European Commission

JRC SCIENTIFIC INFORMATION SYSTEMS AND DATABASES REPORT

EU Bioeconomy Monitoring System indicator update

Addressing indicator gaps: Climate change adaptation in fisheries and aquaculture, climate change adaptation in forestry, and share of wood in construction

Pablo Jose Sanchez-Jerez, Yannis Raftoyannis, Markku Riihimäki

S. Mubareka (ed)

2023

Joint Research Centre

Contact information
Name: Sarah B. Mubareka
Email: sarah.mubareka@ec.europa.eu

EU Science Hub
https://ec.europa.eu/jrc

JRC132405

PDF ISBN 978-92-76-61674-0 doi:10.2760/19269 KJ-08-23-012-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Sanchez-Jerez, P.J., Raftoyannis, Y. and Rihimaki, M., EU Bioeconomy Monitoring System indicator update, Mubareka, S. editor(s), Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/19269 (online), JRC132405.

Contents

Abstract

The conceptual framework of the EU Bioeconomy Monitoring System was designed to assess the EU's progress towards a circular and sustainable bioeconomy. Indicators were selected to cover the various parts of the framework but gaps in the knowledge or data still exist.

This document describes the progress made in filling gaps in the indicators that had been identified as being important to understand the progress of the EU Bioeconomy. In 2022, three gaps were addressed: Climate change adaptation in fisheries and aquaculture, climate change adaptation in forestry and share of wood in construction.

Indicators of adaptation to climate change in fisheries and aquaculture presented in Chapter 2 of this report are chosen for their ability to indicate changes in these sectors either as technical changes, changes in the behaviour of resource users/producers, or changes in the governance system. Many indicators are proposed here, but the final choice of the indicators selected to inform policymakers through the EU Bioeconomy Monitoring System must be preceded by a period of evaluation, consultation with the productive sectors and assessment of their operation in the medium to long term.

For the indicators on climate change adaptation in forestry, indicators need to be applicable in as many forest ecosystems and methods of forest management as possible allowing comparisons across temporal and spatial scales. Moreover, they need to be concise, meaningful, and communicative, easily comprehensible, particularly by decisionmakers. The indicators presented here are proposed based on an in-depth literature review and assessment of data availability at EU level.

Regarding indicators to assess the share of wood in construction, there is little data available. Timber use in construction is highly centred around residential construction, its total use varies from country to country and the data available is highly localized, thus there is no centralized EU-level database available for this indicator. The most feasible indicator is for the volume and share of wooden buildings (load-bearing frame mostly of wood) because of the homogeneity with which it is measured across different countries. So far, such data is only available in five countries: Germany, Sweden, Finland, Czechia, and Bulgaria.

Foreword

This report documents the progress made in filling gaps in indicators that have been identified as important to monitoring the progress towards a sustainable and circular EU bioeconomy. The indicators will be implemented in the EU Bioeconomy Monitoring System. This first set of indicators cover the topics of (a) climate change in fisheries; (b) climate change in forestry; (c) share of wood in construction. This work is fully funded by DG Research and Innovation under the Administrative Agreement DG RTD N° 013 KCB (LC-01591551) JRC Reference N ° 35895 NFP.

Given the very different nature of the topics, they have been developed by different experts. This is reflected as the three core chapters in this report (Chapters 2, 3 & 4).

Acknowledgements

This work was fully funded by DG Research & Innovation.

The author of Chapter 2 would like to thank Javier Atalah, Jose L. Sanchez Lizaso and Kilian Toledo for their critical comments to the text.

Authors

Pablo Jose Sanchez-Jerez

Department of Marine Science and Applied Biology

University of Alicante

Yannis Raftoyannis

Department of Forest and Environmental Sciences

International Hellenic University

Markku Riihimäki

Forecon Ltd

Hermiankatu 6–8 G

Tampere, Finland

Editor

Sarah Mubareka

Introduction

The EU Bioeconomy Monitoring System is pursuant to the Action 3.3.2 of the EU Bioeconomy Strategy (COM/2018/673). It addresses the need for a comprehensive monitoring system by establishing a mechanism to measure the progress of the EU bioeconomy towards the five strategic objectives it tackles. It defines and implements a comprehensive monitoring framework for the EU bioeconomy, which covers environmental, social and economic dimensions of sustainability and relates to the overarching Sustainable Development Goals (SDGs) context.

The EU Bioeconomy Monitoring System was officially launched in November 2020. The system is embedded in the Knowledge Centre for Bioeconomy at this location: https://knowledge4policy.ec.europa.eu/bioeconomy/monitoring_en.

The monitoring framework consists of four levels. As shown in Figure 1, the highest level is that of the EU Bioeconomy Strategy objectives themselves. Each of these is broken down into normative criteria, which in turn, is broken down into key components. The indicators are then assigned to the level of the key components. This hierarchical design allows for a logical aggregation of indicators for higher level indicators to be developed.

This document describes the progress made in filling gaps in the indicators that had been identified as being important to understand the progress of the EU Bioeconomy. In 2022, three gaps were addressed: Climate change adaptation in fisheries and aquaculture, climate change adaptation in forestry and share of wood in construction. The indicators are placed within the framework as shown in Table 1.

Table 1. Gaps filled in relation to the Bioeconomy Monitoring System framework.

Indicator name	**Bioeconomy Strategy Objective**	**Bioeconomy Strategy Normative Criteria**	**Bioeconomy Strategy Key Component**
Adaptation in fisheries	Mitigating and adapting to climate change	Climate change mitigation and adaptation are pursued	Climate change adaptation
Adaptation in forestry	Mitigating and adapting to climate change	Climate change mitigation and adaptation are pursued	Climate change adaptation
Share of wood-based constructions	Reducing dependence on non-renewable unsustainable resources, whether sourced domestically or from abroad	Consumption patterns of bioeconomy goods match sustainable supply levels of biomass	Reduced dependence on non-renewable resources

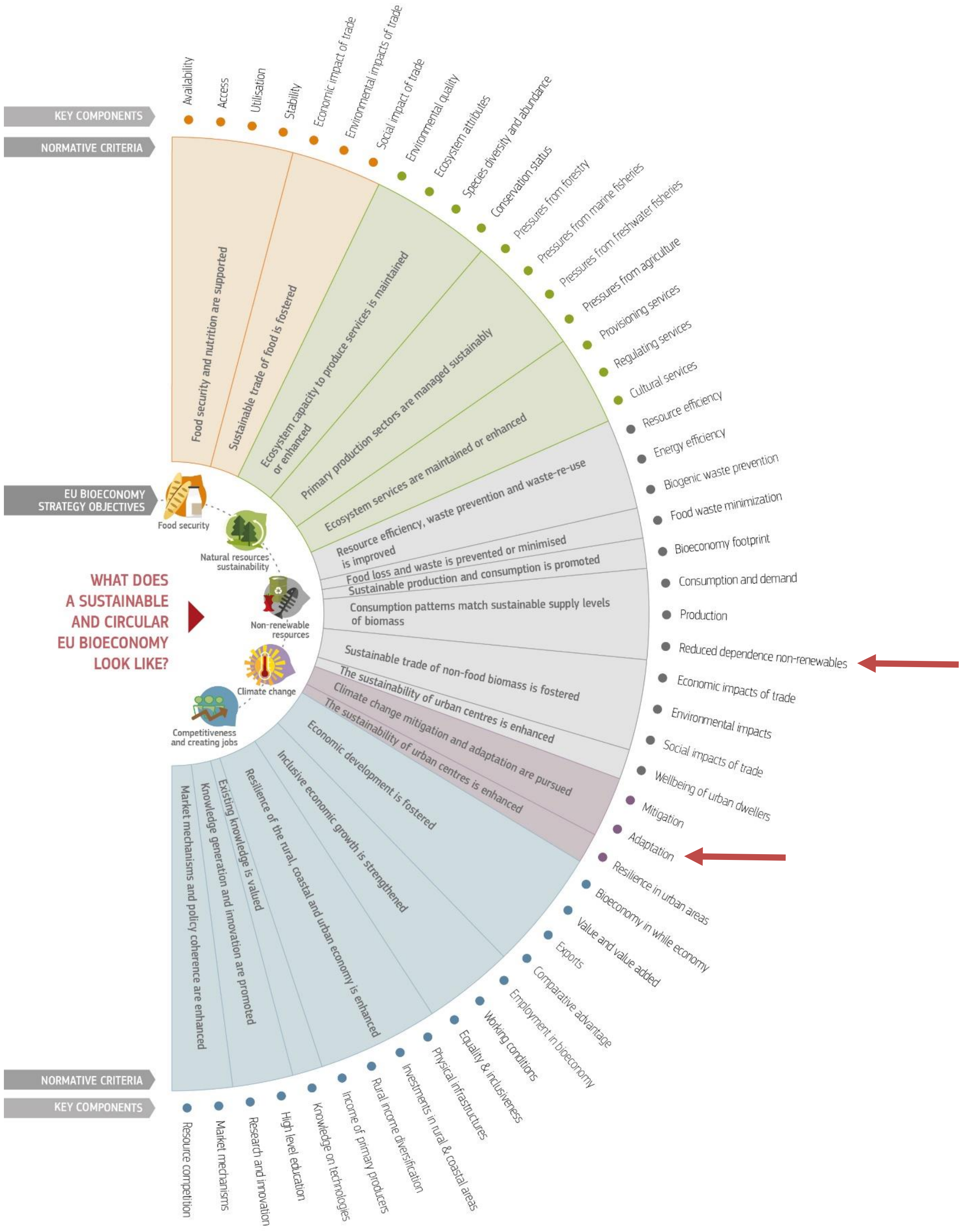

Figure 1.Conceptual framework of the EU Bioeconomy Monitoring System. The red arrows indicate the gaps addressed in this report.

1 Climate change adaptation in fisheries and aquaculture

Pablo Jose Sanchez-Jerez

Climate change is modifying marine and coastal environments across all oceans, with changes observed in sea temperatures, mixing layer, ocean currents, rising sea levels, salinity, acidification, changes in rainfall, and increased severity and frequency of extreme events. It is therefore to be expected that economic sectors that depend on the ecological services of natural ecosystems, such as fisheries and marine aquaculture, will be impacted severely by climate change on several ways. These changes, in turn, are affecting the fish growth, younger age and larger size at maturity; changing fish distribution, including movement toward the poles; altered species composition in catches; reduced production and yield; and increase in diseases (Rosa et al. 2012; Pham et al. 2021).

In favor of maintaining sustainable and rewarding seafood production under climate change stressors, climate adaptation actions should be defined, at a local, national, and global level. The European Commission adopted its new EU strategy on adaptation to climate change on 24 February 2021. The new strategy sets out how the European Union can adapt to the unavoidable impacts of climate change and become climate resilient by 2050. The Strategy has four principal objectives: to make adaptation smarter, swifter and more systemic, and to step up international action on adaptation to climate change. Smarter adaptation actions must be informed by robust data and risk assessment tools that are available to all. To achieve this, the strategy proposes actions that push the frontiers of knowledge on adaptation so that we can gather more and better data on climate-related risks and losses, and enhance Climate-ADAPT as the European platform for adaptation knowledge (https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en).

However, from the point of view of adaptation to climate change in these two productive sectors, it must be taken into account that there are another series of stressors that act synergistically and are difficult to separate from the effect of climate change. The problems of overfishing, eutrophication and political aspects such as Brexit, the war in Ukraine or the effects of the COVID19 pandemic all have an added effect on climate change. It may therefore be difficult to discern changes in European fisheries and aquaculture as a unique response to climate change, rather than as an adaptation measure to a multi-stressor situation (Sarà et al. 2018).

1.1 Fisheries and aquaculture in EU.

The total production of aquatic products (aquaculture plus fisheries) in the European Union in 2019 was 5,404,521 tonnes, a decrease of -9.3% with respect to 2018. It is relevant to take into account that the 48.9 % of all EU fisheries production from catches and aquaculture came from just three Member States in 2019; these were Spain (22.0 %), France (13.8 %) and Denmark (13.1 %). The sharp decline in overall EU production in 2019, principally reflected the mixed developments in these three Member States: production in Spain was moderately lower (-1.1 %); production in France was sharply lower (-7.3 %) due to less catches in in the Northeast Atlantic and the Indian Ocean; and, production in Denmark fell back strongly (-17.4 %, after a reduction of -12.5 % in 2018), almost entirely due to the lower catches in the Northeast Atlantic (Eurostat 2019). The extractive fishing was the 78.9% of total production, and aquaculture production accounts for 21.1% of the total aquatic production volume in the European Union (APROMAR 2021).

Regarding aquaculture, Spain is the EU Member State with the largest aquaculture harvest, with 308,033 tonnes in 2019 (27.0% of the EU total), followed by France with 196,151 tonnes (17.2%), Italy with 143,600 tonnes (12.6%) and Greece with 128,822 tonnes (11.3%). In the EU-27, the main aquaculture products are molluscs and fish. Aquaculture of crustaceans, algae or other invertebrates is very small. Fish farming in 2019 accounted for 535,788 tonnes, representing 46.9 % by weight of total aquaculture, with a first-sale value of 2,218 million euros (68.3 % of the total value of aquaculture production). Harvested molluscs amounted to 604,333 tonnes, 53.0 % of the total weight, reaching a value of 1,013 million euros (31.2 % of the total; APROMAR 2021).

It is relevant, because of the different scales of action, to differentiate between small-scale and large-scale fisheries. According to the FAO definition, contrary to more industrial and technological large-scale fisheries, small-scale fisheries are labour intensive and are conducted by artisanal craftsmen whose level of income, mechanical sophistication, quantity of production, fishing range, political influence, market outlets, employment and social mobility and financial dependence, keep them subservient to the economic decisions and operating constraints placed upon them by those who buy their production. According to the European Commission, small-scale fishing is carried out by fishing vessels of an overall length of less than 12 metres and not using towed fishing gear. On the other hand, consideration should be given to the different types of aquaculture relevant at European level. The different trophic groups of filter feeders (molluscs) and carnivores (fish) would be affected by climate change in very distinct ways, which should be take into account in the definition of adaptation actions (Rosa et al. 2012).

1.2 Understanding climate change adaptation in social-ecological systems.

The emergence of climate change and its effects on socio-economic systems (SES) has given rise to a series of concepts that need to be clarified for a correct interpretation of monitoring, mitigation and adaptation actions. The term resilience is one of the most used terms when referring to the ability of a system to cope with disturbances, bounce back, and maintain its state and functionality (Galappaththi et al. 2019). From a more ecological point of view, resilience is a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables (Holling 1973). In the social-ecological systems domain resilience is a system's capacity to continually change and adapt while remaining within the same critical thresholds (Berkes & Ross 2013). Additionally, it is interesting to consider the term resistance, which is a close term to resilience that defines a system's tendency to remain in a reference state, despite perturbation (Chapin et al. 2002). With respect to the issue at hand, the resilience and resistance of the aquaculture and fisheries sectors would explain the ability to maintain sustainable production over time, based on changes in the receiving ecosystems and changes inherent to the extractive or productive activity due to climate change.

To reduce the adverse effects of climate change, SES must be able to modify one or more of its axes (ecological, technological, managerial, human, etc.), taking into account their resilience to different climate stresses. It is relevant to differ coping capacity from adaptive capacity; coping capacity are the short-term responses, including autonomous responses to climate change and associated impacts and adaptive strategies are long-term responses or shifts in livelihood strategies in response to multiple stressors, including climate change (Galappaththi et al. 2019). It should be noted that coping can result in unsafe adaptation that may solve the problem in the short term but have little long-term benefit. It is therefore advisable to develop science-based climate change adaptation measures.

Furthermore, adaptation could be a spontaneous reaction to environmental change or planned action based on climate-induced changes. Autonomous adaptation in fisheries may be changing the timing or locations of fishing as species arrive earlier/later or shift to new areas. Planned adaptation in aquaculture may be research funding for finding species resistant to salinity and temperature fluctuations (Shelton 2014). Adaptation in fisheries and aquaculture can include a variety of policy and governance actions, specific technical support or community capacity building activities that address multiple sectors, not just capture fisheries or aquaculture farmers. Therefore, it is relevant to indicate that the best option is to use a co-creating climate approach to design adaptation plans, that requires the participation of scientists, industry representatives, policymakers, and other relevant stakeholders (Pham et al. 2021).

1.3 Purpose, objectives and scope

There are gaps in knowledge and data in the EU Bioeconomy Monitoring System. One such gap is in understanding climate change adaptation in the fisheries and aquaculture sectors. This indicator, or set of indicators, would allow the Commission to track the adaptation of the fisheries and aquaculture sectors over time.

The work comprises of:

- Identifying existing indicators that could be used as a proxy for climate change adaptation in the EU fisheries and aquaculture sectors.
- In the absence of existing indicators, define a reproducible and updatable methodology to either directly measure or approximate climate change adaptation in the relevant sectors, based on existing data that is updated regularly.
- In case new indicators need to be computed, interact with JRC technical staff to automate the computation of the indicator(s) through scripting or programming, to be performed by JRC staff.

1.4 Methodology

This report has been developed on the basis of the following research strategies:

i) Extensive review of scientific literature and specialise magazines, web pages, EU projects and other relevant source of information about climate change adaptation on fisheries and aquaculture.

ii) Exploration of available database related with the subject.

iii) Definition of potential indicator.

1.5 Indicators, databases and toolboxes of climate change adaptation in fisheries and aquaculture.

In the different EU research framework programmes, tools have been developed to facilitate the processes of adaptation to climate change in fisheries and aquaculture. Some of the most significant of these are listed below. In addition, there is a whole series of databases of organisations, foundations and professional associations that can be very useful for obtaining indicators regarding adaptation to climate change in different productive sectors.

1.5.1 Research and toolboxes

- **Climate change adaptation: research, science and innovation (2018). European Commission.** https://ec.europa.eu/info/sites/default/files/climate_change_adaptation_booklet_2018.pdf
This publication summarises strategies at the EU level to prepare member countries to adapt to climate change, listing the initiatives and resources that have been generated at different levels.

- **CLOCK: climate adaptation to shifting stocks.** https://futureoceanslab.org/projects/clock/
This research project argues that the combination of fisheries management science and socio-ecological systems thinking is necessary in order to advance in fisheries adaptation to climate change.

- **ClimeFish: Co-creating a decision support framework to ensure sustainable fish production in Europe under climate change.** https://climefish.eu/. The overall goal of ClimeFish is to help ensure that the increase in seafood production comes in areas and for species where there is a potential for sustainable growth, given the expected developments in climate, thus contributing to robust employment and sustainable development of rural and coastal communities.

- **CERES. Climate change and European aquatic RESources.** https://ceresproject.eu/. CERES investigated how climate change is affecting different European fish/shellfish species – and how Europe's fishermen and fish farmers can adapt in the future to climate change.

- **FutureMARES. Climate Change and Future Marine Ecosystem Services and Biodiversity.** https://www.futuremares.eu/. FutureMARES is an EU-funded research project examining the relations between climate change, marine biodiversity and ecosystem services. The activities are designed around two Nature-based Solutions and one Nature-inclusive Harvesting.

- **EcoScope. Ecocentric management for sustainable fisheries and healthy marine ecosystems.** https://ecoscopium.eu/. The EU-funded EcoScope project will develop an interoperable platform and a decision-making toolbox, available through a single public portal to decision-makers and end-users, to promote ecosystem-based fisheries management. With the assistance of policymakers and scientific advisory bodies, EcoScope will address ecosystem degradation and the anthropogenic impacts that are causing several European fisheries to be unsustainably exploited.

- **EVOMA. The influence of Environmental Variability On Mussel Aquaculture and adaptation in the context of global ocean change.** https://cordis.europa.eu/project/id/747637. Global ocean change (GOC, including warming and acidification) poses one of the largest threats to marine fisheries and aquaculture. Yet, there are still few predictive consequences, due to the limited understanding of species' in situ responses. Recent studies suggest that spatial differences in environmental conditions influence physiological tolerances of marine populations. This project tests the hypothesis that environmental variability of multiple stressors (temperature, pH, salinity) enhances physiological hardiness of sensitive early life-stages of an economically valuable mollusk, the mussel *Mytilus galloprovincialis*.

- **FutureEUAqua. Future growth in sustainable, resilient and climate friendly organic and conventional European aquaculture.** https://futureeuaqua.eu/. The overall objective of FutureEUAqua is to effectively promote sustainable growth of resilient to climate changes, environmental friendly organic and conventional aquaculture of major fish species and low trophic level organisms in Europe, to meet future challenges with respect to the growing consumer demand for high quality, nutritious and responsibly produced food.

- **ECONADAPT:** https://www.ecologic.eu/10743. The ECONADAPT project, on the Economics of Adaptation, was a research project funded by the European Union Seventh Framework Programme (FP7). Recognizing that there is an economic rationale for climate change adaptation, the ECONADAPT project set out to advance the knowledge and evidence base on the economics of adaptation and to develop practical material to support decision-making processes.

1.5.2 Online databases

- **Data.Europe.eu:** https://data.europa.eu/en. Official portal for European data
- **EUROSTAT:** https://ec.europa.eu/eurostat/web/main/data/database. Eurostat (European Statistical Office) is a Directorate-General of the European Commission. Eurostat's main responsibilities are to provide statistical information to the institutions of the European Union (EU) and to promote the harmonisation of statistical methods across its member states and candidates for accession as well as EFTA countries. The organisations in the different countries that cooperate with Eurostat are summarised under the concept of the European Statistical System.
- **European Environment Agency (EEA):** https://www.eea.europa.eu/ims. EEA indicators are designed to support all phases of environmental policy making, from designing policy frameworks to setting targets, and from policy monitoring and evaluation to communicating to policy-makers and the public. Each indicator tells the reader about the trend (or status) of the phenomenon being investigated over a given period of time. It also specifies whether or not associated policy objectives are being met and quantitative targets reached. Some of the climate change adaptation in this web are more related to the impact of climate change that adaptation (European sea surface temperature or ocean acidification).
- **European Centre for Medium-Range Weather Forecasts** https://www.ecmwf.int/en/about. ECMWF is both a research institute and a 24/7 operational service, producing global numerical weather predictions and other data for our Member and Co-operating States and the broader community. The Centre has one of the largest supercomputer facilities and meteorological data archives in the world. Other strategic activities include delivering advanced training and assisting the WMO in implementing its programmes. It a key player in Copernicus, the Earth Observation component of the European Union's Space programme, offering quality-assured information on climate change (Copernicus Climate Change Service), atmospheric composition (Copernicus Atmosphere Monitoring Service), flooding and fire danger (Copernicus Emergency Management Service), and through the EU's Destination Earth initiative,The web have relevant forecast related to climate change. https://apps.ecmwf.int/webapps/opencharts
- **Climate ADAPT:** https://climate-adapt.eea.europa.eu/#t-database. The European Climate Data Explorer provides interactive access to many climate indices from the Copernicus Climate Change Service in support of climate change adaptation.
- **Economic Cooperation and Development (OECD):** https://data.oecd.org/searchresults/?q=climate+change. The OECD databases on agriculture constitute a unique collection of agricultural statistics and provide a framework for quantifying and analysing the agricultural economy. This includes forecasts regarding the evolution of the main agricultural markets and commodities, detailed estimates of policy support, as well as indicators of environmental performance of agriculture. This data base includes data on fisheries and aquaculture. An interesting database is related to co-invention patents by country, which could be a proxy of investment for increase productivity and sustainability. https://www.oecd-ilibrary.org/agriculture-and-food/data/patents-in-fisheries-related-technologies/co-invention-patents-by-inventor-country_f7c47cb2-en
- **EU Blue economy indicators:** https://blueindicators.ec.europa.eu/access-online-dashboard. The data and charts below show the economic indicators used for the established sectors in the EU Blue Economy report. The six sectors include: Coastal Tourism, Marine living resources, Marine non-living resources, Port activities, Shipbuilding and repair and Maritime transport. Various filters allow for the customisation of data in terms of sub-sector, activity, Member State, indicator and time period. This database includes information about marine living resources (fisheries and aquaculture) filter in terms of sub-sector, activity, Member State, indicator and time period. Give information about small scale coastal fisheries (SSCF) and large scale fisheries LSF capture fish captures.
- **European market Observatory for Fisheries and Aquaculture Products (EUMOFA):** https://www.eumofa.eu/. The European Market Observatory for fisheries and aquaculture (EUMOFA) is a market intelligence tool on the European Union fisheries and aquaculture sector, developed by the European Commission. It aims to increase market transparency and efficiency, analyses EU markets dynamics, and supports business decisions and policy-making. EUMOFA enables direct monitoring of volumes, values and prices of fisheries and aquaculture products, from the first sale to retail stage, including imports and exports. Data are collected from EU countries, Iceland, Norway, United Kingdom and from EU institutions and updated every day.

- **International Monetary Fund (IMF):** https://climatedata.imf.org/pages/access-data. Interesting database on climate change indicators in many countries around the world. It has trade-related indicators of GHG emissions and economic indicators at the national level. The problem is that they are not disaggregated by productive sectors. At the state level, the data offered on climate-related disasters frequency (1980-2021) is interesting. https://climatedata.imf.org/datasets/b13b69ee0dde43a99c811f592af4e821/explore

- **INFORM Risk:** https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk. The INFORM Risk Index is a global, open-source risk assessment for humanitarian crises and disasters. It can support decisions about prevention, preparedness and response. In particular, there is a INFORM Warning, a tool to monitor how crisis and disaster risk is changing and where a new or worsening crisis could occur. It can help us act early and prepare and respond better. https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Warning. Risk Data Hub is a GIS web platform of European wide risk data and methodology for disaster risk assessment. https://drmkc.jrc.ec.europa.eu/risk-data-hub/#/

- **Sea Around Us:** (https://www.seaaroundus.org/data/#/feru) The Sea Around Us is a research initiative at The University of British Columbia (located at the Institute for the Oceans and Fisheries, formerly Fisheries Centre) that assesses the impact of fisheries on the marine ecosystems of the world, and offers mitigating solutions to a range of stakeholders.

- **Global Aquaculture Performance Index (GAPI):** https://www.seaaroundus.org/gapi/. Inside the Sea Around Us webpage, the GAPI is a science-based, data-driven tool enabling rigorous and objective evaluation of the environmental performance of marine aquaculture production systems. Derived from Yale and Columbia University's 2008 Environmental Performance Index (EPI), the GAPI empowers interested parties and key policymakers to make more informed and ultimately more sustainable decisions related to their farmed seafood purchases and policies, respectively.

- **FAO Fisheries and Aquaculture FishStatJ** (https://www.fao.org/fishery/en/topic/166235?lang=en) FishStatJ is a downloadable desktop application providing users with access to a variety of fishery statistical datasets.

- **The European Fisheries and Aquaculture Research Organisations (EFARO)**: https://www.efaro.eu/. EFARO, The European Fisheries and Aquaculture Research Organisations, is an association composed of the Directors of the main European Research Institutes involved in Fisheries and Aquaculture research. EFARO is founded under a consensus agreement in 1989. The starting point was the desire to achieve greater cohesion and coordination of Community fisheries Research and Development.

- **Standing Commitee on Agricultural Research Fisheries and Aquaculture (SCAR-FISH):** https://scar-europe.org/fish-documents. The mission and aims is to contribute to define EU research priorities within relevant initiatives: H2020 Work Programmes, Bioeconomy Strategy, Food & Nutrition security Strategy with inputs from SWG Food Systems, Agro-food and Forestry Strategy, Circular economy.

- **World Aquaculture Performance Indicators (WAPI) :** https://www.fao.org/fishery/en/statistics/software/wapi World Aquaculture Performance Indicators (WAPI) is an endeavour initiated by the FAO Fisheries and Aquaculture Division to develop user-friendly tools for compiling, generating and providing easy access to quantitative information on aquaculture sector performance at the national, regional and global levels. Information and knowledge products developed under WAPI include data analysis tools and associated technical papers and policy briefs. https://www.fao.org/3/ca8183en/ca8183en.pdf

- **Environmental Defense Fund (EDF):** https://fisherysolutionscenter.edf.org/ Interesting global climate vulnerability assessment (CVA) and tools for climate adaptive management for fisheries. https://fisherysolutionscenter.edf.org/resources/new-and-emerging-technologies-sustainable-fisheries. Also measure the performance of a fishery in order to understand the impacts of a fishery reform project. Fisheries performance indicator https://fisherysolutionscenter.edf.org/tools/fishery-performance-indicators

- **Barentswatch:** https://www.barentswatch.no/nedlasting/?lang=en. BarentsWatch collect, develop and share information about Norwegian coastal and marine areas.Interesting database of weekly historical data of sea lice status on site level for salmonoids at sea including sea temperature, historical data of lice countermeasures, medicamental treatments (bath and feed), mechanical removal, cleaner fish and suspected / confirmed status for notifiable fish diseases (PD and ISA).

- **European Marine Observation and Data Network (EMODnet):** https://emodnet.ec.europa.eu/en. The European Marine Observation and Data Network (EMODnet) is a network of organisations supported by the EU's integrated maritime policy. These organisations work together to observe the sea, process the data according to international standards and make that information freely available as interoperable data layers and data products.

- **Copernicus Marine Service:** https://www.copernicus.eu/en/copernicus-services/marine. The Copernicus Marine Environment Monitoring Service (CMEMS) provides regular and systematic reference information on the physical and biogeochemical state, variability and dynamics of the ocean and marine ecosystems for the global ocean and the European regional seas.The observations and forecasts produced by the service support all marine applications, including marine safety, marine resources, coastal and marine environment and weather, seasonal forecasting and climate.

- **SeaDataNet. Pan-European infrastructure for ocean & marine data management.** https://www.seadatanet.org/. SeaDataNet is a distributed Marine Data Infrastructure for the management of large and diverse sets of data deriving from in situ of the seas and oceans.

- **Google Earth Engine**: https://earthengine.google.com/. Google Earth Engine combines a multi-petabyte catalog of satellite imagery and geospatial datasets with planetary-scale analysis capabilities. Scientists, researchers, and developers use Earth Engine to detect changes, map trends, and quantify differences on the Earth's surface. Earth Engine is now available for commercial use, and remains free for academic and research use.

1.6 Proposed indicator of climate change adaptation in the EU fisheries and aquaculture.

An early review of examples of climate change adaptation was carried out by in the FAO report entitled "Climate change adaptation in fisheries and aquaculture: compilation of initial examples", which includes a review of adaptation measures in relation to the impact produced Shelton (2014). Galappaththi et al. (2019) have conducted a comprehensive review of the global literature on climate change adaptation processes in fisheries. The Table 2 of this paper includes a summary of the response actions at different scales, divided into coping and adaptive actions. Many of these, although interesting, are very difficult to use as indicators at EU level due to the difficulty of obtaining data efficiently and reliably. At the end of the report, a summary table is attached with relevant information for the calculation of each indicator (Table 1).

1.6.1 Fisheries

1.6.1.1 Increase fishing efficiency

1.6.1.1.1 Background

Fisheries contribute global greenhouse gas emissions (GHGs) during fish capture, transportation and storage and sustainable fishing practices have the potential to further reduce carbon emissions through increased efficiency and optimized gear types, among other factors. Improving fuel efficiency by switching to more efficient gear types or vessels, switching to sails or changing fishing practices would reduce emissions from fishing activities. This would also reduce fuel costs, although switching to more efficient vessels and/or gear may only reduce fuel use by 20 percent (Shelton 2014). Increasing the efficiency may reduce the cost and increase the profit, which could help to fishers. More efficient fishing means maintaining a level of catches within the maximum allowable catches but at a lower cost in energy derived from catching in the open sea. In this way the fishery resource can generate better profits in the face of a more unstable resource.

1.6.1.1.2 Indicator

By country or total EU-27 total capture in value/Fishing fleet gross tonnage by country or total EU-27

1.6.1.1.3 Databases

- EUROSTAT: https://ec.europa.eu/eurostat/databrowser/view/fish_fleet_alt/default/table?lang=en
- EUMOFA: landings https://www.eumofa.eu/sources-of-data

1.6.1.2 Adaptation of fisheries management

1.6.1.2.1 Background

There is great uncertainty in the nature and direction of changes and shocks to fisheries as a result of climate change. Investments in generic adaptive capacity and resilient fisheries systems seem to be a good strategy to support future adaptations which are not currently foreseen. Better managed fisheries with flexible, equitable institutions are expected to have greater adaptive capacity, such as fisheries co-management. This kind of management is broadly defined as the involvement of users in management, developed in Europe in various experimental forms of participation of fishermen in the management process, in advisory roles or through delegation and sharing of power; Linke & Bruckmeier 2015). Increase of participation of small scale fishers on co-management programs of local fisheries could give an idea of adaptation of unpredictable fluctuations on resources. On the other hand, the use of sustainable fisheries certifications can include aspects related to adaptation to climate change and sustainable exploitation of a given resource. The increase in this type of certification may indicate a tendency to increase the added value of the product and to verify the sustainability of marine resources in a situation of instability due to climate change.

1.6.1.2.2 Indicator

Temporal trend of certifications of sustainable fisheries

Number of fisher associations involve on co-management programs (Annual difference between data and median from temporal series)

1.6.1.2.3 Databases

- Marine Stewardship Council MSC database (https://www.msc.org/)
- Information from European Fisheries Alliance (https://fisheriesalliance.eu/)
- European Association of Fish Producers Organisation (http://eapo.com/)

1.6.1.2.4 Constraints

The information about the number of European fisher companies or associations with a MSC certification should be request previously to this company. There is lack of fisheries producers organisations for small scale fishers. It is possible to obtain national or regional information for example from the Foro Científico de la Pesca Española en el Mediterráneo (Scientific Forum on Spanish Fisheries in the Mediterranean; http://www.pescaforo.net/).

1.6.1.3 Adaptation to spatial readjustment of exploited populations

1.6.1.3.1 Background

Novel accelerated large scale movement of fish driven by unprecedented warming of seawater is affecting to traditional fishing grounds. For example, it seem that the temperature increase due to global warming is responsible for the the northward spread in distribution of many species (Petitgas et al. 2013). For adaptation to this phenomena, national and regional fisheries management requires also shorter term projections on smaller spatial scales, and these need to be validated against fisheries data. the EEA has developed a indicator to asses changes in fish distribution in European seas, checking temporal development of the ratio between the number of Lusitanian and Boreal fish species within ICES Statistical rectangles and ICES divisions (https://www.eea.europa.eu/data-and-maps/indicators/fish-distribution-shifts). Fisher effort should be redistributed in these regions related to northward shift in the distribution of catches.

1.6.1.3.2 Indicator

Improving climate research, monitoring, and forecasting on fish distribution shift (research investment or number of scientific papers).

Comparison of spatial fish resource distribution with fishing effort spatial distribution (Pearson) Bivariate Correlation) across time.

1.6.1.3.3 Databases

- Community Research and Development Information Service https://cordis.europa.eu/en
- OpenAire https://www.openaire.eu/
- SCOPUS database https://www.scopus.com

- EEA https://www.eea.europa.eu/data-and-maps/indicators/fish-distribution-shifts
- Global Fishing Watch (map to monitor global fishing activity from 2012 to the present for more than 65,000 commercial fishing vessels that are responsible for a significant part of global seafood catch) https://globalfishingwatch.org/our-map/

1.6.2 Aquaculture

1.6.2.1 Shift aquaculture to non-carnivorous commodities

1.6.2.1.1 Background

By reducing the trophic level of farmed organisms, aquaculture is less dependent on raw materials rich in protein and fat (fish oil and fishmeal, soya beans, etc.). In an extreme case, if aquaculture is only of filter feeders, it would only depend on local primary production, being more resilient to problems associated with industrial fishing (effects of El Niño in Peru) or problems of deforestation for soya cultivation, especially associated with the cost of transport. Trophic level for produced specie could be obtained from FishBase (https://fishbase.org), accessed through the R library 'rfishbase' (Boettiger et al. 2012). Trophic level is defined as the position of a species in the food chain and is calculated as a function of the number, relative contribution to the diet and TL of its prey. It ranges from 1 to 5, where a TL of 2 represents an herbivorous species, while intermediate predators have values around 3.1 and top predators>4 (Stergiou et al. 2009). Reducing dependence on a feed high in fish protein and oils while increasing the production of filter feeders that take advantage of natural resources in the form of phytoplankton may give an idea of the sector's adaptation to a reduced dependence on the market for exotic raw materials.

1.6.2.1.2 Indicator

(Trophic level of each species * total production of this species) / total production

1.6.2.1.3 Databases

- Fishbase: https://fishbase.org
- EUROSTAT: https://ec.europa.eu/eurostat/databrowser/view/TAG00075/default/table?lang=en&category=fish.fish_aq

1.6.2.2 Selective breeding for increased resilience in aquaculture

1.6.2.2.1 Background

To ensure the food security, the impacts of climate change have to be addressed through resource management, reduction of environmental impacts, and selective breeding strategies. Breeding goals may change toward "resilience," i.e., stability of performance under fluctuating rearing environments or toward new trait mean. The breeding goals may include disease resistance or tolerance for emerging pathogens and parasites (Sae-Lim, 2016).

1.6.2.2.2 Indicator

Total EU investment on selective breeding research for aquaculture across time or scientific production.

1.6.2.2.3 Databases

- Community Research and Development Information Service https://cordis.europa.eu/en
- OpenAire https://www.openaire.eu/
- SCOPUS database https://www.scopus.com

1.6.2.3 Moving/planning siting of cage aquaculture facilities

1.6.2.3.1 Background

The success of an aquaculture project depends to a large extent on the selection of an appropriate site to establish the farm; this entails an intricate multicriteria decision-making process. For site selection, in addition to consideration of physical and environmental factors, other crucial aspects concerning the efficiency and economy of the aquaculture operations are central such as climate risk for production. Haphazard development of aquaculture without adequate planning and regulation can lead to adverse environmental impacts, lack of economic feasibility, and/or social conflicts (Sanchez-Jerez et al. 2016) and climate risk play an important roll. Development of aquaculture without adequate planning can lead to unsustainable economic feasibility due to future climate stressors. In this sense, offshore mariculture could be an alternative for mitigating the effect of coastal warming. The suitability of the coastline in terms of global warming and sea surface temperature trends must be evaluated in the Allocated Zones for Aquaculture (AZA's) where fish aquaculture is currently being developed (López-Mengual et al. 2021).

1.6.2.3.2 Indicator

- Geolocalization of fish farms related to climatic risk
- Distance to coastal line of fish farms

1.6.2.3.3 Databases

- By country: e.g in Spain the Acuivisor tool (https://servicio.pesca.mapama.es/acuivisor/) is a GIS system for aquaculture sector where facilities are located.
- EU level: Google Earth Engine Landsat 8 images based on the Google Earth Engine (GEE) https://earthengine.google.com. Example: small land base fish farms (Duan et al. 2020), oyster prospecting (https://landsat.gsfc.nasa.gov/article/oyster-prospecting-with-landsat-8/)
- NASO (National Aquaculture Sector Overview) aquaculture maps collection of FAO: https://www.fao.org/fishery/naso-maps/naso-maps/en/

1.6.2.4 Change aquaculture feed management: reduction of feed conversion rate

1.6.2.4.1 Background

A low feed conversion ratio (FCR) is the primary indicator of efficient aquaculture. The FCR is the feed input divided by the resulting net production; it indicates the units of feed necessary to yield one unit of biomass. The smaller the FCR, the greater is the feed use efficiency. Feed efficiency is simply the inverse of the FCR – the amount of aquaculture biomass realized per unit of feed input. Reducing FCRs has tremendous benefits. There will be less waste from feed entering the culture system per unit of production, and this is protective of water quality within the culture system. A lower FCR also lessens the pollution potential in farm effluent, and reduces feed cost per unit of production. Moreover, a lower system load in culture systems will reduce the oxygen demand imposed by feed to allow a greater biomass to be supported per horsepower of aeration (Boyd 2021).

1.6.2.4.2 Indicator

Total feed input/fish production

1.6.2.4.3 Databases

- FEAP (Federation of European Aquaculture Producers) https://feap.info/index.php/data/
- EUROMOFA (European Market Observatory for fisheries and aquaculture) https://www.eumofa.eu/

1.6.2.5 Reducing the negative effect of extreme events on fish escapes

1.6.2.5.1 Background

Because of the open nature of net-pen systems, there is an inherent high risk of fish escapes into natural habitats, which is regarded as a major problem for the industry. Fish escapes are an inevitable occurrence caused by several internal and external factors, which result in the occasional release of a large number of individuals (massive escape events) or the recurrent release of a small number of fish (chronic or leakage escapes) (Atalah & Sanchez-Jerez 2020). External causes of massive escapes are commonly linked to oceanic conditions and the increase of extremes events due to climate change could be a determinant factor for suitable aquaculture. Technology can increase the durability and resistance of nets, anchoring systems and the full fish farm facilities, for example using submerged cages or making more robust infrastructures.

1.6.2.5.2 Indicators

- Aquaculture infrastructure investments for avoiding fish escapes: net and anchoring
- New technology implementation: submerge cages.
- Number of escapes across time for different species/countries
- Temporal trend on co-invention patents by inventor country (EU27)

1.6.2.5.3 Databases

- FEAP (Federation of European Aquaculture Producers) https://feap.info/index.php/data/
- OECD https://www.oecd-ilibrary.org/agriculture-and-food/data/patents-in-fisheries-related-technologies/co-invention-patents-by-inventor-country_f7c47cb2-en
- European Patent Office https://www.epo.org/

1.6.2.5.4 Constraints

In most of the EU-27 there is no obligation to report escape events to the competent administrations, quantifying the number of fish accidentally released into the marine environment. In some countries such as Scotland, any suspected escape from a fish farm, or circumstances which give rise to a significant risk of escape, must be reported to the Scottish Government (https://www.gov.scot/publications/what-to-do-in-the-event-of-a-fish-farm-escape/). This makes it difficult to have time trends on extreme weather events and leakages, which would serve as an indicator for adaptation of the sector through different technological improvements.

1.6.2.6 Improve insurance schemes among the producers especially small-scale farmers

1.6.2.6.1 Background

Most climate change predictions indicate that producers will be the strongly affected due to dependence on sea condition. Hence, an insurance scheme could help them build resilience. Therefore insurance for aquaculture producers related to extreme events is gaining considerable attention because the increasing possibility of production loss due to massive escapes or thermal waves. In this scenario, small scales farms will be showed more vulnerability so insurance could help them build resilience (Maulu et al. 2021).

1.6.2.6.2 Indicator

Increase of insurance considering lost due to climate change (extreme events)

1.6.2.6.3 Databases

- FEAP (Federation of European Aquaculture Producers) https://feap.info/index.php/data/
- National scale: e.g. in Spain Agrupación Española de Entidades Aseguradoras de los Seguros Agrarios Combinados S.A. https://agroseguro.es/webmap

1.6.2.6.4 Constraints

There is a great deal of reluctance to provide this type of information, both on the part of production companies and insurance companies.

1.6.2.7 Mollusc production persistence under climatic pressures.

1.6.2.7.1 Background

Increased accumulation of CO2 in water could result in increased water acidity levels (pH decrease). The projected increase in CO2 uptake by oceans at 1.5°C or more global warming will have adverse effects on the growth, development, calcification, survival, and abundance of several aquatic species. The rise in ocean acidity reduces the availability of carbonate required for the construction of coral skeletons (Calcification) in shell-forming organisms, such as shrimps, mussels, oysters, or corals , which potentially threatens marine aquaculture production. On other hand,temperature plays a critical role in the growth and development of aquatic animals. Therefore, prolonged temperature stress may affect also aquaculture productivity (Maulu et al. 2021).

1.6.2.7.2 Indicators

- Granger Causality test relation between temporal production of mollusc and pH in production areas.
- Granger Causality test relation between temporal production of mollusc and temperature in production areas.
- Distribution of shellfish production or parking areas in France related to sea water temperature
- Distribution of shellfish production or parking areas in Galicia (Spain) related to sea water temperature
- Mussel production in Galicia (Spain) related to pH or sea water temperature.

1.6.2.7.3 Databases

- EMODnet North East Atlantic Ocean - Eutrophication and Acidity aggregated datasets 1921/2020 v2021 : https://www.emodnet-chemistry.eu/products/catalogue#/metadata/a6d89ed2-17d0-4a8a-97fe-7e99d8e6520d
- WAPI FAO Production Module: https://www.fao.org/fishery/en/statistics/software/wapi
- Granger test: https://www.rdocumentation.org/packages/MSBVAR/versions/0.9-2/topics/granger.test

1.6.3 Shellfish Production or Parking Areas

- Whole France: https://data.europa.eu/data/datasets/3cef08f1-d59b-478b-8606-1b7cd01cd168-1?locale=en
- Shellfish Production or Parking Areas Galicia (Spain) Acuivisor tool (https://servicio.pesca.mapama.es/acuivisor/)
- Mussel production in Galicia (Spain): https://www.ige.eu/igebdt/selector.jsp?COD=2705&paxina=001&c=0301004
- Copernicus Atlantic-Iberian Biscay Irish- Ocean Physics Reanalysis(BI_MULTIYEAR_PHY_005_002): https://resources.marine.copernicus.eu/product-detail/IBI_MULTIYEAR_PHY_005_002/INFORMATION
- https://resources.marine.copernicus.eu/product-detail/IBI_ANALYSISFORECAST_BGC_005_004/INFORMATION

1.6.3.1 Fish production persistence under climatic pressures

1.6.3.1.1 Background

Increased variability and temporal extremes can act as direct or indirect stressors, increasing production risk and superimposing over potential growth rate benefits. In some instances, increased growth rates due to warmer temperatures have still occurred despite other negative side effects. Small increases in average temperatures across a production cycle may have the potential for increases in growth rate for some aquaculture species, such as mussels and salmon. Temperature has both direct and indirect effects on nutrition, feeding practices, and behaviours. Basal metabolism is the energy used by animals to maintain normal body functions, excluding growth and voluntary activity. As fish are poikilothermic animals, their basal energy needs are directly impacted by the temperature of the water (Reid et al. 2019).

1.6.3.1.2 Indicator

Granger Causality test relation between temporal production of fish and sea water potential temperature in main production areas (Greece and Spain).

1.6.3.1.3 Databases

- WAPI FAO Production Module: https://www.fao.org/fishery/en/statistics/software/wapi
- Copernicus Mediterranean Sea Physics Reanalysis (MEDSEA_MULTIYEAR_PHY_006_004): https://resources.marine.copernicus.eu/product-detail/MEDSEA_MULTIYEAR_PHY_006_004/INFORMATION

1.6.4 Indicators for both fisheries and/or aquaculture

1.6.4.1 Increasing resilience to climate related extremes events

1.6.4.1.1 Background

Between 1980 and 2020, climate-related extremes caused economic losses totalling an estimated EUR 487 billion in the EU-27 Member States. Although analysing trends in economic losses is difficult, partly as a result of high variability from year to year, climate-related extremes are becoming more common and, without mitigating action, could result in even greater losses in the coming years (https://www.c2es.org/content/extreme-weather-and-climate-change/). The EU adaptation strategy aims to build resilience and ensure that Europe is well prepared to manage the risks and adapt to the impacts of climate change, thus minimising economic losses and other harms.

1.6.4.1.2 Indicator

Temporal tendency on economical value of aquatic products (Catches in all fishing regions or aquaculture production in tonnes and value) related with losses by climatological events

1.6.4.1.3 Databases

- Total losses by climatological events *https://ec.europa.eu/eurostat/databrowser/view/CLI_IAD_LOSS/default/table?lang=en&category=cli.cli_iad*
- Aquaculture production in tonnes and value
- *https://ec.europa.eu/eurostat/databrowser/view/TAG00075/default/table?lang=en&category=fish.fish_aq*
- Catches in all fishing regions *https://ec.europa.eu/eurostat/databrowser/view/TAG00076/default/table?lang=en&category=fish.fish_ca*
- Data by country and segregated by small and large fisheries: https://blueindicators.ec.europa.eu/access-online-dashboard

1.6.5 Reducing direct and indirect GHG emissions

1.6.5.1.1 Background

Although aquaculture and fisheries current contribution to GHG emissions from food production are relatively small compared with other industries, it is critical to identify pathways to advance the growth of climate-friendly practices. Doing so provides an opportunity to avoid further environmental degradation associated with the expansion of food production. Ultimately, responsible development of aquaculture is a key strategy to meet growing food demand and nutritional needs and to achieve food security within planetary boundaries (Jones et al. 2022). Therefore, the interest of companies in becoming environmentally certified as a responsible company in reducing their carbon footprint can be considered as an indicator of a company's adaptation process to climate change. The ISO 14067:2018 is accepted as an international standard. This Technical Specification1 details principles, requirements and guidelines for the quantification and communication of the carbon footprint of products (CFPs), including both goods and services, based on GHG emissions and removals over the life cycle of a product. Requirements and guidelines for the quantification and communication of a partial carbon footprint of products (partial CFP) are also provided. The communication of the CFP to the intended audience is based on a CFP study report that provides an accurate, relevant and fair representation of the CFP.

1.6.5.1.2 Indicator

Temporal trend of number of certifications on ISO 14067:2018

1.6.5.1.3 Database

- https://www.iso.org/standard/71206.html

1.7 Final considerations

An indicator can be defined as a measure of variables that serve to monitor changes in your system over time or space. In our case, indicators of adaptation to climate change and aquaculture should be able to indicate changes in these sectors in a process of modifying activities to increase their resilience to the adversities of climate change. It can come in various forms, including technical changes, changes in the behavior of resource users/producers, or changes in the governance system, and the capacity of the producers/fishers to adapt to climate change will likely depend on accurate future projections against different systems. Unrealistic and biased estimation of the potential risks associated with climate change may mislead policymakers. The consequences of maladaptation include increased future vulnerability and/or exposure of the target community, region, or sector to climate change effects (Maulu et al. 2021). The correct application of the proposed indicators must be preceded by a period of evaluation, consultation with the productive sectors and assessment of their operation in the medium to long term.

Some of the indicators that could be more informative are impossible to obtain for the EU-27 due to the lack of transparency in relation to diseases. For example, in Norway farmers are required to report on the recurrence and magnitude of infestations of salmon parasitic copepods (sea lices; https://www.hi.no/en/hi/temasider/species/sea-lice) as they affect natural populations, and the treatments they use to eliminate them. Numerical models of copepod dispersal and abundance are available at state level. In the Mediterranean case of sparicotylosis (http://www.medaid-h2020.eu/wp-content/uploads/2018/06/sparicotylosis-minireview.pdf), a parasite that affects the gills of gilthead sea bream and sea bass, there is no such transparency in the data on the disease and its treatment, being closely related to the increase in temperature. Similarly, the use of antibiotics and vaccinations would be very informative to detect if there is a negative trend in their use despite environmental stress due to climate change (Ried et al. 2019).

Additionally, climate change impacts are being felt across sectors in all regions of the world, and adaptation projects are being implemented to reduce climate risks and existing vulnerabilities but climate adaptation actions also have significant synergies and tradeoffs with the Sustainable Development Goals (SDGs), including SDG 5 on gender equality (Roy et al. 2022). Questions are increasingly being raised about the gendered and climate justice implications of different adaptation options. This aspect of gender equality will be relevant to analyse if data would be available.

1.8 References

APROMAR 2021. La Acuicultura en España. https://apromar.es/wp-content/uploads/2022/04/Informe_La_Acuicultura_en_Espana_2021_APROMAR.pdf

Atalah, J. & Sanchez-Jerez, P. 2020. Global assessment of ecological risks associated with farmed fish escapes. Global Ecology and Conservation 21, e00842, https://doi.org/10.1016/j.gecco.2019.e00842

Berkes, F., Ross, H., 2013. Community resilience: toward an integrated approach. Soc.Nat. Resour. 26 (1), 5–20. https://doi.org/10.1080/08941920.2012.736605

Boettiger, C., D. T. Lang, and P. Wainwright. 2012. rfishbase: exploring, manipulating and visualizing FishBase data from R. Journal of Fish Biology 81:2030-2039. https://doi.org/10.1111/j.1095-8649.2012.03464.x

Boyd, C.E. 2022. A low feed conversion ratio is the primary indicator of efficient aquaculture. Global Seafood Alliance. https://www.globalseafood.org/advocate/a-low-feed-conversion-ratio-is-the-primary-indicator-of-efficient-aquaculture/

Chapin, F.S. III, Matson, P.A. & Mooney, H.A. 2002. Principles of Terrestrial Ecosystem Ecology. Springer-Verlag, New York.

Duan, Y, Xing Li, Lianpeng Zhang, Dan Chen, Shu'an Liu, Hanyu Ji. 2020. Mapping national-scale aquaculture ponds based on the Google Earth Engine in the Chinese coastal zone. Aquaculture 520,734666,

https://doi.org/10.1016/j.aquaculture.2019.734666.

Eurostat 2019. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Fishery_statistics#Fisheries_production:_catches_and_aquaculture

Galappaththi, E. K., Susarla, V. B., Loutet, S. J. T., Ichien, S. T., Hyman, A. A., & Ford, J. D. (2022). Climate change adaptation in fisheries. Fish and Fisheries, 23, 4– 21. https://doi.org/10.1111/faf.12595

https://doi.org/10.1016/j.ocecoaman.2014.11.017

Jones AR, Alleway HK, McAfee D, Reis-Santos P, Theuerkauf SJ, Jones RC. Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture. Bioscience. 2022 Jan 25;72(2):123-143. https://doi.org/10.1093/biosci/biab126.

Holling, C.S. 1973. Resilience and stability of ecological systems. Annual Review of Ecology and Systematics, 4, 1–23. https://www.annualreviews.org/doi/abs/10.1146/annurev.es.04.110173.000245

Linke, S, & Bruckmeier, K. 2015. Co-management in fisheries – Experiences and changing approaches in Europe,. Ocean & Coastal Management, 104,: 170-181. https://doi.org/10.1016/j.ocecoaman.2014.11.017

López Mengual I, Sanchez-Jerez P, Ballester-Berman JD (2021) Offshore aquaculture as climate change adaptation in coastal areas: sea surface temperature trends in the Western Mediterranean Sea. Aquacult Environ Interact 13:515-526. https://doi.org/10.3354/aei00420

Maulu S, Hasimuna O J., Haambiya L H., Monde C, Musuka C G., Makorwa T H., Munganga B P., Phiri K J., Nsekanabo J D. 2021. Climate Change Effects on Aquaculture Production: Sustainability Implications, Mitigation, and Adaptations. Frontiers in Sustainable Food Systems 5: 10.3389. https://doi.org/10.3389/fsufs.2021.609097

Petitgas, P, Rijnsdorp AD, Dickey-Collas M, Engelhard GH, Peck MA, Pinnegar JK, Drinkwater K, Huret M, Nash RDM. 2013. Impacts of climate change on the complex life cycles of fish, Fish. Oceanogr. 22:121-139. https://doi.org/10.1111/fog.12010

Pham, T.T.T., Friðriksdóttir, R., Weber, C.T. et al. 2021. Guidelines for co-creating climate adaptation plans for fisheries and aquaculture. Climatic Change 164, 62. https://doi.org/10.1007/s10584-021-03041-z

Reid GK, Gurney-Smith HJ, Marcogliese DJ, Knowler D et al. 2019. Climate change and aquaculture: considering biological response and resources. Aquacult Environ Interact 11:569-602. https://doi.org/10.3354/aei00332

Rosa, R., Marques, A. and Nunes, M.L. 2012. Impact of climate change in Mediterranean aquaculture. Reviews in Aquaculture, 4: 163-177. https://doi.org/10.1111/j.1753-5131.2012.01071.x

Roy, J., Prakash, A., Some, S. et al. 2022. Synergies and trade-offs between climate change adaptation options and gender equality: a review of the global literature. Humanit Soc Sci Commun 9, 251. https://doi.org/10.1057/s41599-022-01266-6

SaeLim, P. 2016. Climate change and selective breeding in aquaculture, Journal of Animal Science 94(5): 195–196, https://doi.org/10.2527/jam2016-0403

Sanchez-Jerez P, Karakassis I, Massa F, Fezzardi D and others. 2016. Aquaculture's struggle for space: the need for coastal spatial planning and the potential benefits of Allocated Zones for Aquaculture (AZAs) to avoid conflict and promote sustainability. Aquacult Environ Interact 8:41−54. https://www.int-res.com/articles/aei2016/8/q008p041.pdf

Sarà, G., Mangano, M.C., Johnson, M. et al. 2018. Integrating multiple stressors in aquaculture to build the blue growth in a changing sea. Hydrobiologia 809, 5–17. https://doi.org/10.1007/s10750-017-3469-8

Shelton, C. 2014. Climate change adaptation in fisheries and aquaculture. Compilation of initial examples.FAO Fisheries and Aquaculture Circular No. 1088. https://www.fao.org/3/i3569e/i3569e.pdf

Stergiou, K. I., A. C. Tsikliras, & D. Pauly. 2009. Farming up Mediterranean food webs. Conservation Biology 23: 230-232. https://conbio.onlinelibrary.wiley.com/doi/pdf/10.1111/j.1523-1739.2008.01077.x

2 Indicators for climate change adaptation in EU Forestry

Yannis Raftoyannis

The EU Forest Strategy supplements the EU Adaptation Strategy as far as forests are concerned, integrating climate action in the wider coherent approach towards sustainable forest management. One of its priority areas is "Forests in a changing climate", where the Strategic objective is to enhance the forests adaptive capacity and resilience, building on the EU Strategy on Adaptation to Climate Change.

Climate change has already caused many changes in forest ecosystems and negative effects prevail, including warming-induced shifts in species distribution (Lindner et al. 2010; Boisvert-Marsh et al. 2014) and drought-related increases in tree mortality (Allen et al. 2010; Cailleret et al. 2017). Impacts of climate change magnify local disturbances, such as environmental pollution, nitrogen deposition, habitat fragmentation, forest fire, pest outbreak, and alien species, altering forest development trajectories and decreasing capacity for resistance (Millar and Stephenson 2015; Johnstone et al. 2016).

Adaptation to climate change in forestry (the science and practice of managing forests) deals with the reduction of the adverse impacts of climate change on forests, through the adjustment of forestry practices, to optimize the provision of forest goods and services (Seidl and Lexer 2013). Developing adaptive management measures is challenging due to the rapid changes in climate and land use, the wide range of forest types and the traditional management objectives that characterize the European forestry sector.

While an increasing number of adaptation measures exist for sustainably managed forests, many studies highlight that the lead times for adaptation in forestry are long and that some vulnerabilities might remain also after adaptation measures have been implemented. Furthermore, the costs and benefits of adaptation measures relative to other goals of sustainable forest management, such as the conservation of biological diversity, must be considered (Zimová et al., 2020).

Despite the increased awareness among forest decision makers and managers to promote adaptation management strategies, there are still large uncertainties concerning how to evaluate the effects of their implementation. Differences in socioeconomic and environmental conditions, challenges in data collection, and the analysis of climate change impacts are mentioned as causes of these uncertainties (Forsius et al. 2016; Viccaro et al. 2019).

2.1 Purpose, objectives and scope

A Monitoring System for the bioeconomy is a key commitment of the Commission under the 2018 EU Bioeconomy Strategy. The JRC has taken the lead to develop and implement a conceptual framework, based on the definition of a sustainable bioeconomy as stated in the Strategy, for a holistic analysis of the trends in the bioeconomy sectors, following the three dimensions of sustainability (economy, society and environment) and inspired by the internationally agreed Principles and Criteria for a Sustainable Bioeconomy. The framework is populated with a set of indicators that were selected to provide information on the condition, performance and trajectory of the bioeconomy as a whole. Many of the indicators that were identified do not actually contain a methodology to quantify them yet. One such gap is to define a set of robust indicators that are comparable across different countries, to monitor climate change adaptation in forestry through the assessment of adaptation measures in forest management.

The objective of this study is to provide an indicator, or set of indicators, to be added in the EU Bioeconomy Monitoring System that would allow the Commission to track the climate change adaptation of forestry over time.

2.2 Indicators

Developing adaptive management strategies requires accurate and updated information about forest resources. For this reason, appropriate indicators for monitoring and supporting forestry are necessary to counteract and promptly respond to ongoing environmental changes. An indicator is a variable, generally quantitative, that describes the condition of sectors and systems. In forestry, indicators need to be applicable in as many forest ecosystems and methods of forest management as possible allowing comparisons across temporal and spatial scales. Moreover, they need to be concise, meaningful and communicative, easily comprehensible, particularly by decision makers.

Forest inventories are systematic collections of data on the location, composition, and distribution of forest resources. The generated data allows for the assessment of various forest products and services and is a prerequisite for sustainable forest management. National Forest Inventories (NFIs) represent the most important source of data about forestry. NFIs are defined as a technical process of data compilation and forest resources analysis for a whole country. NFIs can build upon multiple data sources, including field inventories and remote sensing, to estimate relevant forest characteristics at points in time. NFIs are collected in a harmonized way, are broadly accepted by policy makers, and are publicly available. This makes them a suitable basis for further development toward an indicator set for the assessment of climate change adaptation in forestry.

Below is a list of the proposed indicators.

- **Forest area damage by agent**. Damage caused by any factor (biotic or abiotic excluding wildfires) that adversely affects the vigor and productivity of the forest. Disturbances include diseases attributable to pathogens, such as bacteria, fungi, phytoplasma or viruses and abiotic factors, such as snow, storm, droughts, etc. Reducing forest damages, due to biotic and abiotic disturbances, is crucial to promoting resistance and resilience to climate change (Jandl et al. 2013; Hlásny et al. 2017). For this reason, continuous monitoring of damages in forest ecosystems is crucial to identifying the best adaptive management strategies to prevent and reduce the negative impacts caused by climate change on forest health.
- **Forest fire burnt area.** Forest fires are expected to have a significant effect on European forestry. Adaptation measures to increased fire risks include improved planning of residential development such as to avoid inevitable wildfire, improved fire suppression capacities and strategies (Regos et al., 2014; Khabarov et al., 2016), thinning, slash management and prescribed burning techniques, as well as understory grazing (Vilà-Cabrera et al., 2018).
- **Forest connectivity.** Maintaining and improving connectivity is important in promoting nature recovery in fragmented habitats, especially under a changing climate. Ensuring forested areas are large and/or interconnected including specific climate refugia and climate corridors is recommended for climate adaptation. When habitats are more connected, species can expand populations or migrate at different rates in response to threats and pressures (Schmitz et al. 2015; Hagerman & Pelai, 2018).
- **Tree species composition**. Within managed forests, using diverse planting stock and managing for biodiversity improves resilience to disturbances from future climate changes (Keenan, 2015; Pörtner et al. 2021). Increasing the diversity of tree species within stands can have positive effects on tree growth and reduce disturbance impacts (Ammer, 2019) like increasing the share of drought-tolerant species and provenances (Hlásny et al., 2014).
- **Forest area under management plans that incorporate CC adaptation measures.** Sustainable forest management can build resistance to climate driven disturbances. Managing for continuous forest cover and practices like uneven-aged can help to maintain the forest microclimate and buffer tree regeneration and the forest floor community against climate change (Zellweger et al., 2020). Thinning has been found to effectively mitigate drought stress (Gebhardt et al., 2014; Elkin et al., 2015; Bottero et al., 2017), yet effects vary with species and ecological context (Sohn et al., 2016; Castagneri et al., 2021). Shortened rotation periods have been suggested in response to climate-induced increases in growth and disturbance (Jönsson et al., 2015; Schelhaas et al., 2015). However, recent evidence suggests that these measures diminish in efficiency under climate change and can have corollary effects on other important forest functions such as carbon storage and habitat quality (Zimová et al., 2020). Conversely, some other practices should be approached with caution, notably these which affect above ground biodiversity, and cause the loss of carbon in the roots and part of the carbon in the soil. These silvicultural practices include clear-cutting, for which environmental and ecosystem concerns, including the needs of certain species, should be increasingly considered.
- **Forest policy, legislation and governance**. Successful adaptation to CC in forest management can be achieved if there are partnerships between key stakeholders such as researchers, forest managers and local actors (Keenan, 2015). Such partnerships will lead to a shared understanding of climate-related challenges and more effective decisions (Sousa-Silva et al., 2016). Incorporating adaptation to CC of forestry sector in environmental laws and policies as well as strong and clear land tenure often leads to more sustainable management of forested areas, so building resistance and resilience to climate change.

Table 2. Indicator name, data source and ranking based on accessibility, relevance, and reliability of the indicator (H=high, M=medium, L=low).

Indicator	Data source	Rank
Forest area damage by agent	https://fra-data.fao.org/EU27/fra2020/disturbances/	1 HHH
Forest fire burnt area	https://fra-data.fao.org/EU27/fra2020/areaAffectedByFire/ https://effis.jrc.ec.europa.eu/apps/effis.statistics/	2 HHH
Forest connectivity	https://data.jrc.ec.europa.eu/dataset?keyword=Forest%20connectivity,%20EUROSTAT,%20Regional%20Yearbook	3 MHM
Tree species composition	https://fra-data.fao.org/FE/panEuropean/treeSpeciesComposition/	4 MML
Forest area under management plans that incorporate CC adaptation measures.	https://fra-data.fao.org/EU27/fra2020/designatedManagementObjective/ with an addition of a new sub-variable related to climate change adaptation measures	5 LHM
Forest policy, legislation and governance	https://fra-data.fao.org/EU27/fra2020/forestPolicy/ with a possible addition of a new sub-variable related to climate change adaptation measures	6 LHM

2.3 References

Allen CD, Macalady AK, Chenchouni H et al (2010) A global overview of drought and heatinduced tree mortality reveals emerging climate change risks for forests. For Ecol Manag 259:660–684. https://doi.org/10.1016/j.foreco.2009.09.001

Ammer, C., 2019: Diversity and forest productivity in a changing climate. New Phytol., 221(1), 50–66, doi:10.1111/nph.15263

Boisvert-Marsh L, Périé C, de Blois S (2014) Shifting with climate? Evidence for recent changes in tree species distribution at high latitudes. Ecosphere 5:art83. https://doi.org/10.1890/ES14-00111.1

Bottero, A., et al., 2017: Density-dependent vulnerability of forest ecosystems to drought. J Appl Ecol, 54(6), 1605–1614, doi:10.1111/1365-2664.12847.

Cailleret M, Jansen S, Robert EMR et al (2017) A synthesis of radial growth patterns preceding tree mortality. Glob Change Biol 23:1675–1690. https://doi.org/10.1111/gcb.13535

Castagneri, D., Vacchiano, G., Hacket-Pain, A., DeRose, R. J., Klein, T., & Bottero, A. (2021). Meta-analysis reveals different competition effects on tree growth resistance and resilience to drought. Ecosystems, 25, 30– 43. https://doi.org/10.1007/s10021-021-00638-4

Elkin, C., A. Giuggiola, A. Rigling and H. Bugmann, 2015: Short- and long-term efficacy of forest thinning to mitigate drought impacts in mountain forestsin the European Alps. Ecol Appl, 25(4), 1083–1098, doi:10.1890/14-0690.1.

Forsius M, Akujärvi A, Mattsson T et al (2016) Modelling impacts of forest bioenergy use on ecosystem sustainability: Lammi LTER region, southern Finland. Ecol Indic 65:66–75. https://doi.org/10.1016/j.ecolind.2015.11.032

Gebhardt, T., et al., 2014: The more, the better? Water relations of Norway spruce stands after progressive thinning. Agric For Meteorol, 197, 235–243, doi:10.1016/j.agrformet.2014.05.013

Hagerman, S.M. and R. Pelai, 2018: Responding to climate change in forest management: two decades of recommendations. Front. Ecol. Environ., 16(10), 579–587, doi:10.1002/fee.1974.

Hlásny T, Barka I, Roessiger J, Kulla L, Trombik J, Sarvašová Z, Bucha T, Kovalčík M, Čihák T. Conversion of Norway spruce forests in the face of climate change: a case study in Central Europe. Eur J Forest Res. 2017;136:1013–1028. doi: 10.1007/s10342-017-1028-5.

Hlásny, T., et al., 2014: Climate change increases the drought risk in Central European forests: What are the options for adaptation? For. J., 60(1), 5–18, doi:10.2478/forj-2014-0001.

Jandl R, Schüler S, Schindlbacher A, Tomiczek C (2013) Forests, carbon Pool, and timber production. In: Lal R, Lorenz K, Hüttl RF, Schneider BU, von Braun J (eds) Ecosystem services and carbon sequestration in the biosphere. Springer Verlag, Berlin, pp 101–130.

Johnstone JF, Allen CD, Franklin JF et al (2016) Changing disturbance regimes, ecological memory, and forest resilience. Front Ecol Environ 14:369–378. https://doi.org/10.1002/fee.1311

Jönsson, A.M., F. Lagergren and B. Smith, 2015: Forest management facing climate change – an ecosystem model analysis of adaptation strategies. Mitig. Adapt. Strateg. Glob. Change, 20(2), 201–220, doi:10.1007/s11027-013-9487-6

Keenan, R.J., 2015: Climate change impacts and adaptation in forest management: a review. Ann. For. Sci., 72(2), 145–167, doi:10.1007/s13595-014-0446-5

Khabarov N, Krasovskii A, Obersteiner M, Swart R, Dosio A, San-Miguel-Ayanz J, Durrant T, Camia A and Migliavacca M 2016 Forest fires and adaptation options in Europe Reg. Environ. Change 16 21–30

Lindner M, Maroschek M, Netherer S et al (2010) Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystems. For Ecol Manag 259:698–709. https://doi. org/10.1016/j.foreco.2009.09.023

Millar CI, Stephenson NL (2015) Temperate forest health in an era of emerging megadisturbance. Science 349:823–826. https://doi.org/10.1126/science.aaa9933

Pörtner H., Scholes R., Agard J., Archer E., Arneth A., Bai X., et al. (2021). "Report on IPBES-IPCC Co-sponsored workshop report on biodiversity and climate change," IPBES Secretariat, Bonn. doi: 10.5281/zenodo.4659158

Regos A, Aquilue´ N, Retana J et al (2014) Using unplanned fires to help suppressing future large fires in Mediterranean forests. PLoS ONE 9:e94906. doi:10.1371/journal.pone.0094906

Schelhaas, M.-J., et al., 2015: Alternative forest management strategies to account for climate change-induced productivity and species suitability changes in Europe. Reg Environ Change, 15(8), 1581–1594, doi:10.1007/s10113-015-0788-z

Schmitz, O.J., et al., 2015: Conserving biodiversity: practical guidance about climate change adaptation approaches in support of land-use planning. Nat. Areas J., 35(1), 190–203

Seidl R, Lexer MJ (2013) Forest management under climatic and social uncertainty: Trade-offs between reducing climate change impacts and fostering adaptive capacity. J Environ Manage 114:461–469. https://doi.org/10.1016/j.jenvman.2012.09.028

Sohn, J.A., S. Saha and J. Bauhus, 2016: Potential of forest thinning to mitigate drought stress: A meta-analysis. For. Ecol. Manag., 380, 261–273, doi:10.1016/j.foreco.2016.07.046

Sousa-Silva, R., et al., 2016: Adaptation of forest management to climate change as perceived by forest owners and managers in Belgium. For. Ecosyst., 3(1), 22, doi:10.1186/s40663-016-0082-7.

Viccaro M, Cozzi M, Fanelli L, Romano S (2019) Spatial modelling approach to evaluate the economic impacts of climate change on forests at a local scale. Ecol Indic 106. https://doi. org/10.1016/j.ecolind.2019.105523

Vilà-Cabrera, A., L. Coll, J. Martínez-Vilalta and J. Retana, 2018: Forest management for adaptation to climate change in the Mediterranean basin: a synthesis of evidence. For. Ecol. Manag., 407, 16–22, doi:10.1016/j.foreco.2017.10.021

Zellweger, F., et al., 2020: Forest microclimate dynamics drive plant responses to warming. Science, 368(6492), 772–775, doi:10.1126/science.aba6880

Zimová, S., et al., 2020: Reducing rotation age to address increasing disturbances in Central Europe: Potential and limitations. For. Ecol. Manag., 475, doi:10.1016/

3 Indicators for woody biomass use in EU construction

Markku Riihimäki

While wood is a traditional building material in many regions of the world, especially North America and other northern regions, wooden or wood-walled buildings are not characteristic of the European building stock. Wood is a highly local material, and overall, it only accounts for a small fraction of the European building stock.

The main feedstock used for construction in Europe includes concrete, brick and steel. An overwhelming proportion of sawn wood consumed in European construction is used in one- and two-family houses and small buildings. Secondary wood is mainly used for other construction purposes, such as roof structures and joinery (flooring, doors, windows, stairs, cupboards, etc.) and in construction site use.

A building is defined as a wooden building when its load-bearing frame material is mostly timber. This is the most common way of categorising buildings based on their material.

What makes statistics keeping more difficult is the versatility of the materials used: they can be used in many places and in different forms in construction. Construction largely consists of hybrid construction, which means that the shares and variables covered with statistics do not fully explain the overall use of materials. The same also applies to other construction materials besides timber. If a building is reported as timber-framed, it may still contain many other materials even in its load-bearing frame. On the other hand, a lot of wood may also be used in other building elements or secondary structures in non-timber-framed buildings.

In Finland, approximately 45–50% of timber use in construction focuses on new construction, 30–35% on renovation, 8% on civil engineering and 12% on construction site use, mainly in new construction. In countries where timber use in structures (new construction) is fainter, the share of timber is accentuated in construction site use and in renovation.

The construction site use of timber covers various protective and support structures, moulds, accessways etc. Most of the timber is only used once, but some of it can be used several times.

In new construction, approximately 60–70% of timber products and volume used in Finland are accounted for by timber-framed buildings, which are classified as wooden buildings. Similarly in renovation, timber use is presumably mainly focused on timber-framed buildings.

Also, timber use in construction is highly centred around residential construction. In Finland, timber use in residential construction accounts for approximately 70% of overall timber use in new construction. This is one third of total wood consumption in construction. In Europe, the share of new housing in total wood consumption is approximately one fourth. This makes new housing the most relevant category as regards timber product use.

In renovation, timber products in existing buildings are replaced by new timber elements. However, the amount of wood in buildings typically increases when renovated. In façades, for example, the share of timber increases during the building life cycle as façades are being renovated.

Timber is also widely used in small outbuildings and in the yard in general. In many countries, small outbuildings are excluded from construction statistics, but the timber use related to them is quite notable. In the example figures for Finland, timber use in garden construction has been included in renovation even though a part of the use is surely comparable to new construction.

Timber use in construction varies a lot by region. More wood is used in rural areas while the use is fainter in urban construction. No direct correlation can be made in timber construction based on regional shares, however.

In many countries, such as Finland and the Nordic countries, timber construction is heavily focused on specific small buildings, such as 1+2 family houses. The same does not apply to most European countries, although timber has an important role in secondary structures even in smaller buildings. In other words, no correlation can be made in wooden buildings based on building size.

The production statistics of wood products are clearly better than construction statistics. The problem with wood production statistics is that they do not itemise the uses of the wood – wood is also widely used in other types of industry besides construction. Focusing the volumes reported in production statistics on construction would require a lot of analysis.

3.1 Purpose, objective and scope

There are gaps in knowledge and data in the EU Bioeconomy Monitoring System. One such gap is in understanding the share of wood-based construction within the whole construction sector. This chapter addresses this gap to allow the Commission to track the penetration of woody biomass in construction over time.

This chapter mainly focuses on construction as a whole, while the indicators concentrate on new construction rather than renovation or civil engineering structures.

3.2 Statistics on the use of wood in construction in European countries

Various organisations and research institutes compile statistics on the amount and share of wood in construction, such as TMF in Sweden (https://www.tmf.se/bransch-naringspolitik/branschgrupper/trahus/), Graz University of Technology in Austria, VITO Vision of technology in Belgium, Wageningen University in the Netherlands and certain wood associations as listed in Table 2. These statistics help to estimate the share of wood construction in specific countries, but not all of the statistics are necessarily regular or continuous or are modelled.

Few statistics are being kept on the share of use of different materials in construction around Europe. Statistics on the use of wood as a construction material in European countries is also lacking. The share of wood in construction is tracked statistically in a few countries:

- Germany,
- Sweden,
- Finland,
- Czech Republic and
- Bulgaria.

Furthermore, timber has not been a relevant enough construction material in much of Europe to justify its being separately tracked.

Table 3 indicates the European countries in which timber construction is tracked statistically in one form or another.

Table 3. Summary of data coverage for construction statistics in EU countries.

	Total						Material of structure (at least timber)						Total		Materials		Source
	Residential construction			Others			Residential construction			Others							
	Permits	Starts	Completions	Permits	Starts	Completions	Permits	Starts	Completions	Permits	Starts	Completions	Dwellings	Other	Dwellings	Other	Statistical office
Netherlands	k		v										x				https://www.cbs.nl/en-gb
Belgium	k, v			k, v									x	x			https://statbel.fgov.be/en
Italy	n			n													https://www.istat.it/en/
Luxembourg																	https://etat.public.lu/fr.html/
France	k,v			k,v													https://www.insee.fr/en/accueil
Germany	k, v		k, v	k, v		k,v	v			v			x				https://www.destatis.de/EN/Home/_node.html
Ireland	q, y		q, y	q, y													https://www.cso.ie/en/index.html
Denmark	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y							x	x	x	x	https://www.dst.dk/en
Greece																	https://www.statistics.gr/en/home/
Spain													x				https://www.ine.es/en/index.htm
Portugal	q, y																https://www.ine.pt/xportal/xmain?xpid=INE&xpgid=ine_main&xlang=en
Austria	q, y		y										x	x			https://www.statistik.at/
Sweden	q	q, y	q, y	q					y				x				https://www.scb.se/en/
Finland	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	m, q, y	x	x			https://www.stat.fi
Cyprus																	https://www.statistics.gr/en/home/
Latvia	q, y		q, y	q, y		q, y							x				https://stat.gov.lv/en
Lithuania	q, y	q, y	q, y	q, y	q, y	q, y							x				https://www.stat.gov.lt/en/
Malta																	https://nso.gov.mt/en/Pages/NSO-Home.aspx
Poland	m, q, y	m, q, y	q, y	m, q, y		y											https://stat.gov.pl/en/
Slovakia	q, y	q, y	q, y										x				https://slovak.statistics.sk/
Slovenia	m		y	m		y											https://www.stat.si/StatWeb/en/home
Czech Republic	q, y	q, y	q, y			y			y				x				https://www.czso.cz/csu/czso/home
Hungary	m, q, y		q, y	m, q, y									x				https://www.ksh.hu/?lang=en
Estonia	q, y		q, y	q, y		q, y							x				https://www.stat.ee/en?lang=en
Bulgaria	q, y	q, y	q, y	q, y	q, y				q (by buildings)								https://nsi.bg/en
Romania																	https://insse.ro/cms/en
Croatia	m		y	m		y											https://dzs.gov.hr/

k=monthly data
n=quarter data
v=yearly data

3.3 Suggested indicators to monitor woody biomass in construction

The compilation of statistics on wood use is riddled with challenges and imprecision. Despite the vagueness, statistics should be compiled, and in as similar a manner as possible across different countries.

The most logical and perhaps the most feasible manner would be to track the volume and share of wooden buildings (load-bearing frame mostly of wood). This can be done in a similar manner across different countries. So far, such data is only available in five countries (Table 4). The proposed methodology, however, can be applied for other countries once data becomes available. The share of wood in load-bearing frames does not equal all timber use in construction, but it provides an overview and a reference point for timber construction. Renovation is also largely focused on timber-framed buildings. Most new construction is subject to licence across Europe, which means that information on the frame materials could be added to the statistical data and related information requested for construction projects.

Even though only a part of timber use is focused on new construction and timber-framed buildings based on the frame structure of the building, it is still the largest group of timber use and also the longest-term wood reserve in buildings. Therefore, tracking the volume of timber-framed buildings would be the best way to start estimating the share and volume of timber use in construction. Moreover, timber use largely centres around residential construction, which is an easier group statistic-wise and enables easier coverage of timber use. A timber-framed building can also be jointly defined in general terms and similarly interpreted across countries.

A good example of how statistics could be compiled is this link for Germany:

https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Bauen/Publikationen/Downloads-Bautaetigkeit/baugenehmigungen-baustoff-pdf-5311107.html

If willing to specify timber-use in construction in more detail, specific information on construction element materials can be requested related to construction projects and included in the statistics. Relevant parts for timber include façades and roof structures. The volume of wood is also high in them, and wood is widely used even if another material is used in the frame of the building. In Finland and Denmark, for example, façade materials are being used as one information category in building attributes. It would be feasible to add the façade material or roof structure material as one of the requested details for buildings and to include them in statistics. This would also serve other building stock analysis going forward.

Statistical data varies by country (the units, construction stage and building types). The most common units include square metres (m^2) and completed buildings. The data could be gathered on an annual basis, and the end result could be the share of wooden buildings in all buildings, specified by the building type.

3.4 Other means to estimate timber volumes

Before launching statistics compilation through statistics institutions, timber construction statistics can be advanced with organisations and research institutions operating in the timber field and tracking timber construction activities. Through them, it would be possible to receive data on the volume and share of timber construction and to establish the starting point for timber construction tracking. At least in France and Sweden, there are research institutes that track timber construction.

Table 4. Wood industry associations in European countries

	European Woodworking Industry Confederation - CEI-Bois
Netherlands	https://nbvt.nl/
Belgium	https://www.fedustria.be/
Italy	https://www.federlegnoarredo.it/it/federazione/associarsi/assolegno
Luxembourg	
France	
Germany	https://www.holzindustrie.de/
Ireland	
Denmark	
Greece	
Spain	
Portugal	
Austria	
Sweden	https://www.tmf.se/, https://www.forestindustries.se/
Finland	https://puutuoteteollisuus.fi/
Cyprus	
Latvia	https://www.lvkoks.lv/aboutus/
Lithuania	
Malta	
Poland	
Slovakia	
Slovenia	https://www.sloles.eu/goals/?lang=en
Czech Republic	
Hungary	
Estonia	https://www.empl.ee/
Bulgaria	
Romania	
Croatia	http://www.drvniklaster.hr/

If willing to specify and analyse actual timber use in construction, this would require a research project in which timber use is analysed and modelled in construction based on construction statistics, wood production statistics and construction contents. This would be an extensive project, but once the foundation has been laid, timber volumes could be estimated based on a calculation model and various statistics.

In the future, material data collection may be revolutionised by electronic construction licence processes, electronic construction licences as well as building, material and design data related to green building ratings, such as BIM. With effective and uniform data collection and metadata, it is possible to attain much more detailed material volumes, and timber use in various applications can be established in great detail. When developing electronic licence processes and environmental assessments, it would be wise to also further develop the collection of building attribute and material information. Going forward, this would allow construction element-specific assessment of the shares of timber and thus reaching a more detailed view of woody biomass build-up in construction and the shares of timber use compared to other materials. Closer collection of building material and attribute data would also serve other purposes, such as the assessment of building renovation needs. However, it is likely that the development of information collection related to electronic and detailed building data will take a long time.

List of figures

List of tables

Annex I: Summary of climate change in fisheries indicators

Table I1. Summary of indicators for each category, indicating units of measurement, accessibility of the time series data, their relevance for defining changes in adaptation to climate change (better to worst range 1-5) and the ease of obtaining the data (difficult to easy range 1-5).

Concept	Indicator	Unit of measure	Time series data accessibility	Relevance for climate change adaptation	Data availability
Increase fishing efficiency	by country or total EU-27 total capture in value/Fishing fleet gross tonnage by country or total EU-27	Tonnes/Tonnes	2012-2021	5	5
Adaptation of fisheries management	Temporal trend of certifications of sustainable fisheries	Coefficient linear correlation	2000-present	3	3
	Number of fisher associations involve on co-management programs	Number: Annual difference between data and median of temporal data set	-Depending on information provided by fisher association	4	1
Adaptation to spatial readjustment of exploited populations	Improving climate research, monitoring, and forecasting on fish distribution shift.	-M€ -Number of scientific papers	1980- present	4	5
	Comparison of spatial fish resource distribution with fishing effort spatial distribution	Pearson bivariate correlation across time	2012-2020	3	2
Shift aquaculture to non-carnivorous commodities	Trophic level of each specie*total production of this specie)/total production	Ponderate TL (1-5)	2009-2021	5	5
Selective breeding for increased resilience in aquaculture	Total EU investment on selective breeding research for aquaculture across time or scientific production	-M€ -Number of scientific papers	1980- present	4	5
Moving/planning siting of cage aquaculture facilities	Geolocalization of fish farms related to climatic risk	Number of displacement by year	2000- present	4	2
	Distance to coastal line of fish farms	Km (Annual difference between data and median of temporal data set)	2000- present	3	2
Change aquaculture feed management: reduction of feed conversion rate	Total feed input/fish production	Kg dry weight/Kg fresh weight	2009- present	5	4
Reducing the negative effect of extreme events on fish escapes	Aquaculture infrastructure investments for avoiding fish escapes: net and anchoring	M€	Depending on information provided by aquaculture associations	3	2
	New technology implementation: submerge cages.	M€	Depending on information provided by aquaculture associations	3	2
	Number of escapes across time for different species/countries	Biomass (tonnes) or individual	Depending on information provided by administration	4	2
	Temporal trend on co-invention patents by inventor country (EU27)	Number	2000	3	5
Improve insurance schemes among	Increase of insurance considering lost due to climate	M€ Number	Depending on information provided by	5	3

the producers especially small-scale farmers	change (extreme events)		aquaculture associations		
Mollusc production persistence under climatic pressures	Granger Causality test relation between temporal production of mollusc and pH in production areas.	p value	1993-present	4	5
	Granger Causality test relation between temporal production of mollusc and temperature in production areas.	p value	1993-present	4	5
	Distribution of shellfish production or parking areas in France related to sea water temperature	Pearson bivariate correlation across time	Depending on information provided by aquaculture associations-association	4	2
	Distribution of shellfish production or parking areas in Galicia (Spain) related to sea water temperature	Pearson bivariate correlation across time	2000	4	2
	Mussel production in Galicia (Spain) related to pH or sea water temperature	Coefficient linear correlation	2007-present	5	5
Fish production persistence under climatic pressures	Granger Causality test relation between temporal production of fish and sea water potential temperature in main production areas (Greece and Spain).	p value	2009-present	4	5
Increasing resilience to climate related extremes events	Temporal tendency on economical value of aquatic products (Catches in all fishing regions or aquaculture production in tonnes and value) related with losses by climatological events	%	2011-present	5	5
Reducing direct and indirect GHG emissions	Number: Annual difference between data and median of temporal data set	Number: Annual difference between data and median of temporal data set	2013-present	4	5

The European Commission's science and knowledge service

Joint Research Centre

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.