'sections' successively into 'divisions', 'groups' and 'classes'.

CICES has been adopted by the Mapping and Assessment of Ecosystems and their Services (MAES), the hierarchical structure of CICES is very useful to bundle services at class level and could be used for data poor systems where indicators may only be available at division or group level.

The first fully operational version CICES (V4.3) was published in 2013. On the basis of the experience gained since then by the user community, its structure and scope has been reviewed, and a fully revised version (V5.1) is now available (https://cices.eu/resources/)

Table 4 Common International Classification of Ecosystem Services

Section	Division	Group	Class
	This column divides section categories into main types of output or process.	*The group level splits division categories by biological, physical or cultural type or process.*	*The class level provides a further sub-division of group categories into biological or material outputs and bio-physical and cultural processes that can be linked back to concrete identifiable service sources.*
Provisioning	Nutrition	Biomass	Cultivated crops
			Reared animals and their outputs
			Wild plants, algae and their outputs
			Wild animals and their outputs
			Plants and algae from in-situ aquaculture
			Animals from in-situ aquaculture
		Water	Surface water for drinking
			Ground water for drinking
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing
			Materials from plants, algae and animals for agricultural use
			Genetic materials from all biota
		Water	Surface water for non-drinking purposes
			Ground water for non-drinking purposes
	Energy	Biomass-based energy sources	Plant-based resources
			Animal-based resources
		Mechanical energy	Animal-based energy

Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals
		Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems
			Dilution by atmosphere, freshwater and marine ecosystems
			Mediation of smell/noise/visual impacts
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates
			Buffering and attenuation of mass flows
		Liquid flows	Hydrological cycle and water flow maintenance
			Flood protection
		Gaseous / air flows	Storm protection
			Ventilation and transpiration
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal
			Maintaining nursery populations and habitats
		Pest and disease control	Pest control
			Disease control
		Soil formation and composition	Weathering processes
			Decomposition and fixing processes
		Water conditions	Chemical condition of freshwaters
			Chemical condition of salt waters
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations
			Micro and regional climate regulation
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings
			Physical use of land-/seascapes in different environmental settings
		Intellectual and representative interactions	Scientific
			Educational
			Heritage, cultural
			Entertainment
			Aesthetic
	Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Spiritual and/or emblematic	Symbolic
			Sacred and/or religious
			Existence

	[environmental settings]	Other cultural outputs	Bequest

2.3.3.4 Cross tabulation of classification systems

A cross tabulation of Millennium Ecosystem Assessment, TEEB and CICES classification systems is presented in table 6.

Table 5 cross tabulation of MA, TEEB and CICES classification systems. Source:(Maes et al., 2013)

Section	MA categories	TEEB categories	CICES v4.3 group*
Provisioning services	Food (fodder)	Food	Biomass [Nutrition]
			Biomass (Materials from plants, algae and animals for agricultural use)
	Fresh water	Water	Water (for drinking purposes) [Nutrition]
			Water (for non-drinking purposes) [Materials]
	Fibre, timber	Raw Materials	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
	Genetic resources	Genetic resources	Biomass (genetic materials from all biota)
	Biochemicals	Medicinal resources	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
	Ornamental resources	Ornamental resources	Biomass (fibres and other materials from plants, algae and animals for direct use and processing)
			Biomass based energy sources
			Mechanical energy (animal based)
Regulating services (TEEB) Regulating and supporting services (MA) Regulating and maintenance services (CICES)	Air quality regulation	Air quality regulation	[Mediation of] gaseous/air flows
	Water purification and water treatment	Waste treatment (water purification)	Mediation [of waste, toxics and other nuisances] by biota
			Mediation [of waste, toxics and other nuisances] by ecosystems
	Water regulation	Regulation of water flows	[Mediation of] liquid flows
		Moderation of extreme events	
	Erosion regulation	Erosion prevention	[Mediation of] mass flows
	Climate regulation	Climate regulation	Atmospheric composition and climate regulation
	Soil formation (supporting service)	Maintenance of soil fertility	Soil formation and composition
	Pollination	Pollination	Lifecycle maintenance, habitat and gene pool protection
	Pest regulation	Biological control	Pest and disease control

	Disease regulation		
	Primary production Nutrient cycling (supporting services)	Maintenance of life cycles of migratory species (incl. nursery service)	Lifecycle maintenance, habitat and gene pool protection
			Soil formation and composition
			[Maintenance of] water conditions
		Maintenance of genetic diversity (especially in gene pool protection)	Lifecycle maintenance, habitat and gene pool protection
Cultural services	Spiritual and religious values	Spiritual experience	Spiritual and/or emblematic
	Aesthetic values	Aesthetic information	Intellectual and representational interactions
	Cultural diversity	Inspiration for culture, art and	Intellectual and representational interactions
		design	Spiritual and/or emblematic
	Recreation and ecotourism	Recreation and tourism	Physical and experiential interactions
	Knowledge systems and educational values	Information for cognitive development	Intellectual and representational interactions
			Other cultural outputs (existence, bequest)
	MA provides a classification that is globally recognised and used in sub global assessments.	*TEEB provides an updated classification, based on the MA, which is used in on-going national TEEB studies across Europe.*	*CICES provides a hierarchical system, building on the MA and TEEB classifications but tailored to accounting.*

2.4 Forest ecosystem services

Forests are a crucial element not only of landscapes but of human living conditions. Forests have supported people's livelihoods throughout history, particularly when crops failed. Covering nearly a third of the earth's land surface, they provide multiple ES and habitats for a multitude of species. They hold the majority of the world's terrestrial species. However, these biologically-rich systems are increasingly threatened, largely as a result of human activity, such as land-use and climate change, deforestation, afforestation, wildfires, storms, insects and pathogen outbreaks (Burkhard and Maes, 2017).

Timber production has often dominated the way in which forests were managed until the 20th century. New challenges and increasing pressures in the 21st century have stimulated a multi-functional approach, involving the delivery of multiple goods and services including regulating ES (e.g. climate regulation and mitigation, erosion control, hydrological regulation). Nowadays, in most regions of the world, forests, trees on farms and agro-forestry systems play important roles in the livelihoods of people by providing employment, energy, nutritious foods and a wide range of ES. Well-managed forests have a high potential to contribute to sustainable development and to a greener economy (Burkhard and Maes, 2017).

The values of the flows of benefits from forest ESs to society can only be approximated, as scarcely any data that would allow such a valuation exist. The value of the stock of forest capital has been roughly estimated from values of timber and the available values of a few non-wood forest products. The outputs of such interactions are functions of the ecosystem, such as primary production. This expresses the potential of the ecosystem to deliver ESs, which are linked to ecosystem health. A healthy forest ecosystem would be fully functioning, as it would include the full range of ecosystem interactions needed for the support of service generation (EEA, 2016a).

Forest Provisioning services which include products such as food (e.g. game, roots, seeds, nuts and other fruit, spices and fodder), fibre (e.g. wood, water and cellulose), medicinal products (e.g. aromatic plants and pigments), and drinking water.

Forest Regulation and maintenance services include all the ways in which forest ecosystems can mediate or moderate the environment that affects human performance and are of paramount importance for human society and include services for (1) carbon sequestration; (2) climate and water regulation; (3) protection from natural hazards, such as floods, avalanches, rock-fall and erosion; (4) water and air purification; and (5) disease and pest regulation

Forest cultural services include the non-material outputs of forest ecosystems. Cultural services should be regarded as the physical settings, locations or situations that satisfy the spiritual and aesthetic appreciation of ecosystems and their components.(EEA, 2016a)

Finally, ESs also support biodiversity. In the EU Biodiversity Strategy, biodiversity and ESs are defined as natural capital (EEA, 2016a). Figure 5 illustrates the interconnections among the structural elements of a forest ecosystem, which comprises living and non-living elements that are based on fundamental ecosystem processes.

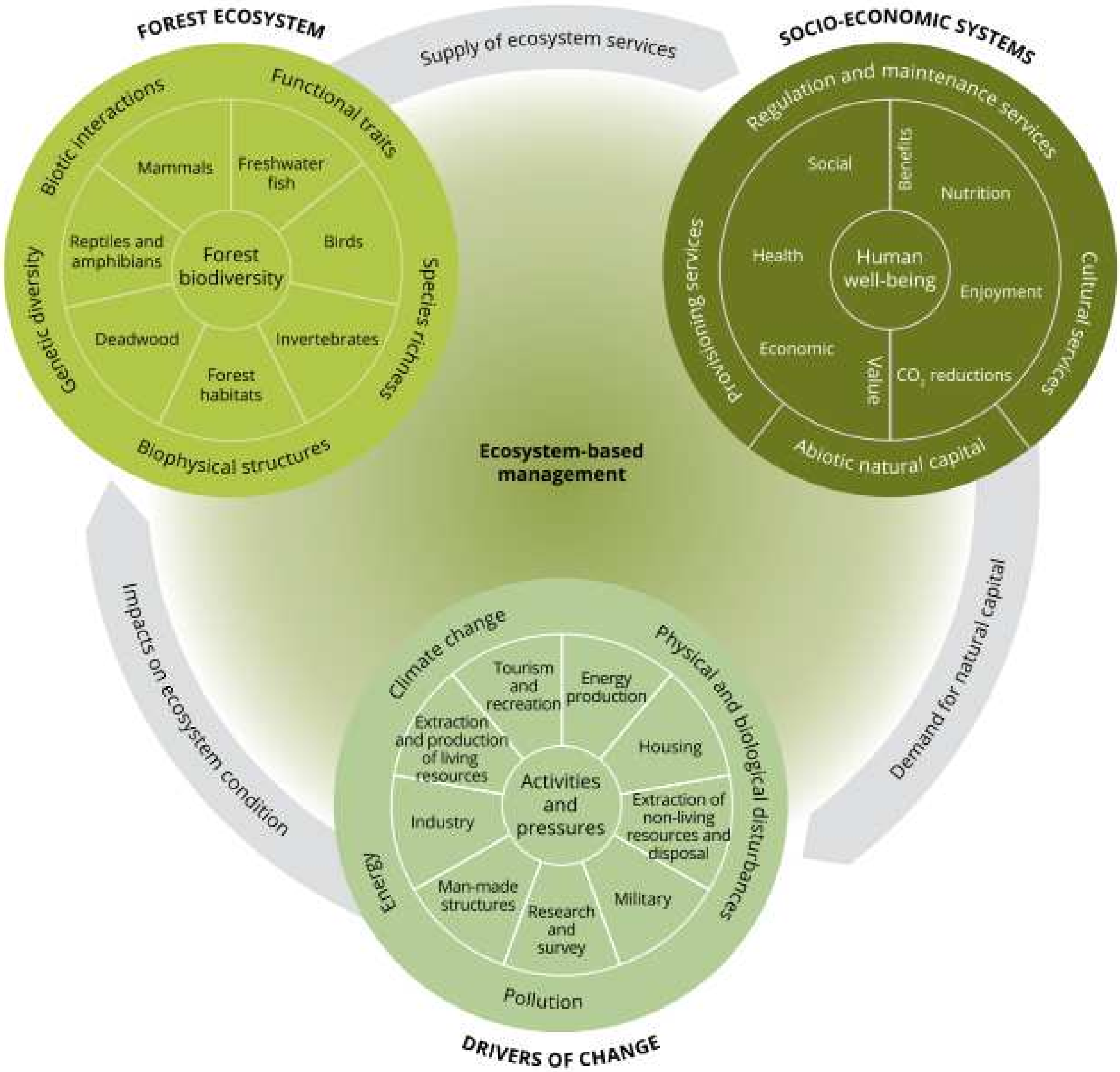

Figure 4 Conceptual framework for forest ecosystems. Source: (EEA, 2016a).

2.4.1 Typology of forest ecosystem services

The services provided by forests and woodlands are numerous and diverse on all spatial and temporal levels, and include provisioning, regulating, and cultural services. Some national classifications account for as many as 100 different kinds of forest services, such as delivery of industrial and fuelwood, water protection and regulation, ecotourism, and spiritual and historical values (Figure 6.) These various forest ecosystem services (FES) relate to each other in many different ways, ranging from synergistic to tolerant, conflicting, and mutually exclusive (Mace et al., 2005).

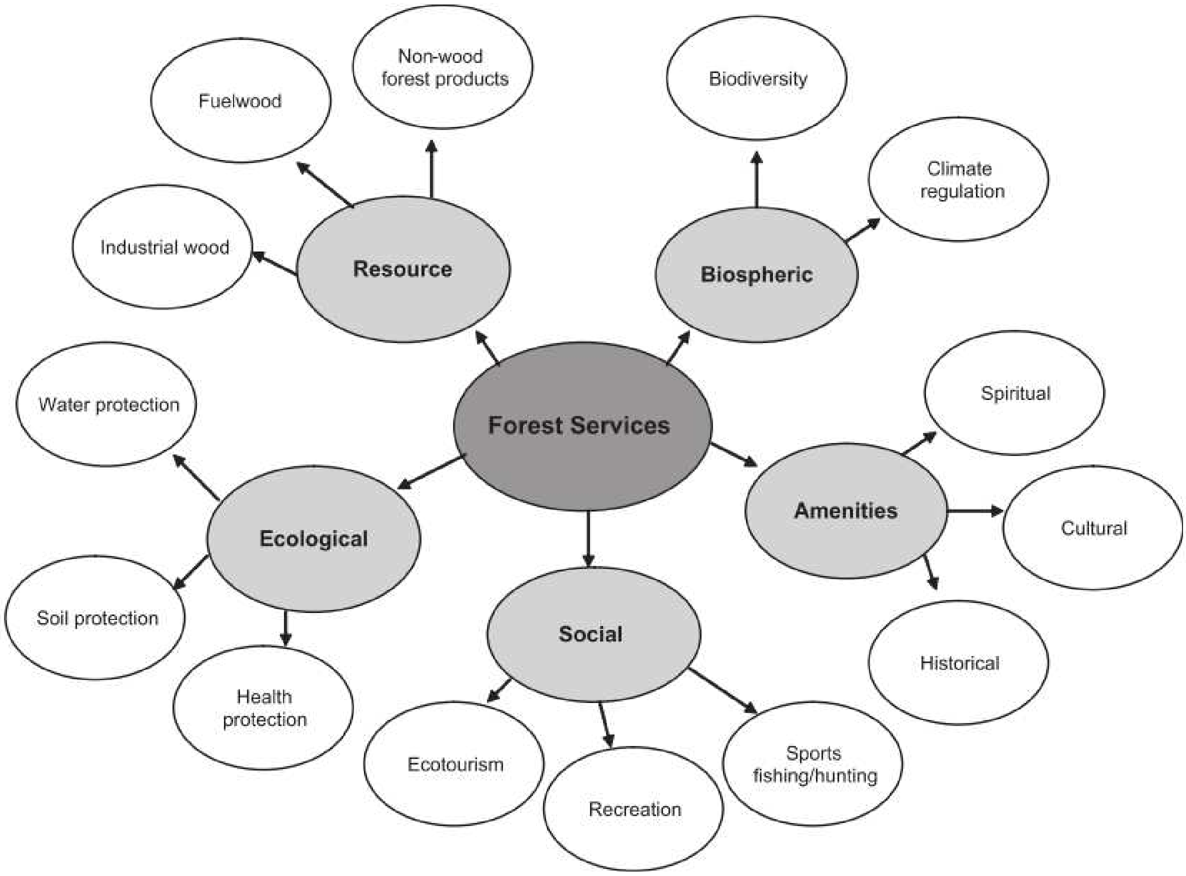

Figure 5 Major Classes of Forest Services. Source (Mace et al., 2005)

From the original classification of ES from MA, TEEB and CICES a comparison including only FES is shown in Table 7. The main categories of provision, regulation (and maintenance) and cultural (and amenity) are comparable and in many cases the subcategories are also coincident.

Table 6 Comparison of three main classifications of ecosystem services (only those services supplied by forest ecosystems are shown)

MA	TEEB	CICES
PROVISIONING	**PROVISIONING**	**PROVISIONING**
Industrial wood	Raw materials	Materials / Biomass, fibre
Fuelwood		Energy / Biomass-based energy
Non-wood forest products	Food / Raw materials	Nutrition / Biomass
		Materials / Biomass, fibre
Fresh water (water purification) (also Regulation service)	Water supply	Materials / Water
		Nutrition / Water
Genetic resources	Genetic resources	Materials / Biomass, fibre (genetic resources)
REGULATION	**REGULATING**	**REGULATION AND MAINTENANCE**
Pest regulation	Biological control	

Disease regulation Health protection		Maintenance of physical, chemical, biological conditions / Pest and disease control
Water regulation	Regulation of water flows	Mediation of flows / Liquid flows
	Disturbance prevention or moderation	Mediation of flows / Air flows (storms)
Water purification and waste treatment	Waste treatment (water purification)	Maintenance of physical, chemical, biological conditions / Water conditions
Air quality regulation	Air purification	Maintenance of physical, chemical, biological conditions / Atmospheric composition and climate regulation
Climate regulation (incl. C sequestration)	Climate regulation (incl. C sequestration)	Maintenance of physical, chemical, biological conditions / Atmospheric composition and climate regulation
Soil protection (erosion regulation)	Erosion prevention	Mediation of flows / Mass flow
Soil formation (supporting service)	Maintaining soil fertility	Maintenance of physical, chemical, biological conditions / Atmospheric composition and climate regulation
Pollination	Pollination	Maintenance of physical, chemical, biological conditions / Lifecycle maintenance, habitat and gene pool protection
	HABITAT	
Biodiversity repository	Maintenance of genetic diversity	Maintenance of physical, chemical, biological conditions / Lifecycle maintenance, habitat and gene pool protection
	(especially in gene pool protection)	
	Lifecycle maintenance	
CULTURAL	**CULTURAL & AMENITY**	**CULTURAL**
Spiritual	Spiritual experience	Spiritual, symbolic and other interactions with ecosystems and landscapes / Spiritual and/or emblematic
Cultural	Inspiration for culture, art & design	Spiritual, symbolic and other interactions with ecosystems and landscapes / Intellectual and representative interactions
Historical		
Ecotourism	Recreation & Tourism	Physical and intellectual interactions with ecosystems and landscapes / Physical and experiential interactions
Recreation		
Sports: fishing/hunting		
Aesthetic values	Aesthetic information	Spiritual, symbolic and other interactions with ecosystems and landscapes / Other cultural outputs
Knowledge systems & Education	Information for cognitive development	Physical and intellectual interactions with ecosystems and landscapes / Intellectual and representative interactions

SUPPORTING (in MA services necessary for the production of all other ES)		
Nutrient cycling		
Primary production		

2.4.2 *Urban forest ecosystem services*

2.4.2.1 *Urban forest ecosystems*

The use of trees in cities in the modern world has a long history in many and diverse places. Tree practices in "walks and avenues" have been applied in Britain in the 1600s–1900s (Johnston 2015). According to Lawrence (1993), tree planting in European cities is originated from boulevard and allée planting in private gardens, as well as in avenues and then public gardens, squares and promenades. In the United States, "tree wardens" were employed in the early 1900s, while the specific discipline of urban forestry was established for first time in 1894. However, it has been evolved mainly in the 1960s, in order to address problems related to trees in urban areas (Konijnendijk van den Bosch et al. 2006). In the 1970s–80s, the "trees outside forests" concept has been described as urban forestry to address the practical uses of trees and their close connection with people (Long and Nair 1999). In China, urban forestry began to attract research attention in 1989 and urban greening polices applied (Wang 1995).

Definitions of urban areas and their boundaries vary between countries and regions (Gómez-Baggethun et al. 2013). As a result, there are also various definitions of urban forests. According to FAO (2016), "urban forests can be defined as networks or systems comprising all woodlands, groups of trees, and individual trees located in urban and peri-urban areas; they include, therefore, forests, street trees, trees in parks and gardens, and trees in derelict corners". Urban forests are the main component of the green infrastructure. They bridge rural and urban areas and they ameliorate environmental footprint of the cities. Following the FAO (2016) classification there are five main urban forest types:

a) Peri-urban forests and woodlands. They include forests and woodlands surrounding towns and cities. They can provide a variety of ecosystem services such as wood, non-wood forest products, clean water and recreational activities.

b) City parks and urban forests (>0.5 ha). Large urban or district parks are included in this type. They are, at least partly, equipped with facilities for leisure and recreation.

c) Pocket parks and gardens with trees (<0.5 ha). This type includes small district parks equipped with facilities for leisure and/or recreation, as well as private gardens and green spaces.

d) Trees on streets or in public squares. Lines of street trees, small groups of trees and individual trees.

e) Other green spaces with trees. Urban agricultural plots, sports grounds, lawns, river banks, open fields, cemeteries and botanical gardens can be included

2.4.2.2 *Classifying Urban Ecosystem Services*

Since the publication of the Millennium Ecosystem Assessment (MEA 2005), the term Ecosystem services (ES) is used prodigiously with respect to current urban ecosystems and in urban forest research (Haase et al. 2014). It has to be noted that less attention has been paid to urban forest ecosystem services in comparison to other ecosystems like wetlands or forests, although the majority of the world's population is living in cities (Gómez-Baggethun et al. 2013). Only recently research on urban forest ecosystem services has been increased (Seppelt et al. 2011; Cilliers et al. 2013; Roy et al. 2012; Haase et al. 2014; Haase 2015). However, the concept of managing and planting trees in cities to improve life quality of the citizens is much older.

The aim of this section is to classify and describe ecosystem services provided in urban forests and also to demonstrate how these services may benefit quality of life in cities.Urban forest ecosystems are especially important in providing services with direct impact on human health and security such as air purification, noise reduction, urban cooling, and runoff mitigation. The following classification and the description of important ecosystem services provided by urban forests are based on CICES

1. Provisioning Services

Although timber and fuel wood production is not included in the main goals of urban forestry in the developed countries, they are still important products of peri-urban forests, and especially in some less developed countries. Non-wood forest products (NWFPs) are also very important and can include hunting & fishing products, honey, mushrooms, truffles, cork, nuts, fruits, resin, essential oils, forage, ornamental plants etc. Likewise timber production, NWFPs production of urban forests is relatively small. Besides NWFPs, food production in urban forests can take place on rooftops, in backyards and in community gardens (Andersson et al. 2007; Barthel et al. 2010). Food production in cities is only a small proportion of the food that consumed, and do not meet the city demands (Folke et al. 1997; Ernstson et al. 2010). However, food production in urban forestry can play an important role for food security, especially during economic and political crises (Smit and Nasr 1992; Buchmann 2009; Barthel et al. 2011; Barthel and Isendahl 2013).

In 2014 more than the half of the global population was urban, while in Europe this was 70% (United Nations 2015), while it is estimated that approximately 65% of the world's population and 84% in Europe will be living in urban areas by 2050. The demand for natural resources (MA, 2005), and particularly for energy and water, is expected to be increased as a result of the urban (and total) population increase. The demand for water is expected to be increased by 55% between 2000 and 2050 (United Nations World Water Assessment Programme 2014). Ecosystems provide cities with fresh water for drinking and other human uses and by securing storage and controlled release of water flows. Vegetation cover and forests in the city catchment play an essential role to the quantity of available water (Gómez-Baggethun et al. 2013). One example of the importance of functioning ecosystems for city water supply is the Omerli Watershed outside Istanbul, Turkey, a megacity with over ten million people. The Omerli Watershed is the most important watershed which provides drinking water to Istanbul. However, it is threatened by urban development in and around its drinking water sources, and it faces unplanned pressures of urbanization with serious potential impacts on water quality (Wagner et al. 2007). The effect of urban population growth on peri-urban forests is expected to be particularly prominent since urban land cover increases even faster than could be expected from demographic pressure, resulting in substantial land use conversions (Angel et al. 2011; Seto et al. 2011).

2. Regulating Services

Urban heat island effects and summer heat waves are among the serious environmental and human health challenges facing in the cities (Hamin and Gurran 2009; McGeehin and Mirabelli 2001). Summer heat waves specifically, have been recognised as the most prominent hazard in Europe regarding human fatalities (EEA 2010). Urban forests and other green infrastructure can reduce the intensity of heat islands by providing shade and evapotranspirational cooling. Vegetation reduces temperature in the hottest months through shading and through absorbing heat from the air by evapotranspiration (Hardin and Jensen 2007). Water from the plants absorbs heat as it evaporates, thus cooling the air (Nowak and Crane 2000). Trees can also regulate surface and air temperatures by reflecting solar radiation and shading surfaces, such as streets and sidewalks that would otherwise absorb heat. Urban trees are perhaps the most effective and cheap solution to urban heat island mitigation and adaptation (Norton et al. 2015; Solecki et al. 2005), while this service is among the most important regulating ecosystem services that trees provide to cities (McPhearson et al. 2011).

Noise pollution due to traffic and construction constitutes a major problem in cities, which negatively affects human health through stress. Urban forests can mitigate noise pollution through absorption, deviation, reflection, and refraction of soundwaves (Aylor 1972; Fang and Ling 2003). Vegetation factors important for noise reduction include density, width, height and length of the tree belts as well as leaf size and branching characteristics. The wider vegetation belt, the higher density and species with more foliage and branches increase the noise reduction effect (Fang and Ling 2003).

Air pollution from transportation, industry and solid urban waste incineration is probably the most essential problem for environmental quality and human health (respiratory and cardiovascular diseases) in the cities (Garty et al., 1996; Sawidis et al., 2011). Thus, improving the air quality in cities is among the main challenges for the European Union (EU). Air pollution due to particulate matter (PM) represents one of the main health risks for European citizens (EEA, 2015). The daily air quality limit value for coarse PM (PM10) frequently exceed the limits laid down in air pollution regulations. Urban forests can improve air quality by removing pollutants from the atmosphere, including ozone (O3), sulfur dioxide (SO2), nitrogen dioxide (NO2), carbon monoxide (CO) and PM less than 10 μm (PM10) (Nowak 1994; Escobedo et al. 2008; Samson et al. 2017). Nowak et al. (2014) reported that the improvement in air quality, measured as a percentage of air pollution removal by trees, accounts for less than 1% in the USA. In the city of Barcelona, urban forest reduce PM10 air pollution by 2.66% (Barò et al. 2014). However, in highly vegetated areas, trees can improve air quality by 16% (Nowak et al. 2006). Removal of pollution takes place as plants filter out airborne particulates through their leaves (Nowak 1996), while this procedure varies greatly between plant species (Aylor et al. 2003).

Besides the role in air pollutant uptake, urban green infrastructure and particularly urban forests can highly influence the carbon sequestration capacity in the urban areas (Edmondson et al., 2012; Pataki et al., 2006). Urban trees act as a sinks of CO2 by storing excess carbon as biomass during photosynthesis (McPherson and Simpson 1999). The amount of CO2 stored is generally proportional to the biomass of the trees. Urban soils also act as carbon pools (Nowak and Crane 2000; Churkina et al. 2010). Thus, there is great interest in the carbon sequestration potential of urban vegetation systems both above- and below-ground.

Urban stormwater runoff and flash flooding occur when impermeable surface cover increases due to continued urbanization (Walsh et al. 2012). This is a growing problem in the cities as the frequency of extreme rainfall events will be increased as a consequent of climate change (Wissmar et al. 2004). Urban forests can reduce surface water runoff by intercepting water through the vegetation canopy (Villarreal and Bengtsson 2005). The underlying soil can also significantly reduce infiltration rates by storing water in the pore spaces until it percolates. It has been well documented that interception of rainfall by tree canopies slows down flooding effects and green areas reduce the pressure on urban drainage systems by percolating water (Bolund and Hunhammar 1999; Pataki et al. 2011). Moreover, vegetation can stabilize the ground and reduce the likelihood of landslides.

Urbanized catchments maybe also suffer by nitrate, phosphate, sulfate, carbon, and heavy metal pollution in waterways (Bernhardt et al. 2008; Kaushal and Belt 2012) mainly due to wastes from urban effluents. Urban forest ecosystems can play a significant role in decreasing nutrient pollution concentrations in urban catchment run-off by filtering wastes.

Pollination, pest regulation and seed dispersal are important processes in the functional diversity of urban forest ecosystems and can play a critical role in their long-term durability (Andersson et al. 2007). Management practices applied in urban forests may promote functional groups of insects that enhance pollination and bird communities, which in turn enhance seed dispersal (Andersson et al. 2007). However, these procedures are threatened by habitat loss and fragmentation due to urbanisation.

Moreover, Interest in maintaining and even enhancing biodiversity within urban forest ecosystems is increasing, not only for the inherent value of biodiversity conservation itself but also because of their societal benefits (e.g., environmental awareness, mental health and well-being) realised from viewing and interacting with biodiversity. Urban forests play a significant role as habitat for many species of avifauna, amphibians, bees, and butterflies (Melles et al. 2003; Müller et al. 2010). Biodiversity usually peaks at intermediate levels of urbanization, while it typically declines as urbanization intensifies (Blair 1996) following the intermediate disturbance hypothesis existing in various other types of ecosystems.

3. Cultural Services

Recreation is one of the numerous benefits that individuals and societies gain from landscapes and natural environments. Recreational ecosystem services benefit people through improved physical health via exercise, as well as psychological and emotional well-being (Konijnendijk et al. 2013). As city environments are usually stressful for people, the recreational aspects of urban forest ecosystems are among the highest valued ecosystem services in cities (Kaplan and Kaplan 1989; Bolund and Hunhamar 1999; Chiesura 2004; Konijnendijk et al. 2013) and are investigated more than the other ecosystem services provided by urban forests. According to Kaplan and Talbot (1983) a park experience may reduce stress, enhance contemplativeness, rejuvenate the city dweller and provide a sense of peacefulness and tranquillity. The recreational value of urban forests is depending on ecological characteristics such as diversity components, as well as on built infrastructure (eg availability of benches and sport facilities). Social criteria like accessibility, penetrability, safety, privacy and comfort also influence the recreational opportunities of urban forests. It has to be noted that recreational opportunities can often provide an economic basis for communities and related businesses.

Aesthetic benefits from urban forests have been associated with reduced stress (Ulrich 1981) and with increased physical and mental health (Maas 2006). Ulrich (1984) reported that a view through a window to urban green can accelerate recovery from surgeries, while according to van den Berg et al. (2010b) the proximity of an individual’s home to urban forest can reduce stress-related health problems.

Urban forests are often used for environmental education purposes (Groening 1995; Tyrväinen et al. 2005) due to their proximity and accessibility, while they provide multiple opportunities for cognitive development which increases the potential for stewardship of the environment and for a stronger recognition of ecosystem services (Krasny and Tidball 2009; Tidball and Krasny 2010).

Attachment to urban forests can also increase other important societal benefits, such as social cohesion, promotion of shared interests, and neighbourhood participation (Gotham and Brumley 2002). The European Union Environmental Authorities have emphasized the role of urban forest ecosystems to provide opportunities for interaction between individual persons and groups that promote social cohesion and reduce criminality (European Environmental Agency 2011; Kázmierczak 2013).

A synthesis of the above classification of urban ecosystem services is provided in Table 7.

Table 7 Classification of the most important ecosystem services provided by the main urban forest types. Their relative significance is a modification of FAO (2016)

ECOSYSTEM SERVICE	Peri-urban forests and woodlands	City parks and urban forests	Pocket parks and gardens with trees	Trees on streets/public squares	Other green spaces with trees
Provisioning					
Timber and fuel wood	5	2	1	1	2
NWFPs	5	3	2	1	2
Food	5	4	2	1	3
Water supply	5	4	3	2	3
Regulating					
Temperature regulation	5	5	4	3	2
Noise reduction	5	5	4	2	2
Air purification	5	4	3	3	1
Carbon sequestration	5	3	2	2	2
Runoff mitigation	5	4	3	2	2
Water purification	5	3	2	2	3
Pollination, Seed dispersal	5	5	4	2	2
Habitat for biodiversity	5	4	3	2	3
Cultural					
Recreation	4	5	3	2	3
Aesthetic benefits	4	5	3	2	2
Education	5	4	1	1	3
Societal benefits	2	5	3	1	2
Human health	5	5	5	5	5

2.4.2.3 Urban Forest Ecosystem Disservices

Urban forests not only produce ecosystem services, but also some functions of ecosystems that are perceived as negative for human well-being, which are identified as ecosystem disservices (Lyytimäki and Sipilä, 2009). Urban biodiversity can damage physical infrastructures. Microbial activity for instance can result in decomposition of wood structures, while bird excrements can cause corrosion of stone buildings and statues and can transmit diseases (avian influenza). The roots of woody vegetation often cause serious damages by breaking up pavements (de Stefano and Deblinger, 2005; Lyytimäki and Sipilä, 2009).

Allergic reactions of people caused by wind-pollinated plants can be also included in the disservices of urban forests (D'Amato, 2000), while fear of crime, especially expressed by women at night-time, in urban green areas (Jorgensen and Anthopoulou, 2007; Sreetheran and Konijnendijk van denBosch, 2014) is probably recognised as their main disservice

2.4.3 Status in Forest ecosystem services

2.4.3.1 Forest condition

The Millennium Ecosystem Assessment revealed that all of the earth's ecosystems have been transformed in some way through human actions in the past 50 years (MEA, 2005). The interim report of TEEB further elaborates that forests have shrunk by about 40 % in the past 300 years, the world has lost about half of its wet- lands since the beginning of the 20th century (TEEB, 2008). This has severely compromised the ability of ecosystems to deliver the provisioning, regulating, supporting and cultural services that are of such importance to human well-being.

Increasing demands for land for agriculture, urban expansion and transport infrastructure, coupled with unsustainable exploitation for timber and wood products, climate change, pollution and nutrient enrichment, is driving habitat loss and the fragmentation and degradation of woodland and forest ecosystems (Maes et al., 2014). Woodland and forest ecosystems have slowly increased in recent years to cover almost 40 % of the EU-28. About 73 % of Europe's forests are even aged and only 5 % have more than six tree species. Growing demand for wood and timber products is expected to intensify the pressure of exploitation and land use change, resulting in marginally unsustainable levels of harvest by 2020. Moreover, Member States report that the main pressures on species and habitats are forestry practices, especially felling and the removal of dead or dying trees (EEA, 2015e). Table 7 present the major pressures on woodland and forest and their impact to biodiversity in Europe. The most important direct drivers of change in ecosystems are habitat change land overexploitation, invasive alien species, pollution, and climate change)

Table 8 Major pressures on woodland and forest and their impact to biodiversity in Europe. Source: (EEA, 2016b)

Habitat changes	Climate change	Overexploitation	Invasive alien species	Pollution and nutrient enrichment
Land use change: urbanisation, conversion to agriculture Changes in forest pattern Fragmentatio n due to roads, forest isolation	Changes in temperature and precipitation Fires Extreme events (droughts, frost, floods, storms) Pests and disease	Unsustainable exploitation of timber and non-wood products Recreation and tourism Game hunting Overgrazing	Fast-growing invasive alien species Pests and disease agents, e.g. Phytophthora	Nitrogen enrichment Acidification Heavy metals Air pollution Critical levels of ozone

Observed impact on biodiversity to date		
(yellow)	(light orange)	(red)
Low	Moderate	High

Forest condition (health and vitality) can be defined based on the combined presence of abiotic and biotic disturbances and can result in substantial economic and environmental losses. These pressures can affect tree growth and survival, the yield and quality of wood and non-wood products, wildlife habitat, recreation and scenic and cultural values (FAO, 2017). The capacity of providing non-wood products and other forest services is central for understanding the condition of forests. In fact, the condition of forests affects their capacity to provide ESs (Maes et al., 2018). The Balkan countries occupy an intermediate place, being characterized by modest production that may be extremely important at the local level.

Table 8 present the change per indicator as a percentage per decade (10 years), according to Maes et al., (2015).

Table 9. Decadal change in ecosystem services per ecosystem. Source(Maes et al., 2015).

	Indicator	**Crop land**	**Grass land**	**Wood land and forest**	**Heath land and shrub**	**Bare land**	**Wet lands**	**Rivers and lakes**
Provisioning	Harvested production	+7.7%						
	Agricultural Area	−1.9%						
	Total Organic Crop Area	+78.5%						
	Total timber Removal			+2.3%				
	Grazing Livestock		−13.9%					
	Timber growing stock			+10.3%				
	Industrial water abstraction							−1.8%
	Agricultural water abstraction							−11.1%
	Public water abstraction							−4.7%
Regulating and maintenance	Forest area with protective function			+29.4%				
	Pollination Potential	−4.1%	−26.8%	−27.7%	−40.6%			
	Water Retention	+0.4%	−0.04%	−0.1%	−0.2%	+0.05%		
	Erosion control	+0.2%	+0.2%	−0.1%	+1.6%			
	Soil retention	+17.8%	−8.3%	+9.6%	−4.0%			
	NO_2 Removal							
	Urban Green							
	Net ecosystem productivity	+9.2%	+9.2%	+9.6%	+10.3%	+11.0%	+10.3%	
	Crop production deficit	+0.5%						

	Habitat Quality	–0.9%
Cultural	Recreation opportunity	+3.5
	Special protection area	+87.7
	Site of community importance	+63.4

2.4.3.2 Threats of urban forest ecosystems and their services

The benefits derived from urban forest ecosystems are garnering increasing attention in both environmental research and municipal planning agendas (Pincetl 2009; Duinker et al. 2015). The ecological, social, and economic benefits they provided have prompted a large number of municipalities to develop tree protection policies and strategic urban forest management plans (Ordóñez and Duinker 2013; Gibbons and Ryan 2015; Baró and Gómez-Baggethun 2017). However, urban forests and the ecosystem services they provide are inherently vulnerable to a myriad of stressors. Urban landscapes are highly fragmented, frequently changing, and densely-settled environments with complex ownership regimes and high levels of competition for space (Trowbridge and Bassuk 2004; Konijnendijk et al. 2005). These threats are very common in the Mediterranean Basin, where urban population has been increased by over 150 million during the last 40 years. Urbanization in the Mediterranean region is expected to be further accelerated due to environmental changes, tourism and housing development especially in coastal areas and near culturally important cities (EEA, 2011; Houimli 2008). Mediterranean cities are considered attractive places to settle for retirees from northern Europe (Membrado-Tena, 2015), and for return migrants to the Maghreb countries (Cassarino, 2008). Consequently, the quality of life in urban is in danger to be reduced due to land degradation (Tzoulas et al., 2007).

Engaging the urban population with urban forests and nature is a must and can indeed improve the awareness, appreciation, and willingness to tackle all the pressing environmental issues rising in the cities.

2.4.3.3 Policy framework

Recent assessments of forest and woodland habitats under Annex I of the Habitats Directive reveal that only 15 % are in favorable conservation status while 80 % have unfavourable (inadequate or bad) conservation status. Therefore, the EU Forest Strategy, adopted in 2013, aims to coordinate Member States' efforts in forest protection, biodiversity conservation and the sustainable use and delivery of forest ESs. (EEA, 2016b). The most relevant policies and instruments for European state forest in regard to ESs (Eustafor and Patterson, 2011) are covered below.

The **Rural Development Regulation** (RDR) (EC)1698/2005) under the CAP has most importance to EU forests and forestry. Not all measures are open to State Forests but there is good scope for State Aid (Community guidelines (2006/C 319/01; Chapter VII) for activities which are "directly contributing to maintaining or restoring ecological, protective, and recreational functions of forests, biodiversity, and healthy forest ecosystems". Changes to this Regulation, and any associated Implementing Regulations, after 2013, may offer more direct support to ESs. The European Parliament is discussing how to make “public bodies” eligible for forestry funding measures in Pillar 2. This may be a significant opportunity for state forest organizations.

EU Forest Strategy was adopted in 2013 (European Commission, 2013a). In common with the previous EU Forestry Strategy (European Commission, 1998) and EU Forest Action Plan 2007–2011 (European Commission, 2007), the Forest Strategy focusses strongly on sustainable forest management and the multifunctional nature of forests delivering multiple ESs. The role of ESs from forests is recognised for overall economic and social development, especially in rural areas. The Forest Strategy also emphasises the need for protection of the forest, notably in relation to biodiversity and climate change. Resource efficiency would optimise the contribution of forests and the forest sector to rural development, growth and job creation. Finally the Strategy aims at promoting global forest responsibility, sustainable production and consumption of forest products

Forest Multi-Annual Implementation Plan of the EU Forest Strategy (or “Forest MAP”)(European Commission, 2015c) is a follow-up of the 2013 Forest Strategy, updating the challenges which the sector faces, while still balancing the economic, social and environmental benefits of forests. The Forest Multi-Annual implementation Plan (Forest MAP) provides a concrete list of actions for the period 2015-2020, the actors and timing of the different activities as well as the expected outcomes. It is structured according to the eight priority areas of the EU Forest Strategy, providing actions and target dates for each area in order to ensure a coherent, coordinated approach to the various policies and initiatives relating to the forest sector, with the particular involvement of stakeholders. It also adds a crosscutting element as the Strategy foresees a mid-term review in 2017-18. The plan also includes actions to enhance essential ESs provided by forests - such as flood, landslide and erosion protection, carbon sink, climate stabilisation, habitat for animals and plants, genetic resource, and recreational space - and to provide both experts and the public with comprehensive and harmonised information on EU forests through the Forest Information System for Europe (FISE).

The Birds Directive (2009/147/EC) and Habitats Directive (1992/43/EEC) are the most important tools for protecting biodiversity and habitats in the EU, and together protect more than a thousand species and 200 habitat types mostly in Natura 2000 sites, which cover 18% of EU land area. The Birds and Habitats Directives require compensation for damage or destruction to valuable habitats, so they have the potential to support future markets for biodiversity and habitat offsetting and are to some degree already doing this.

The EU Biodiversity Strategy 2020 serves as the main vehicle for EU action to address biodiversity issues, reaching the 2020 headline target will require the full implementation of all existing EU environment-related legislation, as well as action at national, regional and local level. The strategy aims to halt the loss of biodiversity and the degradation of ESs in the EU by 2020. It also aims to restore them in so far as feasible, while stepping up the EU contribution to averting global biodiversity loss. The Biodiversity Strategy has six mutually supportive and inter-dependent targets and 20 supporting actions. Target 2 calls for better protection and restoration of ecosystems and their services. Within target 2, Action 5 pleas for all Member States to map and assess the state of ecosystems and their services, their economic value and to promote the integration of these values into accounting and reporting systems at EU and national level by 2020.

2.5 Case studies for Ecosystem Service Assessment

2.5.1 National Ecosystem Service Assessment

Several European countries have started to assess biodiversity, ecosystems, and ES at the national scale. We identified published European National Ecosystem Service Assessments (NEAs) on the basis of current overview studies (Braat 2014), information of the EU Mapping and Assessment of Ecosystems and Their Services (MAES) working group (Teller 2014) and the IPBES Catalogue of Assessments on Biodiversity and Ecosystem Services (http:// catalog.ipbes.net).

All NEAs referred to specific policy documents, conventions, and initiatives to frame the assessment. The most commonly mentioned framing was the MA, followed by TEEB and national accounting initiatives such as the World Bank–led Wealth Accounting and the Valuation of Ecosystem Services (WAVES) project and UN System of Environmental–Economic Accounting (SEEA) framework (Schröter et al., 2016).

Interactions between ES were assessed in three NEAs (UK, SP, VL), mainly using literature review and expert judgment. Some NEAs (UK, SP, VL) also developed their own conceptual frameworks for their assessments. These frameworks were adaptations of the MA framework (MA 2005), with a more prominent position of ecosystems (or natural capital) forming the basis of ES provision.

Most frequently methods employed for the NEAs, were literature reviews and national statistics. These were followed by expert judgement, in particular for the interactions between ES, and the relationship between biodiversity and ES. Mapping and spatial modeling were used for elements, such as the state and trends of ES, the valuation of ES.

Although the EU Biodiversity 2020 strategy requested the mapping and assessing of ES by member states, few assessments have to date mapped ES systematically. The Flemish assessment provided maps on all assessed ES, which, depending on the ES, show the ecosystem condition, capacity, flow, use, and/or demand of the respective ES. The Spanish NEA presented maps showing qualitative trends of ES per ecosystem type and quantitative maps that depicted ES flow or capacity depending on the service. The German report contained preliminary maps on selected indicators, which depict the capacity or flow of the respective ES as well as indicators for ES demand. The UK NEA (performed before the launch of the EU biodiversity strategy) contained few maps for single selected services (e.g., soil-carbon storage) and few maps for sub-regions. The UK NEA and the Finnish assessment contained maps on the economic value of ES for parts of the country.

Table 10 National Ecosystem Assessments in Europe: A Review. Source:(Schröter et al., 2016)

Country (Year)	Framing policy documents and initiatives	Interactions between ES	Relationship between biodiversity and ES	Own conceptual framework	State of ES	Trends of ES	Reference
Portugal (PT) (2009)	Millennium Ecosystem Assessment EU directives and common policies National and regional strategies, plans, and programs	no	no	no	Literature review Statistics Expert judgement	Literature review Statistics Expert judgement	Pereira et al. (2009)

					Modeling		
United Kingdom (UK) (2011)	CBD and other international treaties Millennium Ecosystem Assessment IPBES EU directives and common policies Parliamentary committee report TEEB and national accounting initiatives	Literature review Expert judgement	no	Conceptual thinking	Literature review Statistics Maps Expert judgement Modeling	Literature review Statistics Expert judgement	UK NEA (2011)
Spain (SP) (2012 and 2014)	CBD and other international treaties Millennium Ecosystem Assessment IPBES EU biodiversity strategy 2020 EU directives and common policies National and regional strategies, plans, and programs TEEB and national accounting initiatives	Literature review Expert judgement	Literature review Expert judgement Conceptual thinking	Conceptual thinking	Literature review Statistics Maps Expert judgement Modeling	Literature review Statistics Maps Expert judgement Modeling	EME (2012) EME (2014)
Norway (NO) (2013)	CBD and other international treaties Millennium Ecosystem Assessment IPBES EU biodiversity strategy 2020 TEEB and national accounting initiatives	no	Literature review Expert judgement	no	Literature review Statistics	Literature review Statistics	NOU (2013)
Flanders (region of Belgium) (VL) (2014)	CBD and other international treaties Millennium Ecosystem Assessment IPBES EU biodiversity strategy 2020	Maps Expert judgement	Literature review Expert judgement Conceptual thinking	Conceptual thinking	Literature review Statistics Maps	Literature review Statistics	NBO (2014)

	EU directives and common policies National and regional strategies, plans, and programs TEEB and national accounting initiatives						
Netherlands (NL) (2014)	Millennium Ecosystem Assessment EU biodiversity strategy 2020 National and regional strategies, plans, and programs TEEB and national accounting initiatives	no	Expert judgement	no	Literature review Statistics Maps Expert judgement Modeling	Literature review Statistics Expert judgement Modeling	de Knegt (2014)
Finland (FI) (2015)	CBD and other international treaties Millennium Ecosystem Assessment EU biodiversity strategy 2020 EU directives and common policies National and regional strategies, plans, and programs TEEB and national accounting initiatives	no	no	no	Literature review Statistics	Literature review Statistics	Jäppinen and Heliölä (2015)
Germany (DE) (2015)	CBD and other international treaties Millennium Ecosystem Assessment EU biodiversity strategy 2020 TEEB and national accounting initiatives	no	no	no	Literature review Statistics Maps	no	Albert et al. (2015)

2.5.1.1 Portugal

Two assessments are detailed for Portugal, MAES and the 'Portugal Millennium Ecosystem Assessment produced as a sub-global assessment under the Millennium Ecosystem Assessment (MA) process. (Ling et al., 2018). The **Portuguese** NEA (Pereira et al. 2009) assessed nine ecosystem types and a selection of ES, and it contained five case studies. (Sing et al., 2015). In the assessment's executive summary there is reference to the economic value of ES groups (i.e. provisioning versus supporting). There are also some links to economic information on the total value of water supply; however, the marginal contribution of ESs to this value is not provided (i.e. it is included along with inputs associated with labour and equipment) (Ling et al., 2018)..

2.5.1.2 United Kingdom

The first UK National Ecosystem Assessment (UK NEA), conducted between 2009 and 2011, assessed the main broad habitat types in the UK and their current state, the benefits these ecosystems provide for people in terms of goods and services and consequent well-being, and the main drivers of change that affect them (UK NEA, 2011).

The UK NEA (2011) assessed eight ecosystem types and a large number of related ES. It contained four regional assessments on the status and trends of ecosystems and ES, as well as an exploration of different forms of the valuation of ES. The UK NEA Follow-On project (2014) produced a range of new tools and information for decision makers.

http://webarchive.nationalarchives.gov.uk/20160105160709/http://www.ons.gov.uk/ons/rel/environmental/uk-natural-capital/natural-capital-accounting-2020-roadmap--interim-review-and-forward-look/index.html

2.5.1.3 Spain

There are two nationally relevant assessments listed for Spain; one focusses on the Basque country, and the other is the national scale Spanish Ecosystem Assessment.

The Spanish NEA (EME 2012) focused on biophysical elements of ecosystems and biodiversity, and not their economic or social value. It assessed 14 ecosystem types (including terrestrial, aquatic, transition, and urban ecosystems) and 22 ES, including five case studies.

As part of the Spanish NEA, a further report on economic valuation "the use and non-use values of biodiversity, as well as a plurality in terms of valuation methods (monetary and non-monetary methods related with market prices, stated preferences techniques, and demand ranking" was published in 2014 (EME 2014).

2.5.1.4 Nordic

The Norwegian NEA (NOU 2013) was an expert report for the Norwegian national parliament. It contained an assessment of 11 ecosystem types, as well as a biophysical and monetary valuation of a selection of ES.

The TEEB-inspired synthesis for the Nordic countries (i.e. Denmark, Finland, Iceland, Norway and Sweden), known as 'TEEB Nordic', set out to "bring together existing information on the socio-economic role and significance of biodiversity and ESs for the Nordic countries". None of the Nordic countries have yet developed or adopted indicators for ESs. To assist the development of indicators, it appears that all Nordic countries have integrated environmental parameters into their national sustainable development indicators. These are environmental, economic and social indicators used to give an overall picture of sustainable development at a national level.

2.5.1.5 Belgium

The assessment for the Belgian region of Flanders (INBO 2014) was a subnational ecosystem assessment that focused on spatially quantifying 16 ES and the state and trends of biodiversity, as well as its role in the provision of ES.

There is reference in this report to valuation activities carried out in a regional area called Rivierenland; these included interviewing key land users to assess how they rank their preferences for

ESs. In the document 'Nature Report 2014: Flanders Regional Ecosystem Assessment - State & Trends Synthesis Report40, chapter 7 provides some maps of the values of crop cultivation (net price), wood production, and carbon storage under alternative multifunctional forest management scenarios. This identifies some areas where focusing on ESs rather than just food production would result in socio-economic gains.

The assessment for the **Belgian** region of Flanders (INBO 2014) was a subnational ecosystem assessment that focused on spatially quantifying 16 ES and the state and trends of biodiversity, as well as its role in the provision of ES.

2.5.1.6 Netherland

Three national assessments were identified for The Netherlands, the first of which is a TEEB study called 'TEEB Netherlands: Regional cases project', for which no outputs are listed. Two additional multi-country assessments are also detailed: MAES and the PRESS initiative.

A pilot project was carried out by Statistics Netherlands and Wageningen University. An ES accounts (physical and monetary supply and use tables) were developed as part of the Limburg Case Study. Statistics Netherlands and Wageningen University have recently started a new, national scale project. Funding is guaranteed for the first project year, where emphasis will be placed on physical data. A second project year with emphasis on monetary valuation is planned. In the first project phase, the following topics will be addressed at country and provincial levels: 1) carbon account, 2) biodiversity account, 3) physical supply and use tables and 4) condition account.

2.5.1.7 Finland

In 2015 the Finnish Ministry of the Environment published the TEEB for Finland synthesis and roadmap report. This report presents a synthesis of case studies and a review of policy coherence with ecosystem management, and it was based on a defined set of priority ESs.

The Finish Environment Institute has been developing national ES indicators for nationally important provisioning services, regulating services and cultural services. The indicator framework was developed using CICES for classifying the ESs and formulate approximately ten classes for each of the three ESs sections; provisioning, regulating and maintenance, and cultural services. The Finnish assessment (Jäppinen and Heliölä 2015), contained a short assessment of 28 ES and case studies on mapping the value of ES.

They focused on ESs that are currently relevant in Finland while being aware that new ESs may emerge in the future. They consulted multidisciplinary national biodiversity indicator expert groups of main ecosystem types: forests, mires, the Baltic Sea, inland waters and farmlands. They organized a one-day stakeholder workshop for a wide national audience, including ministries, sectors of the economy such as agriculture, forestry, and tourism, research institutes, universities, and NGOs. In the workshop they presented the indicator framework and asked for feedback concerning the applicability of the indicators. After this meeting the indicator framework was updated developed indicators for 28 ESs (10 provisioning, 12 regulating and maintenance, and 6 cultural services), a set of four indicators for every stage of the cascade; altogether 112 indicators (Mononen et al., 2016). The results are now reported online at www.biodiversity.fi/ecosystemservice.

2.5.1.8 Germany

As part of the project "National Indicators for Ecosystem Services", led by the IOER Dresden '(Leibniz Institute of Ecological Urban and Regional Development'), Germany has developed a set of national indicators for ESs. According to the implementation of MAES in Germany (MAES-DE), indicators are planned to inform different policies, e.g. agriculture, forestry, tourism, traffic planning, spatial planning, climate change mitigation and adaption, flood control, water quality, fresh water supply, air quality, etc. Additionally, MAES-indicators can become a nationwide data base for enhanced landscape planning (Grunewald et al., 2017).

MAES-DE approach follows the recommendations of the European MAES working group (Maes et al. 2014, Maes et al. 2013) as well as internationally and nationally accepted approaches (Brouwer et al. 2013, econcept/WSL 2013, Burkhard et al. 2014, Grunewald and Bastian 2015, Grunewald et al. 2016, Staub et al. 2011 and others), and includes the modules of (1) mapping the ecosystems, (2) assessing the ecosystem conditions, (3) assessing the ESs and (4) integrated ecosystem assessment with connection to natural capital accounting.

The principal system in Germany is based on ES classes of the international classification CICES. Only selected ES indicators of relevance are implemented and monitored in Germany.

2.5.2 Projects of Mapping and Assessment of Ecosystems services

Enhancing ecoSysteM sERvices mApping for policy and Decision mAking (ESMERALDA) is a H2020 Coordination and Support Action aiming to deliver a 'flexible methodology' for use for pan-European, national and regional ESs mapping and assessment as set out in Action 5 of the EU Biodiversity Strategy. This builds on existing ESs projects and databases (e.g. MAES, MESEU, OpenNESS, OPERAs, and national studies) to develop mapping approaches that integrate biophysical, social and economic assessment technique It is hoping such an approach will support the timely delivery by all EU Member States of Action 5. In particular ESMERALDA is engaging with Member States that are lagging behind due to capacity.(Ling et al., 2018)

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) was established in 2012 as an independent intergovernmental body open to all member countries of the United Nations, with the goal of 'strengthening the science-policy interface for biodiversity and ESs for the conservation and sustainable use of biodiversity, long-term human well-being and sustainable development' (http://www.ipbes.net). Developed in the wake of other international assessments, specifically the Millennium Ecosystem Assessment and the Intergovernmental Panel on Climate Change (IPCC), IPBES was designed to proactively develop assessments matched to policy needs, and to support capacity building across scales and topics To achieve this objective, IPBES has four interconnected functions: to catalyse the generation of new knowledge; to produce assessments of existing knowledge; to support policy formulation and implementation; and to build capacities relevant to achieving its goal.

Operationalisation of Natural Capital and Ecosystem Services (OpenNESS) is a European research project that translate the concepts of natural capital and ESs into operational frameworks that provide tested, practical and tailored solutions for integrating ESs into land, water and urban management and decision-making. It examines how the concepts link to, and support, wider EU economic, social and environmental policy initiatives and scrutinises the potential and limitations of the concepts of ESs and natural capital. In particular methods relating to mapping and assessment are being utilised by Member State to undertake activities related to the implementation of MAES. The OpenNESS consortium consists of 35 partners, including 10 SMEs, from 14 European and four non-European countries.

The aim of OpenNESS is to increase conceptual understanding in relation to the four key ESs challenges: (i) human well-being; (ii) sustainable ecosystem management; (iii) governance; and (iv) competitiveness. In addition, we undertake reviews of existing methods for policy and scenario analysis, biophysical ESs assessment and ESs valuation and assessing the relevance of each method for the four key challenges

Central to the OpenNESS project is a set of multi-scale case study approaches on the application of ES and natural capital approaches in decision-making situations. These are listed at www.openness-project.eu/cases.

Project "Robinwood PLUS" (INTERREG IV C), promoting participatory forest planning and sustainable forest management

Project ''COMMONS'' (INTERREG IV C) that seeks to re-establish, maintain and sustainably manage former common woodlands which often still constitute a treasure of biodiversity

Project INFORM (LIFE08 ENV/GR/000574) for building a structured, indicator based knowledge system for sustainable forest policy and management

Project ForeStClim (Interreg IVb) aiming to develop proactive and adaptive regional forestry management and forest protection strategies in the face of the expected climate change scenarios.

3 APPROACHES USED IN ASSESSING STATUS AND TRENDS OF FOREST SERVICES

3.1 Quantification

3.1.1 Biophysical quantification

Biophysical quantification is the measurement of ES in biophysical units. Biophysical units are used to express, for example, quantities of water abstracted from a lake, area of forest or stocks of carbon in the soil (Burkhard and Maes, 2017).

To quantify ES we need to address two questions: what do we measure and how do we measure. The first question is addressed in the scientific literature by developing and proposing indicators. ES indicators are used to monitor the state or trends of ecosystems and ES delivery within a determined time interval. The choice for an indicator depends on many factors including the purpose, the audience, its position on the ES cascade, the spatial and temporal scale considered and the availability of data

Once an indicator is proposed or selected for inclusion in an ecosystem assessment, the second question becomes important: how can we measure the service or the indicator in biophysical terms or units? Which methods or procedures should be applied to come to an reasonable estimate of the quantity of service provided? Appropriate methods could be a) direct measurements, b) Indirect measurements c) ES modelling.

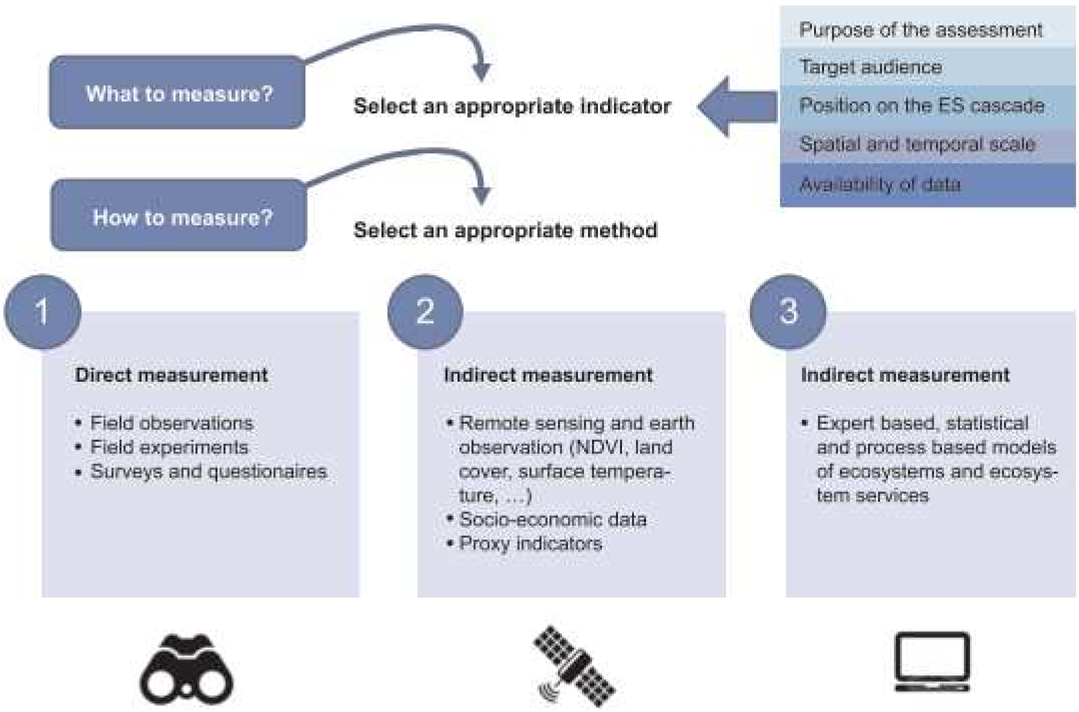

Figure 6 Biophysical quantification of ecosystem services. Source (Burkhard and Maes, 2017)

3.1.1.1 Primary data-direct measurements

Primary data are also referred to as direct measurements. Direct data of an ES indicator is the actual measurement of a state, a quantity or a process from observations, monitoring, surveys or questionnaires which cover the entire study area in a representative manner. Direct measurements of ES deliver a biophysical value of ES in physical units which correspond to the units of the indicator.

Examples of direct measurements of ES are counting the number of visitors visiting a national park (nature based recreation); measuring the total volume of timber in a forest stand (timber production) water from ground water layers (water provision) or asking citizens how many times they visit a forest to pick berries, mushrooms or chestnuts (wild food products). When the spatial extent or relative surface area of ecosystems is used to approximate ES, also botanical and forest inventories, permanent plots or any other direct observation on the terrain can be used as proxy. In certain cases remote sensing can be considered also as direct measurement. Direct measurements are feasible in particular for provisioning ES (Burkhard and Maes, 2017).

3.1.1.2 Secondary data- Indirect measurements

Secondary data are also referred to as indirect measurements. Secondary data of ES deliver a biophysical value in physical units, but this value needs further interpretation, certain assumptions or data processing, or it needs to be combined in a model with other sources of environmental information before it can be used to measure an ES. Indirect measurements of ES deliver a biophysical value of ES in physical units which are different from the units of the selected indicator (Burkhard and Maes, 2017).

In many cases, variables that are collected through remote sensing qualify as indirect measurement. Examples for terrestrial ecosystems are land surface temperature, NDVI (Normalised

Difference Vegetation Index), land cover, water layers, leaf area index and primary production. (Burkhard and Maes, 2017)

Many of these data products do not measure stocks or flows of ES but they are highly useful to quantify climate regulation as well as all those ES which depend directly on the vegetation biomass of ecosystems to regulate or mediate the environment. Soil protection and water regulation, for example, are strongly driven by the presence of vegetation which can be inferred from earth observation datasets. Air filtration by trees and forest is directly related to the canopy structure which, in turn, can be measured by the leaf area index (Burkhard and Maes, 2017).

A specific role is reserved for land cover and land use data which are used for both direct and indirect quantification of ES.

ES modelling can be used to quantify ES if no direct or indirect measurements are available. This is virtually always the case in any ecosystem assessment. Models can vary from simple expert based scoring systems to complex ecological models which simulate the planetary cycles of carbon, nitrogen and water.

3.2 Indicators

3.2.1 Indicator theory and properties

Assessing the biophysical status and trends in ESs relies on identifying indicators that either directly or indirectly reflect the biophysical status of services. In general, indicators of ESs' status and trends can be divided into indicators for the availability of a given service (quantity) or for the general status of natural system(s) (quality), both reflecting ecosystems' general capacity to maintain and provide ESs.

ES indicators are information that efficiently communicates the characteristics and trends of ES, making it possible for policy-makers to understand the condition, trends and rate of change in ES (Burkhard and Maes, 2017). An indicator acts as a surrogate measure of more complex aspects of the reality being assessed, it can simplify the multivariate nature of the attribute being measured into a single value, thus allowing for spatial and temporal comparisons between values (Pereira et al., 2005).

Indicators needed to comply with the following minimum requirements (Maes et al., 2015):

- The indicator is standardized across the EU
- The indicator has quantitative values at least at the country scale
- The indicator is available for at least two years

The most common sources of data for ES indicators can be divided into four categories (Brown et al., 2014):

1. National statistics
2. In-situ observations
3. Remote sensing
4. Numerical simulation models

Different indicators can be used to measure or indicate a single ES. Many ES indicators are proposed to report the state and trends of ES under different biodiversity policies from global to local scale. Many countries and regions have developed ES indicator sets; the setting of global or regional biodiversity targets has also spurred the development of indicators.

Several lists of recommended ES indicators appeared in the literature, e.g.(De Groot Rudolf et al., 2010). We reviewed indicators that have actually been used to map and model ES between 1997 and 2018. From each paper we extracted information about the ES indicators used and general information about the specific study (see Appendix 1 for a complete overview).

All indicators and services were grouped according to the classification presented by CICES, in which the three following categories are defined: i) Provisioning services, e.g. food, water, and other resources; ii) Regulating services, e.g. climate, air and soil quality, carbon sequestration, erosion prevention; and iv) Cultural services (non-material benefits), e.g. recreation, tourism, and inspiration. It is apparent that there are far more data and indicators available for provisioning services and human well-being than for regulating, supporting, and cultural services.

Table 11 Examples of sources, websites and key publications for ecosystem service indicators. Source: (Burkhard and Maes, 2017)

Scale	Location	Publication
Global		Convention on Biological Diversity Technical Series No. 58 (Secretariat of the Convention on Biological Diversity 2011) https://www.cbd.int/doc/publications/cbd-ts-58-en.pdf
		Measuring ecosystem services: Guidance on developing ecosystem service indicators (UNEP-WCMC, CSIR, Sida and SwedBio 2014) https://www.unep-wcmc.org/system/dataset_file_fields/files/000/000/303/original/1850_ESI_Guidance_A4_WEB.pdf?1424707843
		A Global System for Monitoring Ecosystem Service Change (doi: 10.1525/bio.2012.62.11.7)
		Guidance for National Biodiversity Indicator Development and Use (Biodiversity Indicators Partnership 2011) https://www.bipindicators.net/system/resources/files/000/002/191/original/Framework_Brochure_UK_0311_LOWRES_%281%29.pdf?1481634262
		Review of indicators and JRC-data for mapping ecosystem services (European Commission / JRC-Ispra, Institute for Environment and Sustainability 2012). http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/26749/1/lbna25456enn.pdf
Sub-global	European Union	website: http://biodiversity.europa.eu/maes/mapping-ecosystems article: doi:10.1016/j.ecoser.2015.10.023
		A European atlas of ecosystem services (European Commission 2011) www.aboutvalues.net
National	United Kingdom	UK National Ecosystem Assessment Follow-on Work Package Report 5: Cultural ecosystem services and indicators (Church et al. 2014)

Finland	website: http://www.biodiversity.fi/ecosystemservices/home article: doi:10.1016/j.ecolind.2015.03.041
Canada	Website: https://www.ec.gc.ca/indicateurs-indicators/
Switzerland	Website: http://www.bafu.admin.ch/publikationen/publikation/01587/ index.html?lang=en
Germany	article: Towards a national set of ecosystem service indicators: Insights from Germany (doi:10.1016/j.ecolind.2015.08.050)
Spain	Website: http://www.ecomilenio.es/informe-de-resultados-eme/1760 Article: doi:10.1371/journal.pone.0073249

3.2.2 Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020

To assess the type of ESs indicators that might be available at national level, we selected to present indicators as are suggested by the second MAES report "Mapping and Assessment of Ecosystems and their Services Indicators for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020". The second MAES report presents indicators that can be used at European and Member State's level to map and assess biodiversity, ecosystem condition and ESs according to the Common International Classification of Ecosystem Services (CICES v4.3).

Indicators to measure the condition of an ecosystem, or the quantity of an ES at a given CICES level with harmonized, spatially-explicit data at European scale each evaluated according to 2 criteria: i) data availability and ii) ability to convey information to the policy making and implementation processes:

● indicator with sufficient harmonized spatial data (NUTS2 or finer), which can be easily understood by stakeholders.

● indicator for which either harmonized, spatially-explicit data at European scale is unavailable or which is used more than once in an ecosystem assessment.

● indicator with no harmonized, spatially-explicit data which only provides information at aggregated level and requires additional clarifications to non-technical audiences.

● indicator with unknown availability of reliable data and/or unknown ability to convey information to the policy making and implementation processes.

For an extended version of the color codes, see Mapping and Assessment of Ecosystems and their Services, page 23

3.2.2.1 Indicators for provisioning services

Provisioning services indicators focusing on contribution to well-being are still in the development stage (Brown et al., 2014). Concerning forest ecosystem, the provisioning section includes those services related to forest production of biomass, water and energy. In this section there are a reasonably large number of indicators. Most of these services are related to forest biomass supply and the indicators' data are derived from Forest Inventories and statistics. Within the provisioning FES the situation regarding water-related services seems more problematic because the identified indicators require and/or addition of hydrological modelling techniques for proper assessments and assumptions. According to (Maes et al., 2014) indicators for provisioning services delivered by forests are shown in Table 11.

Table 12 Indicators for provisioning services delivered by forests. Source (Maes et al., 2014)

Division	Group	Class	Indicators
Nutrition	Biomass	Cultivated crops	
		Reared animals and their outputs	Meat production (Iberian pig species)
			Meat consumption (Iberian pig species)
			Number of individuals (Iberian pig)
			Meat production (reindeer)
			Meat consumption (reindeer)
			Number of individuals (reindeer)
		Wild plants, algae and their outputs	Distribution of heathlands and other habitats for bees
			Distribution of plants important for honey production
			Distribution of wild berries, fruits, mushrooms (NFI plot data)
			Distribution of wild berries (modelling)
			Honey production
			Honey consumption
			Wild berries, fruits and mushroom harvest
		Wild animals and their outputs	Amount of meat (hunting)
			Value of game
			Hunting records (killed animals)
		Plants and algae from in-situ aquaculture	
		Animals from in-situ aquaculture	
	Water	Surface water for drinking	Total supply of water per forest area (modelling)
			Area of forest dedicated to preserve water resources
			Surface water supply per forest area (at river basin level)
			River discharge
			Reservoir water (proxy)
			Population and per capita water consumption
		Ground water for drinking	None

Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	Forest biomass stock
			Forest biomass increment
			Forest for timber, pulp wood, etc. production
			Commercial forest tree volume & harvesting rates
			Trees (presence): cork oak for cork & pines for resins
			Tree species (timber tress)
			Wood consumption (industrial roundwood, fuelwood)
			Consumption of cork and resins
		Materials from plants, algae and animals for agricultural use	Distribution of foraging areas in forest; estimate of grassland/shrubland (NPP)
			Marketed forage
		Genetic materials from all biota	Distribution of plants species with biochemical
			/pharmaceutical uses
			Raw materials for medicines
	Water	Surface water for non-drinking purposes	Same as for drinking purposes
		Ground water for non-drinking purposes	
Energy	Biomass-based	Plant-based resources	Wood fuel stock (fraction of forest biomass stock)
	energy sources		Wood fuel production (fraction of forest biomass increment)
			Distribution of tress for wood production
			Fuel wood consumption
		Animal-based resources	
	Mechanical energy	Animal-based energy	

3.2.2.2 Indicators for regulating and maintenance services

Developing indicators to measure well-being from regulating services is still difficult (Brown et al., 2014b). This section of FES seems to be not very well covered by available indicators. Most of the information to describe the indicators is derived from available data in Management plan and National statistics but in some cases some expert assumptions are needed.

Of the most important services provided by forests are climate and water regulation (Egoh et al., 2012). The climate regulation services mainly relate to the regulation of greenhouse gases, where indicators can be carbon storage, carbon sequestration, and greenhouse gas regulation. The most commonly used data to model indicators is aboveground biomass and belowground biomass but soil carbon, nutrients and vegetation maps can also be important input data (Brown et al., 2014).

According to (Maes et al., 2014) indicators for regulating and maintenance services delivered by forests are shown in Table12.

Table 13 Indicators for regulating and maintenance services s delivered by forests. Source (Maes et al., 2014)

Division	Group	Class	Indicators
Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	
		Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	
	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	Area of forest
			Sulphur (S) and Nitrogen (N) retention and removal
		Dilution by atmosphere, freshwater and marine ecosystems	
		Mediation of smell/noise/visual impacts	

Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	Erosion protection (modelling)
			Area of forest
			Area of forest designated to the prevention of soil erosion
			Area eroded by wind and water
			Forest cover in high slope areas (GIS analysis)
			Sediments removed from dams, lakes, rivers
		Buffering and attenuation of mass flows	Forest area designated for attenuation of mass flows
			Erosion risk mitigation
			Flood risk mitigation
	Liquid flows	Hydrological cycle and water flow maintenance	Forest area (designated to preserve water resources)
			Number of floods
			Water retention in forest
			Snow cover
			Infiltration
			Capacity for maintaining baseline flow (modelling)
			Water storage/delivery capacity of soil
			Water supply and discharge (hydrological modelling)
			Important areas for water infiltration and headwater surroundings covered by forest
			Drought and water scarcity
		Flood protection	Special protection areas for preventing mass flows linked to the River Basin Management Plans
			Reforestation of forest territories against floods
			Number of floods
	Gaseous / air flows	Storm protection	Area of forest designated to protect infrastructure and managed nat. resources
			Frequency of storms
			Area of forest
		Ventilation and transpiration	None

Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	Number of pollinator species
			Number of bee hives
			Abundance of pollinators (maps)
			Areas managed for gene conservation
			Pollination potential (maps)
			Surface area of dependent crops
			Honey production (modelling)
			Honey consumption
		Maintaining nursery populations and habitats	Tree species distribution
			Conservation investments
			Protected Areas for nursery populations
			Forest area designated for habitat-landscape protection: Natura 2000, etc.
	Pest and disease control	Pest control	Host-species (trees) abundance
			Surface of healthy Forests (quality parameter of forest health)
			Number of pests and diseases
			Surface affected by pests and diseases
			Number of IAS
			Surface occupied by IAS
			Damage costs
		Disease control	None
	Soil formation and composition	Weathering processes	Area of forest
			Restoration costs
			Forest soil condition: chemical soil properties
		Decomposition and fixing processes	Soil organic matter
			Amount of dead wood
			Thickness of the organic layer
	Water conditions	Chemical condition of salt waters	Area of forest
			Water quality
			Forest area designated to preserve waters resources
			Cost of water purification
		Chemical condition of salt waters	
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	C storage in forest
			C sequestration by forest (NPP; NEP)
			Forest growth, growing stock
			Number of CO2 emissions permits
		Micro and regional climate regulation	Area of forest
			Albedo maps
			Foliar surface index
			Ozone & particle pollution

3.2.2.3 Indicators for cultural services

It is hard to develop indicators for cultural services (Brown et al., 2014). Cultural services can be assessed in many different ways. They mostly are of non-material benefit for the society and are more numerous as compared to other services. The non-material benefits provided by cultural ESs are often deeply interconnected with each other and with material benefits provided by provisioning and regulating services. This means that many of the most important cultural services are co- produced by the same ecosystem components and human activities that produce material objects for consumption (Reyers et al., 2014). According to Maes et al., (2014) indicators for cultural services delivered by forests are shown in Table13.

Table 14 Indicators for cultural services delivered by forests. Source (Maes et al., 2014)

Division	Group	Class	Indicators
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings. And physical use of land- /seascapes in different environmental settings	Distribution of wildlife/emblematic species associated with forest
			Important bird areas associated with forest
			Area of forest accessible for recreation
			Number of visitors
			Number of hunters
			Ecotourism operators
			Area of forests accessible for hunting
	Intellectual and representative interactions	Scientific, educational, heritage,cultural, entertainment and aesthetic	Citations, distribution of research projects, educational projects, number of historic records
			Number/value of publications sold
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Spiritual and/or emblematic	Symbolic and sacred and/or religious	Distribution of sites of emblematic plants/forest
			Number of sites with recognised cultural & spiritual value
			Number of visitors
	Other cultural outputs	Existence and bequest	Distribution of important areas for forest biodiversity and their conservation status
			Condition of forest-associated priority species on habitat and birds directives
			Distribution of sites with forest designated as having cultural values
			Number of visitors

3.3 Remote Sensing

Remote sensing has not been used directly to measure ESs, yet in combination with other data sources it can contribute to the assessment of many ESs (e.g., water quantity and quality, erosion prevention, moderation of extreme events). These data sources can either contribute to assessing the potential supply of ESs or to assess the social-ecological drivers that influence the supply, delivery, contribution to well-being, and value of ESs (Walters and Scholes, 2016)

Remote sensing data are usually obtained from satellite sensors and can be used to monitor Earth's surface and atmosphere on a regional and global scale. Remote sensing allows for the assessment of large areas in a consistent fashion, something which is seldom possible through ground-based surveys, although ground-truthing is an essential component of the classification of remotely sensed images (Pereira et al., 2005). Remote sensing provides spatially explicit, systematic, repeatable data over large areas, yet its widespread use for biodiversity monitoring has been constrained by factors such as cost, data availability, lack of capacity, and ineffective demonstration of the link to components of biodiversity.

The images generated through remote sensing can be used to derive data on land cover, land use, wetland distribution, land degradation, primary productivity, and other attributes of the land. Repeated observations of the same area are possible and allow for the assessment of trends in the above-mentioned attributes (Pereira et al., 2005).

Remote sensing is in essence a technique for gathering spatial information. Based on the role of remote sensing ES assessment can be divided into three categories: a) direct monitoring, b) indirect monitoring and in c) combination with ecosystem models (Figure. 8).

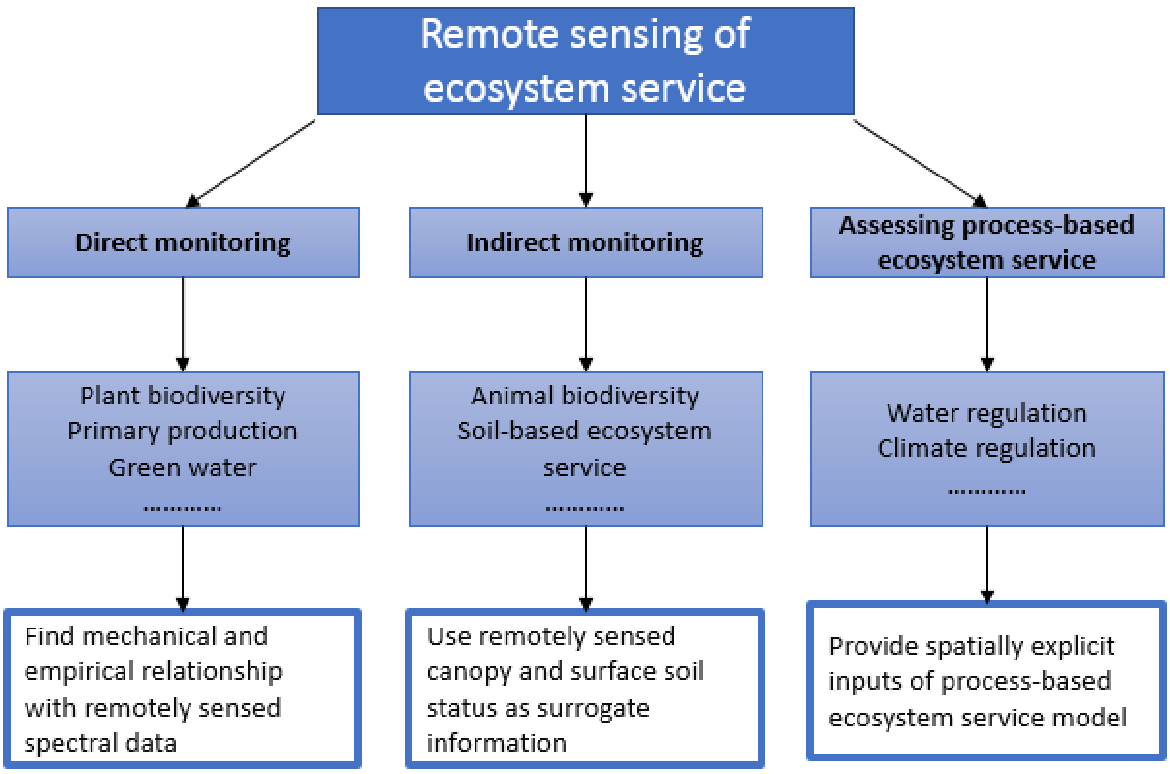

Figure 7 Framework of ecosystem service assessment with remote sensing. Source:(Feng et al., 2010)

3.4 Geographic Information Systems

The analysis of disparate spatial data sets, comprising social, economic, and ecological data, is made possible through the use of geographic information systems. These disparate data sets can be combined in a GIS to generate spatially explicit results. Sub-global to local assessments used GIS for tasks such as: integrating land cover information from different sources; analyzing temporal changes in primary productivity and land use, determining spatial characteristics such as distance, patch size, and shape ,analyzing trade-offs between provisioning services and biodiversity (Häyhä et al., 2015; Koulov et al., 2017; Rodríguez et al., 2015; Thellmann et al., 2017; Vihervaara et al., 2010) and providing a graphic interface with spatial models of ecosystem processes and scenario outputs.

Computing power and data availability that support GIS analysis have evolved substantially in recent years. Several freeware GIS platforms have been developed, such as QGIS (Quantum GIS), GRASS GIS (Geo- graphic Resources Analysis Support System GIS), SAGA (System for Automated Geo-scientific Analyses), and gvSIG (Generalitat Valenciana Sistema de Información Geográfica) that provide similar functionality to the popular commercial ArcGIS software from ESRI

Knowledge acquired by expert surveys flows into a GIS-based Bayesian Network for valuing forest ESs under a land-use and a climate change scenario in a case study in the Swiss Alps (Dynamics et al., 2013). The use of GIS in ES mapping can take three general approaches: (1) analysis tools built into GIS software packages; (2) disciplinary biophysical models applied for ES assessment approach is appropriate for more complex model-based analyses of services that integrate expertise from specific disciplines (e.g., ecology for crop pollination or hydrology for flood regulation mapping); (3)The third approach extends the second one by utilising modelling tools that can assess trade-offs and scenarios for multiple services (Burkhard and Maes, 2017).

3.5 Ecosystem services tools

3.5.1 Maps of ecosystem services

Approaches for mapping ES can be broadly classified into three main approaches (Martnez-Harms and Balvanera, 2012).

1. Valuation of ES through benefit transfer applies a monetary value to a land-cover map based on previous studies from sites having similar land- cover types (Troy and Wilson, 2006; Turner et al., 2007).
2. Community value methods have included spatial measures of social values and other perceptions of place obtained through preference surveys to ES maps that systematically integrate these perceptions with biophysical data (Raymond and Brown, 2006; Sherrouse et al., 2011)
3. Social–ecological assessments of the ES supply have modeled the relationship between measurable ecological (e.g., field samples of services, climate, land-cover, hydrological, remote-sensed data) and social variables (e.g., population, census data, road layers) to quantify and map the amount of ES supplied through space (Nelson et al., 2009)(Eigenbrod et al., 2010).

Within the scope of MAES, maps of ESs are useful for several purposes (Maes et al., 2013):

- Spatially explicit representation of synergies and trade-offs among different ESs, and between ESs and biodiversity;
- Communication tool to initiate discussions with stakeholders; - Visualisation of the locations where valuable ESs are produced or used;
- Tools for communicating the relevance of ESs to the public in their territory;
- Planning and management of biodiversity protection areas and implicitly of their ESs at sub-national level;
- Support to decision makers to spatially identify priority areas, and relevant policy measures.

The methods for mapping ES, meaning the way in which data sources were used to quantify and map the ES supply, are classified into seven categories (Martnez-Harms and Balvanera, 2012)

➢ look- up tables; Use of existing ES values from the literature to land-cover classes. In the lookup tables approach, specific values for an ES or other variable are attributed to every pixel in a certain class, usually a land cover or land use class. These values need to be derived from the scientific literature, for ecosystems that are comparable in terms of vegetation, soil, climate, etc. For instance, every pixel in the land cover class 'deciduous forest' could be given a specific value for its carbon stock, say 250 ton C/ha, based on studies that analyzed the carbon contents of this forest type in a specific agro-ecological zone. In general, the more homogeneous the class is, the more accurate a LUT approach will be.

- expert knowledge; in which experts are asked to rank an environmental variable category based on the knowledge that they have about the potential of these categories to supply ES.
- causal relationships; Knowledge about relationships between biophysical variables and ES, including information from the literature (e.g., Chan et al., 2006; Egoh et al., 2008; Naidoo et al., 2008), can be used in process-based models.
- extrapolation of primary data; Field data databases weighted by cartographical data (generally land cover). The use of primary data for directly mapping ES is useful for mapping provisioning services where statistics of sufficient quality are available (Maes et al., 2013). It is possible to expand this method by extrapolating estimated ES values based on primary data (Rabe et al., 2016).
- statistical and machine learning models; Employing field data of ESs as response variables and proxies (e.g., biophysical data and other sources of information obtained from GIS) as explanatory variables.
- Implicit modeling; use of ES models and software tools, such as InVEST, ARIES, SolVES
- representative sampling; Interviews or/and sampling: convenience sample, representative and stratified sample.

The actual trend in mapping ES shows that pragmatic approaches, such as exclusively land-use-based look-up tables, are used only under exceptional circumstances, inter alia, because of the potential subjectivity of the method. Primary information about ES, complex indicators, and models, including functional traits, are applied more often (Kremen, 2005; Chazal et al., 2008; Bello et al.2010; Larovel et al.,2013)

3.5.2 Ecosystem services models

Specific modelling approaches for mapping ES have been developed by different institutions worldwide, resulting in a wide variety of possibilities for ES analysts' use. Most of these tools are openly available to the public and are constantly evolving (Burkhard and Maes, 2017)

ES models, are practical tools that predict how ESs change through time and space, are increasingly being used to support decision-making. These models are often developed when data availability is scarce, when spatially explicit information is needed, and in order to assess trade-offs among services under alternative future management scenarios.

Model outputs can be in the form of geographic information system (GIS) maps, economic data, yields, water-flow quantities, and many other measures. The outputs of ES models can also be in physical terms, such as the annual water yield from a catchment, or economic terms, such as that water's net present value with the intended use of hydropower production. ES models may generate outputs in either biophysical or economic terms, but few models provide outputs in both formats (Bullock and Ding, 2018).

A wide variety of approaches have been used for building and applying such models. The choice of model is based on user needs, access to modelling capability and availability of parameter sets for a given model in the location it is to be applied. Further it should be noted that some models have been designed to model specific processes better than others for example water partitioning versus biomass accumulation (carbon). 13 of the more commonly used modelling platforms are described here in Table 15.

3.5.2.1 Integrated Valuation of Ecosystem Services and Tradeoffs

The model Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) is applied in two initiatives (Natural Capital project and WAVES). InVEST is a family of tools developed in the Natural Capital Project to map and value the goods and services from nature which are essential for sustaining and fulfilling human life (www.naturalcapitalproject.org). InVEST models are based on production functions that define how an ecosystem's structure and function affect the flows and values of environmental services. The models account for both service supply and the location and activities of people who benefit from services. Currently, InVEST models run as script tools in the ArcGIS ArcToolBox environment. Based on presentations about the tool box, InVEST seems to be primarily a model framework, which can be applied in specific circumstances or case studies based on stakeholder engagement and development of scenarios, which then feed into biophysical and economic models that are or have been adapted to local case study conditions (TEEB, 2010).

3.5.2.2 Lund-Potsdam-Jena managed Land

Lund-Potsdam-Jena managed Land (LPJmL) simulates vegetation dynamics and their impacts on hydrological processes up to global scale; sensitive to land use and climatic change. 35 land cover classes including potential natural vegetation, 9 plant functional types and 13 crop types (irrigated or not).

3.5.2.3 Artificial Intelligence for Ecosystem Services

Artificial Intelligence for Ecosystem Services (ARIES) built from Bayesian belief networks informed by user data. Uncertainty associated with its estimates quantified. Generic models adapted to specific applications at different spatial scales and for particular social-ecological contexts

3.5.2.4 Multiscale Integrated Models of Ecosystem Services

Multiscale Integrated Models of Ecosystem Services (MIMES) simulate changes in biophysical conditions and economic activities over time and through space. Developed in collaboration with stakeholders. Functional and dynamic models over space and time developed from multiple data sources

3.5.2.5 Co$ting Nature

Web-accessible tool to map ESs and conservation priority areas. Also analyses the benefits provided by the natural environment, the beneficiaries of those ESs, and assesses the impacts of possible human interventions on the continued provision of these benefits.

3.5.2.6 WaterWorld

Details process-based modelling of selected provisioning and regulating hydrological services. It incorporates high resolution spatial datasets for the entire world, spatial models for biophysical and socio-economic processes along with scenarios for climate, land use and economic change.

3.5.2.7 Social Values for Ecosystem Services

Social Values for Ecosystem Services- (Solves) is designed to assess, map, and quantify the perceived social values of ESs. Social values, the perceived, nonmarket values the public ascribes to ESs, particularly cultural services, such as aesthetics and recreation can be evaluated for various stakeholder groups.

3.5.2.8 Ecosystem Valuation Toolkit

Ecosystem Valuation Toolkit (EVT) provided by Earth Economics and comprises of a comprehensive, spatially-explicit, web-based repository of published and unpublished economic values for ESs.

3.5.2.9 Land Utilisation Capability Indicator

Land Utilisation Capability Indicator (LUCI) explores the capability of a landscape to provide ESs. It uses map data to look at how the landscape is being used and which services are currently being provided and compares these to an estimate of the landscape's potential to provide services.

3.5.2.10 Toolkit for Ecosystem Service Site-Based Assessment

Toolkit for Ecosystem Service Site-Based Assessment (TESSA) Adaptable suite of methods for identification and evaluation of terrestrial and wetland ESs. Developed to provide a framework for spatial and temporal analysis of land use change at a scale relevant to local policy

3.5.2.11 EcoServ-GIS

EcoServ-GIS adopts a 'service-based' approach, using information about natural processes and how they deliver services in the environment. It overlays spatial datasets incorporating aspects of the physical landscape (e.g. habitat) and socio-economic factors (e.g. health deprivation).

3.5.2.12 i-Tree Eco

i-Tree Eco is a software application designed for urban forest assessment. It uses field data from complete inventories or randomly located plots, along with hourly air pollution and meteorological data. It quantifies the structure and environmental effects of urban forests (or trees) and calculates their value to communities.

3.5.2.13 Natural Capital Planning Tool

The Natural Capital Planning Tool (NCPT) allows the user to assess the impact of new or proposed developments and plans on the value of Natural Capital and ESs. The tool calculates a development impact score for 10 different ESs, indicating the direction and magnitude of the impact on each assessed service as well as all services combined over a 25 year timescale post-development.

3.5.2.14 Ecosystem Services Mapping tool

Ecosystem Services Mapping tool (ESTIMAP) is a collection of spatially explicit models to support the mapping and modelling of ESs at European scale. The main objective of ESTIMAP is to support EU policies with spatial information on where ESs are provided and consumed

Table 15 List of the most common ES mapping tools

Models	**Source**	**Platform**	**Scale**	**Types of ecosystem service**
InVEST	www.naturalcapitalproject.org/InVEST	ArcGIS/Stand- alone	Municipal to provincial	Regulating Provisioning Cultural
LPJmL	www.pik-potsdam.de/research/climate-impactsand-vulnerabilities/models/lpjml	Set of models	global	Regulating Provisioning
ARIES	www.ariesonline.org	Graphical User Interface (GUI)/ Web-based	Municipal to provincial	Regulating Provisioning Cultural
MIMES	www.ebmtools.org/mimes	Simile software	Village/farm to global	Regulating Provisioning Cultural
Co$ting Nature	www.policysupport.org/costingnature	Web-based, Google Earth	Municipal to provincial	Regulating Provisioning Cultural
WaterWorld	www.policysupport.org/waterworld	ArcGIS/Stand- alone	sites to regions	Regulating Provisioning
Solves	http://solves.cr.usgs.gov/	ArcGIS	Municipal to provincial	Provisioning Cultural
EVT	http://esvaluation.org/	Web-based Android	Municipal to provincia	Regulating Provisioning Cultural
LUCI	http://www.lucitools.org/	ArcGIS	Village/farm to provincial	Regulating Provisioning
TESSA	http://tessa.tools/	Web-based	Local	Regulating Provisioning Cultural
EcoServ-GIS	https://drive.google.com/folderview?id=0B_v9QO2jyC4eNlVUbzY1UUStZU0&usp=sharing	ArcGIS	Local to regional	Regulating Cultural
i-Tree Eco	www.itreetools.org	Microsoft Excel, ArcGIS	site to regions	Regulating Cultural
NCPT	http://ncptool.com/.	Microsoft Excel.	site to local	Regulating Provisioning Cultural
ESTIMAP	https://ec.europa.eu/jrc/en/publication/eur-scientific-and-technical-research-reports/estimap-ecosystem-services-mapping-european-scale	Set of models	European continental scale.	Regulating Provisioning Cultural

3.5.3 Data and sources

A fundamental component in the mapping and modelling of ES is the availability of data (Egoh et al., 2012) at various spatial resolutions. The most comprehensive dataset for terrestrial ecosystems at EU level is Corine Land Cover (CLC) (Maes et al., 2014). There are other European data sets concerning the abundance and distribution of selected species (e.g. birds, butterflies) and species groups including the European Red List assessments. The recent EEA report on "Available data for mapping and assessing ecosystems" includes a review of these data sources http://projects.eionet.europa.eu/eea-ecosystem-assessments/library/working-document-data-availability.

The most commonly used data to derive ES indicators in the inventory were land use/cover maps, soil data, and vegetation maps. Data typically available, on continental or global level, albeit at a lower resolution, are vegetation data (including biomass, NDVI), land cover, carbon flux estimates, and agricultural statistics. Land cover and vegetation data, obtained using satellite imagery, are widely available and often free of charge (Egoh et al., 2012).

3.5.3.1 Spatial data

Spatial data are necessary to map the distribution of ESs. A variety of spatial information, representing different aspects of socio ecological systems, is in use. This spatial information can indicate ESs directly or be integrated with other spatial data layers using rule- based, empirical, or process models (Andrew et al., 2015).

3.5.3.1.1 Land use/land cover

By far, the most widely used type of information in ES assessments is LULC maps (Seppelt et al. 2011). LULC products are frequently used in benefits transfer to spatialize per-area estimates of ES supply. They are also often relied on to produce the spatially distributed biophysical parameter values needed for production function models (e.g., many of the InVEST models))

Remotely sensed data, especially coarse-scale LULC products, primarily represent land cover. However, land use and management actions are better indicators of ESs than land cover (Ericksen et al. 2012; Koschke et al. 2013; van Oudenhoven et al. 2012). Land cover may not be a reliable indicator of the ecosystem properties that influence ESs, and consequently may poorly represent the services themselves (Andrew et al., 2015)

3.5.3.1.2 Physical data describing the environment

Many ES models make use of spatial datasets representing various features of the earth's surface. These data products are generally quite well established, and many are available in physical units (Andrew et al., 2015).

Topography. Elevation and topographic variables derived from digital elevation models (DEMs) feature prominently in models of hydrological services.

Soil maps. Soils are essential components of the earth system and play important direct and indirect roles in the provisioning of many ESs (Haygarth and Ritz 2009; Robinson et al. 2013), including agricultural and timber production, and hydrological and carbon services. Soil properties are frequently included in biophysical (Crossman and Bryan 2009; Vigerstol and Aukema 2011) and empirical models of ESs or ES providers

Climate data. Climate and weather are important drivers of ESs and, as such, are often considered in ES assessments. Climate layers are required inputs for process models of carbon sequestration and agricultural or forest production (e.g. Schulp et al. 2012) and for many models of hydrological services (e.g., Dymond et al. 2012). Climate may also influence tourism potential (Ghermandi and Nunes 2013). Sources of gridded climate data include interpolated observations from weather stations and global and regional climate model outputs (e.g., http:// www.ipcc-data.org/).

Productivity. Productivity is understood to have widespread relevance to ESs. Productivity is directly related to provisioning and carbon-related services. Modeled (e.g., Doherty et al. 2010) and remotely sensed (Su et al. 2012; Vicente et al. 2013) estimates of productivity and biomass have been used to assess carbon services, although the latter source of productivity information has been used surprisingly infrequently.

Hydrological data. Some studies use existing spatial datasets of hydrological parameters, such as runoff, baseflow, groundwater recharge, or water quality, to indicate hydrological services directly (e.g., Larsen, Londoño-Murcia, and Turner 2011;O'Farrell et al. 2010). These datasets may be derived from observations (e.g., gauging stations) or from model outputs.

4 SPATIAL INDICATORS AND LANDSCAPE METRICS FOR THE ASSESSMENT OF ECOSYSTEM SERVICES

ES indicators communicate spatial variability in ESs. Many of the ES are difficult to model or cannot be directly observed from the environment. Therefore, we rely on proxy indicators (Maes et al., 2011) and the use of spatial indicators (Egoh et al., 2012). Proxy indicators can be drawn from models that were adapted in order to produce the spatial indicator of interest. Each indicator is identified by a definition, units, spatial resolution, model or data from which is has been extracted and the spatial scale (Maes et al., 2011).

Proxies may be suitable for identifying broad-scale trends in ES, or for global level and rapid assessments, but they are likely to be unsuitable for identifying hotspots or priority areas for multiple ES (Hermann et al., 2014). Additional data beyond land cover observation are therefore often necessary for a proper assessment of ecosystem functions or services, especially at the landscape scale (Englund et al., 2017).

Recent work (Crossman and Bryan, 2009; Bryan and Crossman, 2008; Dymond et al., 2008) has identified the utility of taking a landscape-scale approach to planning for investments in on-ground works that enhance elements of natural capital (e.g. biodiversity, the atmosphere, and stocks of soil and water). This approach typically involves modelling the spatial distribution of various indicators that quantify management priority from the disciplines of landscape ecology and catchment hydrology (Crossman et al., 2011). Spatial indicator could include flora and fauna species richness, species response to climate change, landscape context, pre-European vegetation remnancy, management of remnant vegetation fragments, protected area representativeness, carbon sequestration, water provision, and soil health and stability. These indicators can represented by a separate GIS raster layer (Koulov et al., 2017).

Landscape metrics are tools which can be used to bridge the methodological gap between landscape structure and ES provision (Burkhard and Maes, 2017). Spatial characteristics have implications on the performance of biodiversity and several ES, could quantified with landscape metrics.(Haas and Ban, 2018)

Landscape metrics offer great potential for place-based ES assessment (Syrbe and Walz, 2012). More than one hundred metrics have been developed for the purpose of describing processes and landscape functions in the form of mathematical terms (Burkhard and Maes, 2017). Landscape metrics can be classified into eight groups, area metrics, patch metrics, edge metrics, shape metrics, core area metrics, nearest-neighbor metrics, diversity metrics, and contagion/interspersion metrics (Frank et al., 2012).

Table 15 provides an overview of selected landscape metrics which are applicable for mapping and assessment of ES. Landscape metrics quantify physical landscape structures which themselves determine processes and functions (Burkhard and Maes, 2017).

Table 16 Examples for suitable landscape metrics indicating biodiversity and ES (provisioning, regulating, cultural; following CICES (2013)), without claim to completeness. Source: (Burkhard and Maes, 2017)

Structure/landscape metric		Process/function		Mapping target
				Dimension of Biodiversity
Shannon's diversity index, Patch density	→	Pattern heterogeneity and variety	→	Landscape diversity
Shape index	→	Natural conditions	→	Species diversity
Proximity index, Nearest neighbour index	→	Isolation, Habitat connectivity	→	Species diversity
Effective mesh size	→	Fragmentation	→	Species diversity
				Provisioning service
Total patch area (of arable land)	→	Food and fodder production	→	Food and fodder
Total patch area (of forested/arable land)	→	Biomass production	→	Biomass
Total patch area of lakes	→		→	Food (fish)
				Regulating service
No. / length of landscape elements (hedges, tree lines)	→	Soil erosion due to water runoff	→	Mass flow
Edge length (of hedges, forests and other ecotones)	→	Habitat provision forpollinators (fringe structures)	→	Pollination
Shannon's diversity index / Heterogeneity of agricultural areas	→	Population development	→	Pest control
				Cultural service
Total patch area (of water), Edge length of waters	→	Attraction, Complexity	→	Landscape aesthetics
Shape index Hemeroby index	→	Complexity and Natural conditions	→	Landscape aesthetics
No. of landscape elements	→	Legibility, mystery	→	Landscape aesthetics

5 PROTOCOL

5.1 Steps for assessment of Ecosystem services

ESAST Ecosystem Service Assessment Support Tool (ESAST) offers practical, step-by-step guidance on how to carry out an ES assessment process and to integrate the results into management and decision-making. It contains information about methods and tools to support ES assessment, relevant resources as well as illustrative case study examples. - (www.guideToES.eu). In this report we developed a suggested protocol based on ESAST. Including nine steps.

1. Setting the scene

2. Identification of ESs
3. Identification of ESs
4. Identification of indicators
5. Collect data
6. Quantification method
7. Mapping of ESs
8. Accuracy and validation

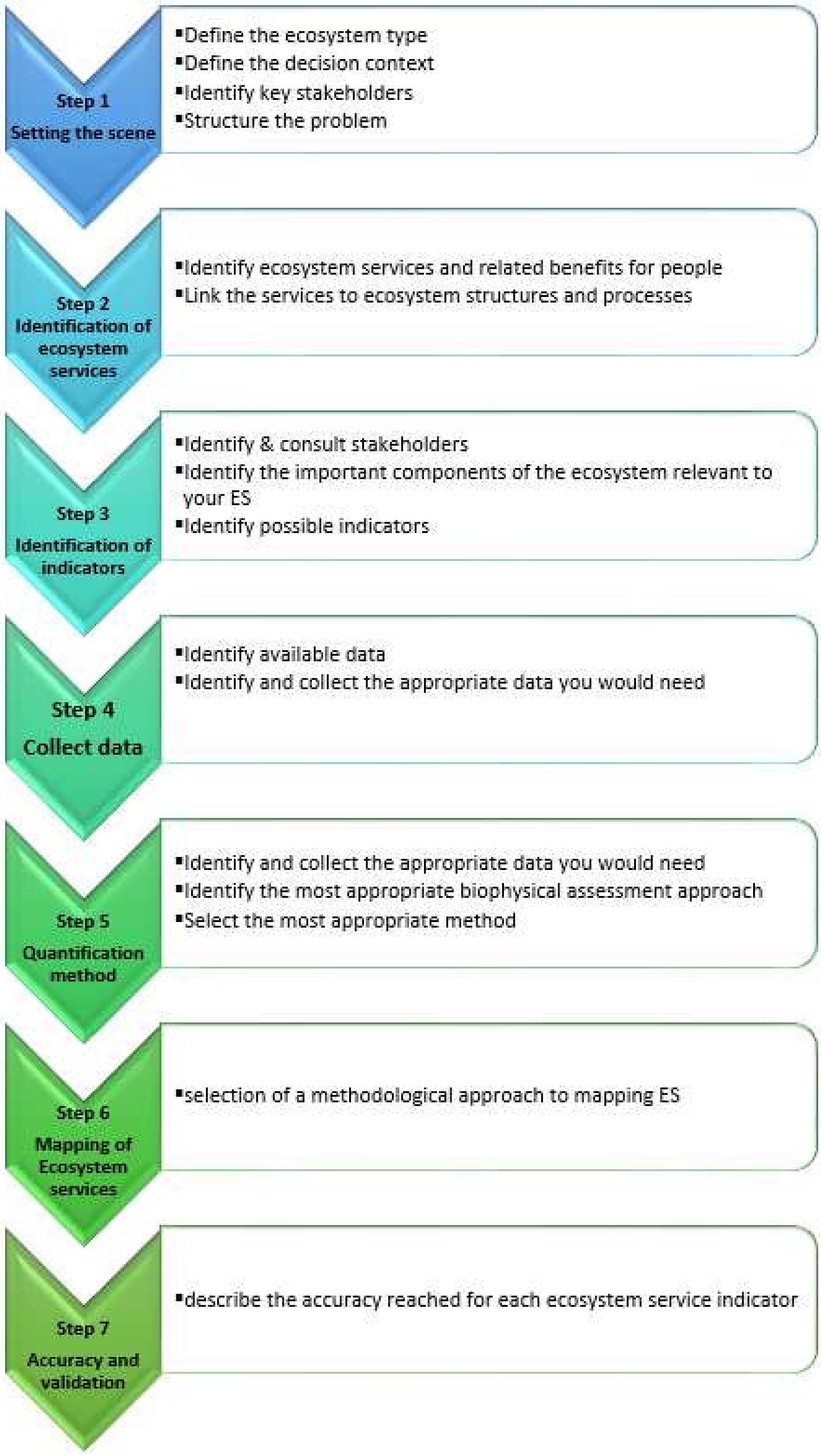

Figure 8 Steps for assessment of Ecosystem services

5.1.1 Step 1 Setting the scene

In the first step we defined the ecosystem type and the decision context. Identify private and public stakeholders and experts

5.1.2 *Step 2 Identification of ecosystem services*

5.1.2.1 *Criteria for selecting Forest Ecosystem Services*

In order to identify and select the most important ESs at a national scale, for further analysis, quantification and valuation, several criteria need to be considered. For example, in case of the Spanish NEA the criteria used for the ES selection were: 1) to select those ESs that proved to have relatively high importance for human well-being and, 2) those ESs that had shown a tendency towards clear degradation over the last 50 years.

According to Lars Hein,(2012), some criteria that could be used to indicate and select ESs are:

- ✓ Characteristics of ESs, the category and types of ecosystem
- ✓ Availability of broadly accepted methods for analyzing ESs supply in physical terms at a high aggregation level
- ✓ Availability of broadly accepted methods for analyzing ESs supply in economic terms at a high aggregation level
- ✓ Availability of data for measuring ESs in physical terms. Both point-based data and spatially explicit data (e.g. on land cover, soils, water levels, ecosystem productivity, etc.) may be required to analyze a service at national level.
- ✓ Availability of data for measuring ESs in economic terms
- ✓ Possibility to generate new data on ESs supply
- ✓ Economic importance of the ES. Initial consideration may be given to those services that generate substantial economic benefits.
- ✓ Possibility to influence environmental and/or economic policy and decision making (decision making context). Initial consideration may be given to services that can relatively easily be influenced by decision making in order to have maximum relevance for policy making
- ✓ Sensitivity of the service to changes in the environment, including from anthropogenic stressors. Initial consideration may be given to services that are sensitive to environmental change / well reflect changes in natural capital stocks.
- ✓ Whether the service is a final or intermediate ES. Final ESs may be prioritized
- ✓ the opinion of the study project's steering group, experts and stakeholders

5.1.3 *Step 3 Identification of indicators*

5.1.3.1 *Criteria for selecting indicators*

The assessment will be focused on the supply side of ESs and did not consider indicators that measure the benefits of ecosystem services. Appropriate indicators should

- ✓ be relevant to environmental and nature-protection policies and further sectoral policies, i.e. maps and assessments should be generated to make the significance of the services of nature for humans visible.
- ✓ be relevant to ecosystem functionality (e.g.: Forest designated for wood supply: for provisioning ES, all parameters for assessment available in the field must be selected, for regulation and cultural ES, the parameters are selected randomly by the verificator- Special and Protective forests: For provisioning ES, the parameters are selected randomly by the verificator, for regulation and cultural ES, all parameters for assessment available in the field. have to be selected.

- ✓ show trends and ranges of values over time, provide information to policy makers and the wider public on the current condition and changes in the states of the environment in forest ecosystems, promoting sustainable management
- ✓ be analytically clean, i.e. secured according to the current theoretical, scientific-technical knowledge and international standards, but also simple, repeatedly measurable and reproducible, practical, easy to interpret
- ✓ be developed from established national or sub-national data, scientific data and publications, data from other data sets available in third parties preferably using an expert based and long time series where this is available given the lengthy time period for many environmental effects to become apparent
- ✓ form a basis for international comparisons and enable an implementation of the ES approach with reference to the EU Biodiversity Strategy (Grunewald et al., 2017).

While the list of indicators is evolving and must be flexible so as to incorporate new indicators or abandon old ones.

A step-by-step process flowing from site identification through selection of ES indicators for assessment, is presented in Figure 10.

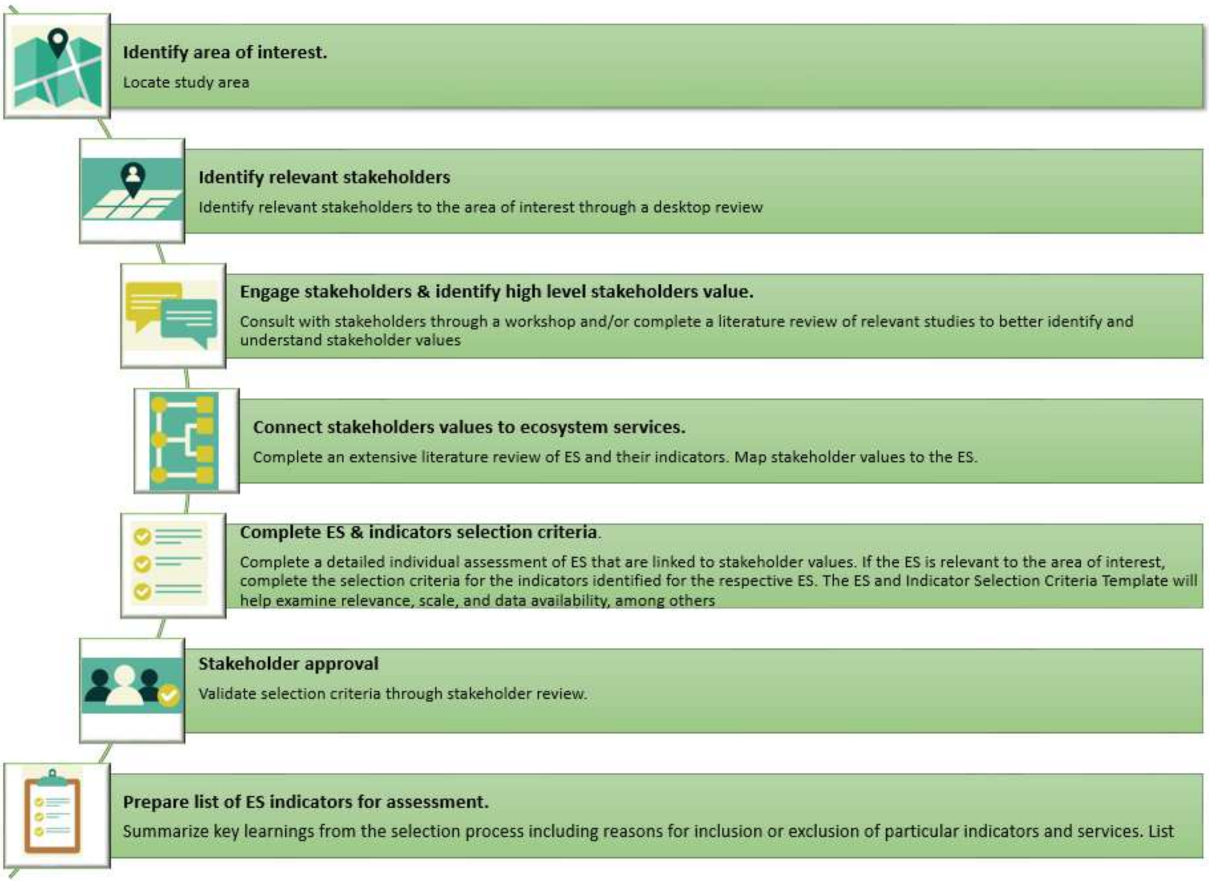

Figure 9 Process flowing from site identification through selection of ES indicators

5.1.3.2 Suggested Indicators

The below listed indicators for ESs were suggested with aim to assess forest services as developed in CICES, as it is accepted by the MAES-initiative. The experts and stakeholders involved in the project may propose other new indicators for assessment and mapping of the services, considered by them useful or more adequate for the purpose to comprehensively assess the ESs that the chosen ecosystem type provide. Also comments and estimations regarding the usefulness and applicability of the indicators listed in this methodology have to be made, on a basis of the experience acquired in their use by the experts performing the assessment.

5.1.3.2.1 Indicators for Provisioning ecosystem services

Provisioning services are one of the most easy to understand. Food provision is fundamental service ensuring existence of human society. It includes plants, their fruits, reared and wild animals. Fibers, medicinal plants and other material from plant and animal species could be mapped using different parameters, but for the current purpose only one should be applied depending on the available data.

The list of potential indicators for each service is generated, based on the JRC report 'Indicators for mapping ESs: a review' (Egoh et al., 2012). Other indicators not included in this list can also be added.

Table 17 Potential indicators for provisioning services

Section	*Division*	*Group*	*Class*	*Indicator Measuring method*	*Parameters and units*
Provisioning	Nutrition	Biomass	Cultivated crops	Harvest	m3/ha
			Reared animals and their outputs	Yield	livestock units/ha
			Wild mushrooms and their outputs	Presence of mushrooms for food	number of species / kg/ha buying stations
			Wild animals and their outputs	Heads of animals reared for hunting	number/ha
				Fishing stock	
		Water	Surface water for drinking	forest cover, age	percentage of forest, age class
			Ground water for drinking	forest cover, age	percentage of forest, age class
	Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	timber, medicinal plants	m3, number of species
			Genetic materials from all biota	plant composition	trees composition, understory composition
		Water	Surface water for non -drinking purposes	forest cover, age	percentage of forest
			Ground water for non-drinking purposes	forest cover, age	percentage of forest
	Energy	Biomass- based energy sources	Plant-based resources for energy	trees and shrubs	stock, m3/ha

5.1.3.2.2 Indicators for Regulating ecosystem services

Forests take part in regulating and maintenance process as control of erosion, buffering mass flow, pollination potential, maintaining existence of particular species and habitats. Data needed to develop indicators for regulating services are becoming available, often from national statistics or remote sensing (Brown et al., 2014).

Table 18 Potential indicators for regulating services

Section	*Division*	*Group*	*Class*	*Indicator Measuring method*	*Parameters and units*
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Filtration/sequestration/storage/ accumulation by micro- organisms, algae, plants, and animals	age distribution, increment	age class, m3/ha
		Mediation by ecosystems	Filtration/sequestration/storage/ accumulation by ecosystems	function of forests	% of protection forests and forests with other special functions
			Mediation of smell/noise/visual impacts	forest cover, age	Percentage of forest cover, age class distribution
	Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	Soil erosion rate	soil erosion rate
			Buffering and attenuation of mass flows	vegetation cover	area [ha]
		Liquid flows	Hydrological cycle and water flow maintenance	forest cover, age, stocking index	Percentage of forest cover, age class distribution
			Flood protection, incl. avalanche protection		
		Gaseous / air flows	Storm protection		
			Ventilation and transpiration		
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection Pest and desease control	Pollination and seed dispersal	Biodiversity	number of plants, number of pollinators
			Maintaining nursery populations and habitats	habitat diversity	number of habitats
			Pest control	General condition	4 level scale
			Disease control		
		Soil formation and composition	Weathering processes	site type	site type classification
			Decomposition and fixing processes	site type	site type classification
		Water conditions	Chemical condition of freshwaters		
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	C storage in forest, C sequestration by forest , Forest growth, growing stock, leaf area index	
		Maintenace and protection of facilities	Protection of infrastructure , objects and facilities	Protection forests	%, type
			Micro and regional climate regulation		

5.1.3.2.3 Indicators for Cultural ecosystem services

Important aspect for cultural indicators is the availability and access of readily available data on, for instance, number of visitors, data on distribution of wildlife, number of hunters, etc. as well as the availability of GIS maps usually needed for computing spatial indicators such as accessibility to forested areas.

Table 19 Potential indicators for cultural services

Section	*Division*	*Group*	*Class*	*Indicator Measuring method*	*Parameters and units*
Cultural	Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	farm tourism,visitors (birdwatch, plantwatch	Number per year
			Physical use of land-/seascapes in different environmental	Visitors, rural tourism, walking and biking trails	Number per year
		Intellectual and representative interactions	Heritage, cultural	cultural monuments	number of monuments/products
			Entertainment	visitors, hunters	number of visitors, number of hunters
			Aesthetic		
	Spiritual, symbolic and other ecosystems and land - settings]	Spiritual and/or emblematic	Symbolic	Aesthetic landscapes	presence of regional management plans
		Other cultural outputs	Existence	Conservation significance	Number of sites in protectedareas (e.g. Natura2000, Biosphere reserves,etc.)
			Bequest	Aesthetic landscapes	

5.1.4 *Step 2: Collect data*

Most of the data needed for mapping and analyzing the condition of forest ecosystems is available but in different format. It is necessary to prepare the database to be useful for current aim.

Egoh et al. (2012) underlines that the primary data leads to more accurate representation of spatial distribution. However, currently most of the data should be derived from existing national and subnational data sources.

The following data sources are to be considered:

- ✓ Forest inventory data, Forest management plan
- ✓ CORINE project, national data bases
- ✓ Scientific publications
- ✓ In-situ data
- ✓ EU data sources
- ✓ Additional remote sensing data

Almost all countries report that they (would) use Corine data, in many cases augmented with their national land use / land cover data (maps). This offers a solid basis for a harmonisation of the ecosystems and ESs maps which are part of the Action 5 ambition (Braat, 2014).

We should make use of existing data, mainly the reported data under EU legislation and, in particular, from assessments under Art. 17 of the Habitats Directive and Art. 12 of the Birds Directive, the Water Framework Directive, and other environmental legislation. For ecosystems without legislative reporting framework, such as forests, either national data or European monitoring data, e.g. from the European Forest Data Centre (EFDAC)or the Copernicus programme can be used. To complete and refine the ecosystem assessment, additional information indicating habitat connectivity or other functionalities as well as information on drivers and pressures reducing the capacity of ecosystems to provide services is needed and must be integrated in the assessment (Maes et al., 2014).

The variety of indicators requires different sources of information. In data collection for indicators the overall quality assurance perspective should be developed and considered (Chipev et al., 2018).

Off-site observations/measurements of the indicators is based on the available sources of information at national level. Spatial, quantitative and qualitative datasets can be used. Only nationally valid data from the authorized institutions/organizations owners of data are recommended. Spatial data from Cadaster, Land Identification Parcel System, Spatial Development Plans, Master plans, scientific data etc. should be used. National and European maps of qualitative parameters and indicators are also applicable. Quantitative data obtained from other systems of monitoring should be analyzed for the period between the monitoring reports (min 5 years) (Chipev et al., 2018).

In-site observations/measurements should follow the standard sampling design and standard methodologies approved at national and European level. All additional laboratory analyses should be conducted according to the standard methods (Chipev et al., 2018)

5.1.5 Step 4 Quantification method

key criteria or features are important for method selection. The ability of a method to address a specific purpose is the primary factor influencing method selection.

To help our decision to select the appropriate biophysical method an ES tool we can use decision tree as proposed by Harrison et al., (2018). The biophysical decision tree (Figure11) provides guidance between different mapping and modelling approaches to ES assessment

The mapping branch of the biophysical decision tree asks the user what they want to map, either individual or a limited number of ESs, or multiple ESs. The latter leads to matrix-based approaches which vary in their complexity in terms of the number of datasets that are combined to estimate service provision.

If their focus is on specific ecosystem processes then they are led to biophysical models, which include a wide range of different ecological, hydrological and other types of models, whilst if they wish to model a range of ESs they are led to ES models, such as InVEST, ESTIMAP and QUICKScan.

If the focus is on a single or a few services and stakeholder perceptions of service demand and supply are important, then deliberative mapping is suggested, or if data are available to map a service directly (e.g. for food production) then simple GIS mapping is given as the option.

If data is not available to map a service directly then the user is directed to the modelling part of the decision tree. The mapping part of the decision tree also recognises that most of the mapping approaches can be implemented with or without stakeholder engagement and refers the user to the socio-cultural decision tree for further guidance on participatory and deliberative approaches(Harrison et al., 2018)

5.1.6 Step 6 Mapping of Ecosystem services

The selection of a methodological approach to mapping ES is data dependent.

When there are secondary data available and there is not much time and resources, a good approach will be the look-up tables; otherwise, if there is a need to improve the quality of the maps and there is more time and resources, the expert knowledge is a good approach to select. The causal relationship approach can also be applied based on the secondary data and occasionally can rely on some primary data to guide the model.

When there are primary data available, the selection of the method will depend on whether there are primary data that are not representative of the study site or whether it is a representative sampling of the study site. In the first case the method selected should be able to extrapolate the primary data to the study area obtaining modeled surfaces of ES. In the second case the method selected should be the regression models, that is the best supported approach providing the more accurate spatial distribution of ES but at the same time implies more time, resources, and knowledge for its application (Martnez-Harms and Balvanera, 2012).

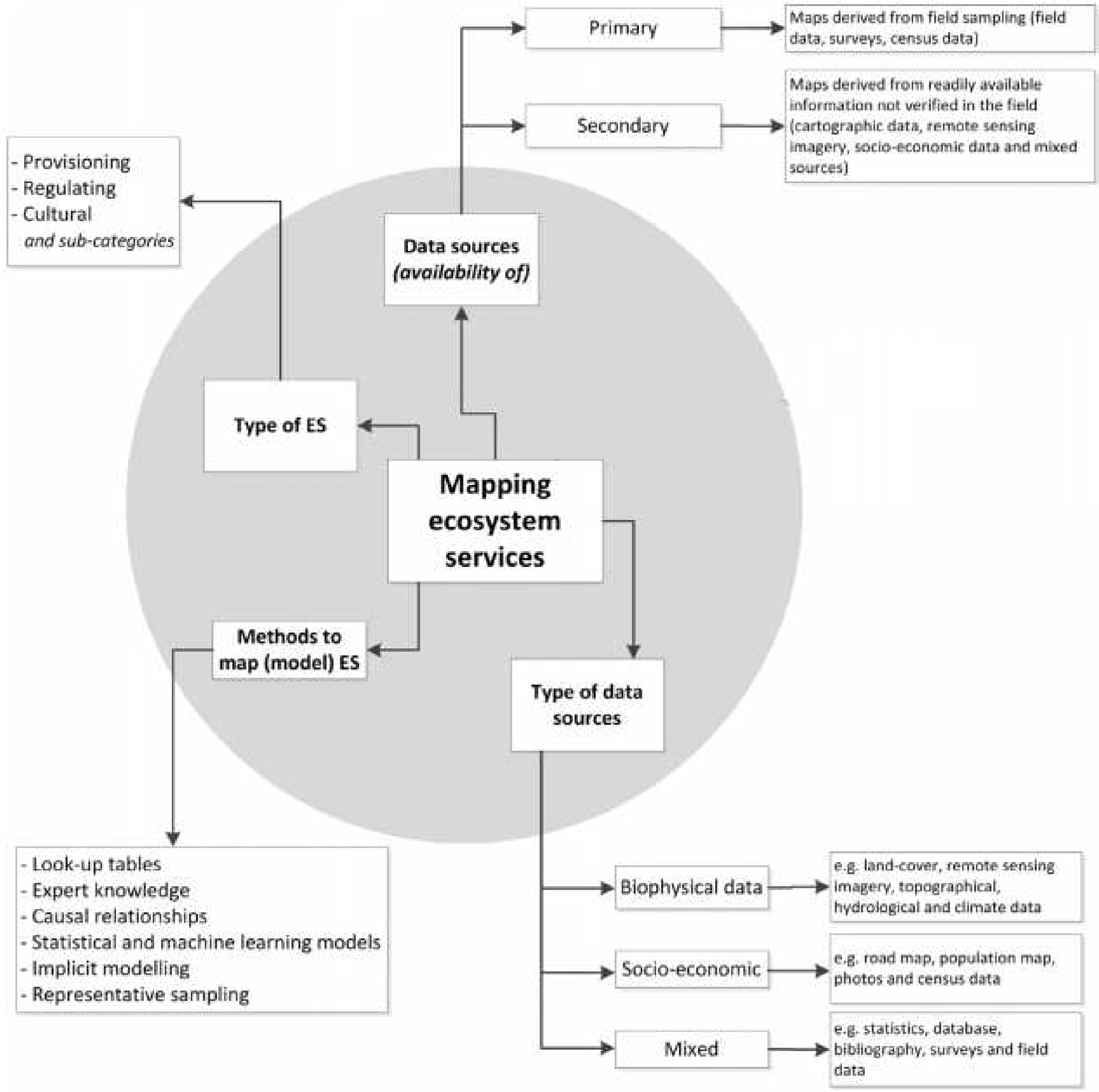

Figure 10 Criteria used for classifying ecosystem services mapping approaches. Source (Martinez-Harm and Balvanera, 2012)

5.1.7 Step 7 Accuracy and validation

The expert should provide scientifically sound approach to describe the accuracy reached for each ES indicator; hence validation approach should be applied. For each validation, accuracy reports should be generated and provided.

There is often a trade-off between the level of accuracy and the complexity of the model and the time available to produce results. More complex models tend to be more accurate but require more data, resources, technical expertise, and time (Bullock and Ding, 2018).

6 SYNERGIES AND TRADE-OFFS AMONG FOREST ECOSYSTEM SERVICES

6.1 Concept of the relationships among ecosystem services

Most of the research conducted in ES has been focused on single or a few ecosystem services of a certain ecosystem. However ecosystems provide a lot of ESs which may influence each other. Thus, despite the essential progress in ES research (Andersson et al. 2007; Daily and Matson 2008), the interactions and feedback among different ecosystem services has not been studied in details and efficiently.

For decision-making and management purposes, it is therefore important to focus on all ES, as well as to the existing relationships among them (Kandziora et al. 2013). It has to be noted that the lack of detailed knowledge of relationships among ES, especially those between provisioning and regulating ecosystem services, has been identified as one of the main reasons for the limited application of the concept of ecosystem services in land use management, planning and local decision-making (Elmqvist et al. 2011). These dynamic relationships among ES may threat the safety and the well-being of humans, while they can affect ecological security (Li and Wang, 2018). Therefore, it is essential to study the trade-offs and synergies among ES to better manage the various services of ecosystems, in order to find balance between economic development, societal needs and environmental protection. Identification of synergies and trade-offs will help managers and policymakers to understand the hidden consequences of preferring one ES to another. The knowledge of synergies is important for any spatial development strategy that aims to increase the supply of ES for the well-being of humans.

The relationships between ES have shown dynamic changes that generally can be classified in three relationship forms: trade-offs, synergies, and no relationship or bundles (Li et al. 2017). The term 'trade-off' first appeared in the 1960s, originated from the economic theory. The term trade-off involves losing one quality or aspect of something in return for gaining another quality or aspect. In ES research the term trade-offs refers to the reduction of supply of certain types of ES due to the increased use of other types (Howe et al. 2014). Synergies (or co-benefits) refer to the increase of two or more ES simultaneously (Austrheim et al. 2016; Grace et al. 2014; Li and Wang 2018), while no relationship, or bundles, means that the considered ES do not interact with each other.

Synergies and trade-offs among ES could be due to true interactions or can be caused by simultaneous responses to the same driver (Bennett et al. 2009). Drivers are usually including ES use, land use changes, ecological changes, management regime, investment choices, etc. It has to be noted that ES trade-offs and synergies may not occur at the same time and/or same location. For example, the upstream land-use conversion for agriculture can increase downstream flood risk (García-Llorente et al. 2015). Additionally, studying ES trade-offs and synergies needs more than assessing potential supply and potential demand (Geijzendorffer et al. 2015). Thus, a trade-off between ES is only invoked whenever an ES is "used", meaning that the ecosystem is managed as a result of a demand (Haines-Young and Potschin 2010). For example, timber harvesting causes a decrease in the land's water retention ability, a well known forest ES trade-off. However, no demand for timber production from the area means that this trade-off will never manifest itself as a management problem that must be solved. According to Howe et al. (2014), ES trade-offs occur mainly when one of the services is a provisioning service with a private beneficiary and the other services are public benefits.

There may be limits to the actual supply of certain ES to the required level. These limits are mainly related to biophysical drivers (e.g. disease, climate change, invasive species), management practices, the stakeholder demands and desires (Mouchet et al. 2014), and/or negative interactions between certain ES. A trade-off can potentially has as a result a conflict between users depending on who benefits of the ES supply and who is not (Kandziora et al. 2013). On the other hand, synergies between ES or no relation can lead to cooperation or co-existence of the ES users (Hicks and Cinner 2014).

6.2 Analysis of ES synergies and trade-offs

Management of multiple ES must take into account trade-offs and synergies. This procedure requires the understanding of the mechanisms affecting ES interactions (Bennett et al. 2009). There are many difficulties to analyse trade-offs including the complexity of ES interactions and the factors determining them, the different value-dimensions of ES (biophysical, socio-cultural and economic) (Castro et al. 2014; Martín-López et al. 2014) and the spatial and temporal scale dependence of ES trade-offs (Rodriguez et al. 2006; Renard et al. 2015).

Various quantitative statistical methods are proposed to assess trade-offs (Mouchet et al. 2014), but they do not fully capture the context-dependent mechanisms of trade-offs and synergies. Moreover, the explanatory variables used (social, economic, ecological) are also highly context-specific. As a result, the knowledge regarding the mechanisms that cause trade-offs and synergies, as well as management implication to minimize trade-offs and enhance synergies is currently limited (Bennett et al. 2009; Ostrom 2009; Howe et al. 2014).

The knowledge of ES interactions at different temporal scales, both short-term and long-term, is crucial (Mouchet et al. 2014; Birkhofer et al. 2015), as historical decisions influence current provisioning of ES (Dallimer et al. 2015) and current decisions can influence the future supply of ES.

Assessing ES over space by using maps to infer ES interactions is also of high importance (Raudsepp-Hearne et al. 2010; Qiu and Turner 2013). The spatial overlap is quantified using correlation coefficients and then the positively correlated ES are recognized as synergistic whereas the negatively correlated ES are categorized as trade-offs (Lautenbach et al. 2010; Raudsepp-Hearne et al. 2010). Unfortunately, inferring trade-offs and synergies using broad-scale spatial correlations among ES often ignores or underestimates several fundamental assumptions of the temporal approach.

Howe et al. (2014) stated that ES trade-offs are approximately three times more than synergies. This is in agreement to Hicks et al. (2013) who reported that according to stakeholder groups trade-offs are more than synergies. Lee and Lautenbach (2016) reviewed that relationships between regulating and provisioning ES are mostly trade-offs while synergies are mostly found among regulating and cultural ES.

Trade-offs between provisioning and regulating ecosystem services at different scales have drown more attention because regulating ES are essential for the sustainable production of provisioning and cultural ecosystem services (Raudsepp-Hearne et al. 2010; García-Llorente et al. 2012; Castro et al. 2014).

6.3 Synergies and trade-offs of ES of forest ecosystems

Multiple-use management of forest ecosystems in order to provide a variety of services requires identification of trade-offs among services and decisions that reflect societal choices among the costs and benefits associated with particular options. Although there is clear evidence of ES relationships in forests, the importance of ES trade-offs, synergies and bundles has not yet been thoroughly examined.

It is probably not possible to maximize timber production, carbon sequestration, habitat conservation and social and cultural benefits in the same forest stand (Chapin 2009). Indeed, provisioning services, such as timber production, require some silvicultural activities that can alter the conditions in the forest and consequently affect the supply of other ecosystem services. For example, timber harvesting may affect negatively the habitat for pollinators, as well as the amount of carbon stored in the forest (Baskent et al. 2011; Borys et al. 2016; Seidl et al. 2007; Sharma et al. 2013). However, pollination and carbon storage are not interacting directly with each other. On the other hand, a strong direct ecosystem service interaction is the synergistic relationship between erosion regulation and primary production: woody vegetation prevents erosion and protects soil fertility, while soil fertility supports the production of vegetation. Moreover, there may be opposite effects to ES, even they are affected by the same drivers: The increasing density of living trees in a forest affects positively the amount of carbon stored in the forest, but at the same time it may affect negatively the yield of forest berries and of forage that are benefited from open canopies. Therefore, understanding the mechanisms behind observed ecosystem service relationships is necessary to manage them effectively (Bennett et al. 2009).

The main drivers influencing the quantity and quality of ecosystem services provided by forests are forest management (Bottalico et al 2016) and climate change (Nelson et al 2013). Forest management plans have to be applied to meet the demand for different ecosystem services from different stakeholders (Reed et al 2013). Possible trade-offs between these services make decisions of forest managers even more complicated as prioritization and stand-based evaluation of management measures are needed (Gutsch et al 2011).

Some examples of synergies and trade-offs between ESs provided by forests are presented in Table 19.

Table 20 synergies and trade-offs between ecosystems services provided by forests

Synergies
Timber harvesting: increased production of some NWFPs (e.g. forage, berries)
Water resources: water provisioning, maintenance of soil resources, regulation of water quantity and quality, flood prevention
Timber production capacity: maintenance of soil resources, genetic diversity of forest
Climate regulation: maintenance of soil resources, regulation of water quantity by maintaining ecosystem structure

Cultural services: maintenance of supporting services
Tradeoffs
Timber production vs carbon storage
Timber harvesting vs water retention ability
Timber production vs habitat conservation
Tourism vs traditional cultural services
Tourism vs habitat conservation

There is limited research on the relationships among forest ecosystem services, especially in the Mediterranean countries. Therefore, future research is needed at local and regional level for studying the complex forest ES interactions and the factors affecting them at biophysical, socio-cultural and economic dimensions, at both spatial and temporal scale. This research will be essential in order to identify how forest management affect ES trade-offs and synergies and their consequences, how to address conflicts among stakeholders and how to take the best decisions for long term ecological, social and cultural implications of trade-offs between economy and environment.

7 QUESTIONNAIRE

A questionnaire (Appendix 2) was developed comprising several questions on aspects of current trends and status of ES. The questionnaire aims to collect experience by the respondents and target the methology to be developed for assessing and valuing ecosystem services.

The questionnaire was specifically developed, structured in three sections. We asked information about: (1) the respondent, (2) the main ecosystem type, (3) the significance of each ecosystem service and (4) the threats of ecosystem services.

The questionnaire is available to sent via with a link to an online-questionnaire to experts/stakeholders. The results will be presented in the next deliverable D3.1.3 Operational models for the economic valuation of biodiversity services in forest ecosystems

8 ANNEXES

ANNEX 1. Literature review

Mapped ecosystem service	Ecosystem Service Indicator		Quantification unit		Input Data source	Quantification mehod	Country /Study	Spatial details		Reference
	Primary	Secondary	Quantity	Area	Label			Scale	Resolution	
Provisioning Services										
Food provision	Food crop production	null	thousand ton	ha	null	Collection of primary data	Europe	null	null	(Maes et al., 2015)
Food provision	Fodder crop production	null	thousand ton	km²	CORINE Land cover	null	Europe	Continental	null	(Maes et al., 2015)
Food provision	Total area of organic farming	null	ha	km²	CORINE Land cover	Collection of primary data	Europe	Continental	null	(Maes et al., 2015)
Food provision	Livestock	null	thousand heads	km²	CORINE Land cover	Collection of primary data	Europe	Continental	null	(Maes et al., 2015)
Raw materials	Timber production	null	thousand m^3 per year	km²	CORINE Land cover	Collection of primary data	Europe	Continental	null	(Maes et al., 2015)
Raw materials	Textile crop production	null	thousand ton	km²	CORINE Land cover	null	Europe	Continental	null	(Maes et al., 2015)
Raw materials	Energy crop production	null	thousand ton	km²	CORINE Land cover	Collection of primary data	Europe	Continental	null	(Maes et al., 2015)
Fresh water	Water abstraction for industry	null	million m^3	km²	CORINE Land cover	Collection of primary data	Europe	Continental	null	(Maes et al., 2015)

Fresh water	Water abstraction for agriculture	null	million m^3	km²	CORINE Land cover	Collection of primary data	Europe	Continental	null	(Maes et al., 2015)
Fresh water	Water abstraction for households	null	million m^3	km²	CORINE Land cover	Collection of primary data	Europe	Continental	null	(Maes et al., 2015)
Timber	Volume of harvest	null	thousant m^3	ha	null	Biophysical models	North Italy	Local	null	(Häyhä et al., 2015)
Wood chips	Amount of wood fuel for bioenergy	null	thousant m^3	ha	null	Biophysical models	North Italy	Local	null	(Häyhä et al., 2015)
Firewood	Amount of firewood for heating private houses	null	thousant m^3	ha	null	Biophysical models	North Italy	Local	null	(Häyhä et al., 2015)
Food provision	Game	Number of hunted animals	thousant head	ha	null	Biophysical models	North Italy	Local	null	(Häyhä et al., 2015)
Food provision	Mushrooms	Amount of harvested mushrooms	thousant kg	ha	null	Biophysical models	North Italy	Local	null	(Häyhä et al., 2015)
Food provision	Berries	Amount of harvested berries	thousant kg	ha	null	Biophysical models	North Italy	Local	null	(Häyhä et al., 2015)
Fresh water	Water consumption	null	thousant kg	ha	null	Biophysical models	North Italy	Local	null	(Häyhä et al., 2015)
Food provision	Reindeer	Land cover	null	km2	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Food provision	Game	Land cover	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Food provision	Fish	Land cover	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Food provision	Berries, mushrooms	Land cover	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)

Fodder	Land cover	null	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Medicines	Land cover	null	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Wood	Land cover	null	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Water	Land cover	null	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Energy	Land cover	null	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Genetic resources	Land cover	null	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Habitat value	Land cover	null	null	km²	CORINE Land cover	GIS mapping	Finnish	Local	25m x 25m	(Vihervaara et al., 2010)
Biomass	Timber services	Timber stock	m³ per ha	n.d	JRC forest inventory & EFISCEN database hosted by EFI	Collection of primary data	EU27	Continental	NUTS-x regions	(Maes et al., 2011)
Habitat diversity	Potential of an area to deliver this service (mean importance score)	null	dimensionless value	null	CORINE Land cover	GIS mapping	EU25 plus Switzerland and Norway	Continental	NUTS-x regions	(Haines-Young et al., 2012)
Wildlife products	Potential of an area to deliver this service (mean importance score)	null	dimensionless value	null	CORINE Land cover	GIS mapping	EU25 plus Switzerland and Norway	Continental	NUTS-x regions	(Haines-Young et al., 2012)
Water	Surface water for drinking	Investments in forest plantations	null	null	CORINE Land cover/NATURA 2000	GIS mapping	Bulgaria	Local	25 ha	(Koulov et al., 2017)
Biomass	Wild plants. algae and their outputs	Quantities of non-timber products gathered from the Central Balkan NP	kg per yr	null	CORINE Land cover/NATURA 2000	GIS mapping	Bulgaria	Local	26 ha	(Koulov et al., 2017)

Biomass	Fibres and other materials from plants.	Quantities of timber harvested from the Central Balkan NP	m³ per ha	null	CORINE Land cover/NATURA 2000	GIS mapping	Bulgaria	Local	27 ha	(Koulov et al., 2017)
Biomass	Game and Wild plants	Number of permits. Central Balkan NP	permits	null	CORINE Land cover/NATURA 2000	GIS mapping	Bulgaria	Local	28 ha	(Koulov et al., 2017)
Biomass	Damask rose	Average yield per year	tonnes per year	null	CORINE Land cover/NATURA 2000	GIS mapping	Bulgaria	Local	29 ha	(Koulov et al., 2017)
Raw materials	Textile crop production	null	thousand ton	km²	CORINE Land cover	InVEST model	Italy	Continental	country	(Salata et al., 2017)
Habitats for species	Habitat Quality	null	Score	ha	Land Use Land Cover - DUSAF	InVEST model	Italy	Sub-National	30*30 meters	(Salata et al., 2017)
Timper	wood volume	Net primary productivity (NPP)	m³ per ha	ha	NDVI	CASA model	China	Local	30 m × 30 m	(Dai et al., 2017)
Cultivated crops Reared	agricultural yield	null	t/ha	ha	Field parcel data	nd	Finnish	Local	hexagonal 1.5 km x 1.5 km	(Tammi et al., 2017)
Reared animals	livestock type and headcount data	null	t/ha	ha	Municipal boundaries	nd	Finnish	Local	hexagonal 1.5 km x 1.5 km	(Tammi et al., 2017)
Fuel	Biogas energy	Agrobiomass by-products and manure	null	null	null	nd	Finnish	Local	hexagonal 1.5 km x 1.5 km	(Tammi et al., 2017)
Wildlife hunting	Hunting permits	null	null	null	Municipal boundaries	nd	Finnish	Local	null	(Tammi et al., 2017)
Food provision	bilberry and lingonberry yield	Bilberry and lingonberry yield	null	null	Multi-source National Forest Inventory spatial data	Regional yield prediction expert models	Finnish	Local	null	(Tammi et al., 2017)
Water	Water extrac- tion	Surface water sources	Mm³	null	Corresponding municipalities	nd	Finnish	Local	null	(Tammi et al., 2017)

Food provision	Cultivable land; amount of food material	null	tonnes per ha-1	ha	Landsat 4 TM/Landsat 8 OLI	GIS mapping	Nepal	Local	30m x 30m	(Paudyal et al., 2015)
Forage production	Number of fodder producing species per ha and hectares of grassland	null	Hl per ha or tonnes per ha	ha	Landsat 4 TM/Landsat 8 OLI	GIS mapping	Nepal	Local	30m x 30m	(Paudyal et al., 2015)
Materials	Timper	Number of large and mature trees per ha of dense forest	tonnes per ha	ha	Landsat 4 TM/Landsat 8 OLI	GIS mapping	Nepal	Local	30m x 30m	(Paudyal et al., 2015)
Energy	Firewood	Wood fuel biomass per ha; no. of fuelwood species per ha	tonnes per ha	ha	Landsat 4 TM/Landsat 8 OLI	GIS mapping	Nepal	Local	30m x 30m	(Paudyal et al., 2015)
Generic resources	No. of new species observed in CMF per ha	null	no.per ha	ha	Landsat 4 TM/Landsat 8 OLI	GIS mapping	Nepal	Local	30m x 30m	(Paudyal et al., 2015)
Local medicines	No. of species of medical value per ha / harvestable amount	null	no.per ha	ha	Landsat 4 TM/Landsat 8 OLI	GIS mapping	Nepal	Local	30m x 30m	(Paudyal et al., 2015)
Water	Freshwater	Presence of water bodies such as no. of springs, ponds and streams; no. of projects using water (watermills, hydropower plants, etc.)	ML per ha year	ha	Landsat 4 TM/Landsat 8 OLI	GIS mapping	Nepal	Local	30m x 30m	(Paudyal et al., 2015)
Food provision	Area	Landscape metrics	null	null	SENTINEL 2 A	GIS mapping	China	Local	20m x 20m	(Haas et al., 2018)
Water supply	Area, edge	Landscape metrics	null	null	SENTINEL 2 A	GIS mapping	China	Local	20m x 20m	(Haas et al., 2018)

Biodiversity	Richness species, habitat quality, protection degree	null	null	null	Hábitats EUNIS	Biophysical model/GIS mapping	Spain	Local	2m x 2m	(Onaindia et al., 2013)
Food provision	Hunting	Game meat	kg per km^2 year	km^2	Dutch land cover map LGN6	GIS mapping	Netherland	Local	25 x 25m	(Villa et al., 2014)
Water	Drinking water extraction	Extracted groundwater	m^3 per ha year	ha	Dutch land cover map LGN6/Groundwater protection zones	GIS mapping	Netherland	Local	25 x 25m	(Villa et al., 2014)
Food provision	Crop production	Harvested crop	kg per ha year	ha	Dutch land cover map LGN6/Soil map	GIS mapping	Netherland	Local	25 x 25m	(Villa et al., 2014)
Fodder Production	Harvested or grazed fodder	null	null	null	Dutch land cover map LGN6/Soil map Groundwater table	Biophysical model/GIS mapping	Netherland	Local	25 x 25m	(Villa et al., 2014)
Food provision	Livestock numbers	Maximum Livestock Capacity (MLC)	LU per ha	ha	Grassland habitat types	Biophysical model/GIS mapping	Czech Republic	National	Average area of natural habitats is 1,76 ha	(Hönigová et al., 2012)
Food provision	Fodder provision	Livestock	head per ha	ha	National Land Cover Dataset (NLCD)	Biophysical model/GIS mapping	China	National	10 km-resolution	(Zhang et al., 2010)
Raw materials	Timber services	Growing stock	m^3 per ha	ha	remotely sensed vegetation data (MODIS	Quantitative modelling analysis using	China	National	500 m x 500 m	(Gallaun et al., 2010)

ANNEX 2 Questionnaire

bioprospect
Interreg
Balkan-Mediterranean
BIOPROSPECT

Project co-fubded by the European Union

QUESTIONNAIRE: Ecosystem Services

This survey is conducted in the framework of the BIOPROSPECT project of INTERREG VB Balkan-Mediterranean (2014-2020). Aim of BIOPROSPECT project is to explore and document the bioprospects of forested protected areas and the ways of sustainable capitalization as a mean for their wise management and conservation. Implementing bodies of the project are:
-Democritus University of Thrace, Department of Forestry and Management of the Environment and Natural Resources (DUTH)
-Aristotle University of Thessaloniki- School of Economics (AUTH),
-Exhibition Research Institute (IEE)
-Centre for Research and Technology-Hellas (CERTH),
-Municipality of Vrapcisht
-Institute of Applied Biosciences-Cyprus University of Technology
-Exhibition Research Agrobioinstitute of Bulgaria,
-Institute Municipality of Maliq- Albania
Thank you for taking the time to complete this survey. We truly value the information you have provided. If you have any questions about this survey or the project please email us (info@balkanmed-bioprospect.eu) or visit the web site http://balkanmed-bioprospect.eu

Organisation Information

Name of your organization:	
Type of organization	mark with X
Academic/ Research institute	
National Government department/ Ministry	
Regional Government department	
Local Government department	
NGO (non-governmental organization)	
Organisation website	
Your position in the organization	
Email of the organisation	

Area information

1.What is the the relative area distribution (%) of the different ecosystem types in your area?

Urban		please complete the percentage
Cropland		please complete the percentage
Grassland		please complete the percentage
Woodland and forest		please complete the percentage
Heathland and shrub		please complete the percentage
Sparserly vegetated land		please complete the percentage
Wetlands		please complete the percentage

6. Forests under your governance/managment (sq. km)

please complete

7.Percentage of forest covered by Natura 2000 (%)

please complete

8.What is the main European forest type presented in your area?

a) Broadleaved forest (crown cover density>30% and minimum tree height >5m)	**b) Coniferous forest** (crown cover density>30% and minimum tree height >5m	**c)Mixed forest**	**d)Grasslands**	**e)Sparsely vegetated areas**

9.In the last 10 years, what has been the overall change in forest health condition?

a) Major improvement	b)Improvement	c)No significant change	d)Deterioration	c)Strong deterioration

10.In your opinion, who are the main beneficiaries/users of the forest ecosystem services provided by your area?

a)Local communities	b)visitors	c) Forest area administration	d)National welfare	e)Industry/Traders

f)Global welfare

Significance of forest ecosystem services

Please rate how significant each ecosystem service (ES) is by circling one number on the scale to no significance (0) to high significance (3)

Provisioning forest ecosystem services

Food (e.g. fish, game, fruit) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Water (e.g. for drinking, irrigation, cooling) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Raw Materials (e.g. fiber, timber, fuel wood, fodder, fertilizer) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Genetic resources (e.g. for crop-improvement and medicinal purposes) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Medicinal resources (e.g. biochemical products, models & testorganisms) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Ornamental resources (e.g. artisan work, decorative plants, pet animals) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Provisioning values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Regulation & Maintenance forest ecosystem services				
Air quality (e.g. capturing (fine)dust, chemicals, etc)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Climate (incl. C-sequestration, influence of vegetation on rainfall, etc.)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Extreme events (eg. storm protection and flood prevention)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Water flows (e.g. natural drainage, irrigation and drought prevention)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Waste (especially water purification)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Erosion prevention	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Soil fertility (incl. soil formation)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Pollination	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Biological control (e.g. seed dispersal, pest and disease control)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Regulating values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Life cycles (incl. nursery service)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Genetic diversity (especially in gene pool protection)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cultural forest ecosystem services				
Aesthetic	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Recreation and ecotourism	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Inspiration/education	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Ethical and spiritual values	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cognitive development /Scientific value	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cultural values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Assessment of forest ecosystem services

Please rate how feasible is the mapping and assessment of the each forest ecosystem service (ES) in your area on the scale to very difficult (0) to already available (3)

Provisioning forest ecosystem services

Food (e.g. fish, game, fruit) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Water (e.g. for drinking, irrigation, cooling) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Raw Materials (e.g. fiber, timber, fuel wood, fodder, fertilizer) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Genetic resources (e.g. for crop-improvement and medicinal purposes) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Medicinal resources (e.g. biochemical products, models & testorganisms) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Ornamental resources (e.g. artisan work, decorative plants, pet animals)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Provisioning values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Regulation & Maintenance forest ecosystem services

Air quality (e.g. capturing (fine)dust, chemicals, etc)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Climate (incl. C-sequestration, influence of vegetation on rainfall, etc.)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Extreme events (eg. storm protection and flood prevention)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Water flows (e.g. natural drainage, irrigation and drought prevention)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Waste (especially water purification)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Erosion prevention	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Soil fertility (incl. soil formation)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Pollination	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Biological control (e.g. seed dispersal, pest and disease control)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Regulating values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Life cycles (incl. nursery service)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Genetic diversity (especially in gene pool protection)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cultural forest ecosystem services

Aesthetic	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Recreation and ecotourism	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Inspiration/education	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Ethical and spiritual values	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cognitive development /Scientific value	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cultural values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don’t know

Valuation of forest ecosystem services

Please rate how feasible is the valuation (monetary) of the each ecosystem service (ES) in your area on the scale to very difficult (0) to already available (3)

Provisioning forest ecosystem services

Food (e.g. fish, game, fruit) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Water (e.g. for drinking, irrigation, cooling) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Raw Materials (e.g. fiber, timber, fuel wood, fodder, fertilizer) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Genetic resources (e.g. for crop-improvement and medicinal purposes) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Medicinal resources (e.g. biochemical products, models & testorganisms) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Ornamental resources (e.g. artisan work, decorative plants, pet animals)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Provisioning values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Regulation & Maintenance forest ecosystem services

Air quality (e.g. capturing (fine)dust, chemicals, etc)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Climate (incl. C-sequestration, influence of vegetation on rainfall, etc.)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Extreme events (eg. storm protection and flood prevention)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Water flows (e.g. natural drainage, irrigation and drought prevention)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Waste (especially water purification)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Erosion prevention	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Soil fertility (incl. soil formation)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Pollination	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Biological control (e.g. seed dispersal, pest and disease control)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Regulating values (general)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Life cycles (incl. nursery service)	0	1	2	3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Genetic diversity (especially in gene pool protection) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cultural forest ecosystem services

Aesthetic 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Recreation and ecotourism 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Inspiration/education 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Ethical and spiritual values 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cognitive development /Scientific value 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Cultural values (general) 0 1 2 3

In the last 10 years, would you say the specific service has..

a)Decreased b)Remained the same c)Increased d)Don't know

Pressures of forest ecosystem services

What are the main threats/challenges to the ecosystem services in the area? circling one number on the scale to no severe (0) to high severe (3)

Habitat conversion and degradation (land conversion) (i.e. fragmentation by roads and other linear feature, Forest cover change and deforestation, landslides, soil sealing)	0	1	2	3
Climate change (i.e. forest damage by storms and/or other extreme weather events, drought, fires)	0	1	2	3
Pollution and nutrient enrichment	0	1	2	3
Over-exploitation	0	1	2	3
Over-harvesting	0	1	2	3
Introduction of invasive alien species	0	1	2	3
Other (Insect outbreaks, pest damage and parasites, damage by wildlife and herbivores, soil erosion)	0	1	2	3

9 GLOSSARY

Biomass is biological material derived from living or dead organisms. The quality aspect of biomass is also relevant, e.g. based on protein synthesis and evolution (La Notte et al., 2017).

Ecosystem services: contributions of ecosystem structure and function—in combination with other inputs—to human well- being (Burkhard etal.,2012a).

Ecosystem processes: changes or reactions occurring in ecosystems; either physical, chemical or biological; including decomposition, production, nutrient cycling and fluxes of nutrients and energy (MEA, 2005).

Ecosystem structures: biophysical architecture of ecosystems; species composition making up the architecture may vary (TEEB, 2010).

Ecosystem functions: intermediate between ecosystem processes and services and can be defined as the capacity of ecosystems to provide goods and services that satisfy human needs, directly and indirectly (de Groot et al.,2010).

Ecosystem service supply: refers to the capacity of a particular area to provide a specific bundle of ecosystem goods and services within a given time period (Burkhard et al., 2012b). Depends on different sets of landscape proper- ties that influence the level of service supply (Willemen et al., 2012**)**

Ecosystem service demand: is the sum of all ecosystem goods and services currently consumed or used in a particular area over a given time period (Burkhard et al., 2012b).

Ecosystem service benefiting areas: the complement to ecosystem service providing areas. Ecosystem service benefiting areas may be far distant from the relevant providing areas. The structural characteristics of a benefiting area must be such that the area can take advantage of an ecosystem service (Syrbe andWalz,2012). Commensurate with *ecosystem service demand*.

Ecosystem service trade-offs: The way in which one ecosystem service responds to a change in another ecosystem service (MEA ,2005).

Ecosystem functions: the capacity of an ecosystem to deliver a service', which is in the sense of Haines-Young and Potschin (2010, 2012),

Human well-being: A state that is intrinsically (and not just instrumentally) valuable or good for a person or a societal group, comprising access to basic materials for a good life, health, security, good physical and mental state, and good social relations (based on MA, 2005).

Indicator: An indicator is a number or qualitative descriptor generated with a well-defined method which reflects a phenomenon of interest (the indicandum). Indicators are frequently used by policy-makers to set environmental goals and evaluate their fulfilment (based on Heink & Kowarik, 2010).

Land cover: Land cover is the observed (bio)physical cover on the earth's surface.

Leaf area index (LAI): the sum of all the upper or all-sided leaf surface areas

Mapping: The process of creating a cartographic representation (map) of objects in geographic space. In the MAES context mapping means a spatially detailed assessment of the elements of the MAES framework, which aims inter alia at creating cartographic representations of the studied elements (based on OpenNESS, 2014).

Natural Capital: all ecosystems and all living species, from fertile soil and productive land and seas to fresh water and clean air as well as biodiversity that supports it

Pressure: Human induced process that alters the condition of ecosystems (Maes et al., 2018)

Standing volume: The volume of standing trees, living or dead, above stump measured over bark to the top. Includes all trees regardless of diameter, tops of stems, large branches and dead trees lying on the ground which can still be used for fibre or fuel. Excludes small branches, twigs and foliage.

Total Economic Value (TEV): Framework: Broad conceptual framework commonly used by economists to organize different types of values (e.g., use and non-use values) that may be associated with a good or service. See chapter 4 for an example of a commonly used TEV framework.

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