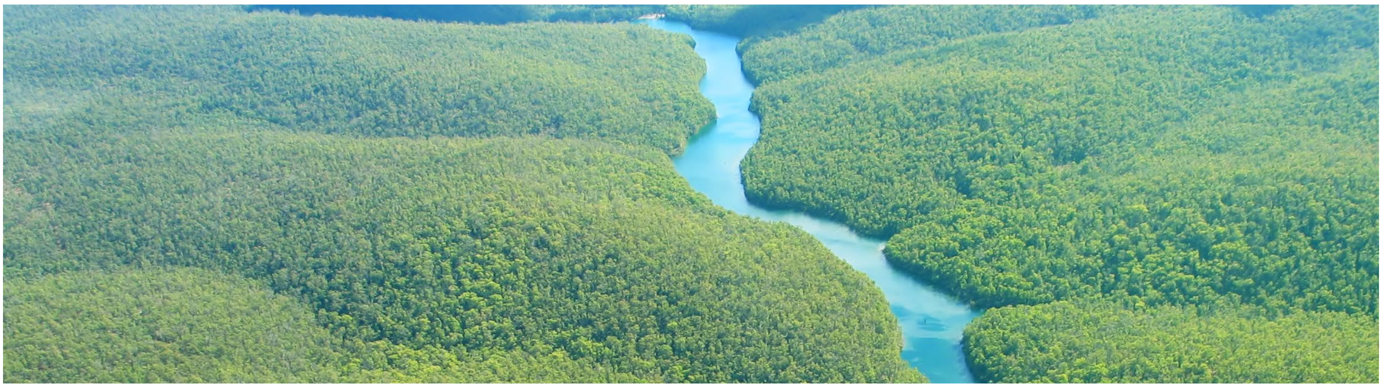

Make nature count; an explorative application of Gross Ecosystem Product for nature inclusive policymaking

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Main messages

- Nature-inclusive decision-making requires that the benefits associated with nature are taken into account in the economic assessment. This calls for a move beyond conventional measures of economic performance such as the Gross Domestic Product (GDP).
- The Gross Ecosystem Product (GEP) is a measure that quantifies the contribution of final ecosystem-related goods and services to the economy in a given period. GEP highlights the importance of ecosystem services and allows to track ecological performance alongside conventional macroeconomic indicators such as GDP.
- The typical analytical tools of policymaking need to be extended and this can be achieved by integrating GEP into macroeconomic models. To this end, we introduce the *GEP module* in the macroeconomic model MAGNET. The new module allows for comparison of the impact of different policies on both GDP and GEP, thus offering a broader view of potential policy consequences.
- The *GEP module* includes Integrated Natural Capital Accounting (INCA) data to determine the ecosystem service valuations: cropland (61,441 million euros), grassland (29,071 million euros) and woodland/forests (81,414 million euros) and the INCA data are particularly suited for calculation GEP indicators.

- The *GEP module* allows comparing different forward-looking scenarios with a reference scenario to characterise different views on the policy implications. The scenario discussed is the plant protein scenario, in which global consumption gradually changes towards more plant protein.
- There is a potential in developing further the *GEP module* as part of ex-ante decision-making in policy. The use of the GEP alongside other macroeconomic indicators such as GDP or industrial production provides a more accurate picture of the structure and coherence of an economic system.
- Moreover, the *GEP module* provides an insight into spillovers and indirect effects of policy decisions between regions or countries. Also, disentangling the different components of GEP – e.g. the ecosystem services value per ecosystem– can deepen the understanding of trade-offs and synergies between different ecosystem services.

There is a need to look beyond GDP

The necessity to acknowledge the importance of environmental goods and services in the decision-making process is gaining traction as awareness grows of the central role of nature in a future-proof and sustainable economy. There is a need to move beyond current measures such as the Gross Domestic Product (GDP) that does not fully capture nature's contribution to the economy and does not factor in environmental impacts (Sen et al., 2010). The latter is particularly important nowadays, given that the global stock of ecosystems, for example wetlands, grasslands and forests, is under increasing pressure from an expanding world population with rapidly changing consumption patterns (EEA, 2023). Ecosystem services, such as crop pollination and water purification, are of great importance to any economy because of the benefits they provide, both directly and indirectly. The way we manage our natural capital will play a key role in determining how well our economies can prosper in the long run. To assure nature-inclusive policymaking we need to introduce innovative measures and make ecological information an integral part of the decision-making process (Dasgupta, 2021). Hence, the Gross Ecosystem Product (GEP) was developed (UN, 2021c); GEP is an indicator that summarises the value that ecosystem services provide to the economy as a single monetary metric.

The concept of GEP is receiving increasing attention worldwide. In March 2021, the UN Statistical Committee approved a global standard on Ecosystem Accounting under the System of Environmental Economic Accounting (SEEA EA), which reflects the contribution of nature in measuring economic prosperity and human well-being (UN, 2021b). Since then, several countries have started developments related to its adoption and policy implementation (La Notte et al., 2021, Comte et al., 2022). Steps have been taken to value ecosystem services in national accounts to reflect their contribution to the economy, for example in the Netherlands and Iceland (de Jongh et al., 2021; Cook et al., 2022). China is the first country to apply GEP in economic planning. Here, local governments have implemented GEP to track ecological performance alongside conventional macroeconomic indicators such as GDP (Ouyang et al., 2020).

The strength of GEP lies mainly in the fact that it complements GDP measures. By using the national accounts approach, it provides policymakers with a clear and intuitive indicator of nature's contribution to the economy, based on the ecosystem services considered. The use of GEP alongside other macroeconomic indicators provides a more accurate picture of the impact of policies on the economy and on nature, which can be included in the decision-making process. Analogous to GDP (ESE, 2023), GEP cannot only be assessed as a single metric: an evaluation of the different components is also useful, such as the aggregated value of ecosystem services for each ecosystem. Trade-offs (and synergies) among different categories of ecosystem services, such as provisioning services, regulating and maintenance services and cultural services, are seen as one of the most important current sustainability issues and should be considered in decision-making (Bennett et al., 2023 and Le et al., 2023).

This article shows how the GEP indicator can be used for policy evaluation by including it into a macroeconomic model. We present the *MAGNET GEP module*, an application of GEP that links ecosystem flows and their values to known macroeconomic indicators for nature-inclusive decision-making. It enables forward-looking macroeconomic scenario studies on the relationship between macroeconomic indicators and GEP. The *GEP module* is a new extension to the computable general equilibrium (CGE) model MAGNET, a typical CGE model used to assess the policy impacts on the economy. MAGNET's endogenous land supply and forestry representation makes this model particularly suitable for implementing the *GEP module*, as does its international dimension.

The *MAGNET GEP module* builds on prior work to develop integrated environmental economic accounts by Wageningen Economic Research in collaboration with the Joint Research Centre (JRC). This work is supported by the Ministry of Agriculture, Nature and Food Quality of the Netherlands as part of the project 'Natural Capital in Macro-Economic Models for Integral Decision Making'. Below, we describe the *GEP module* and an exploratory application for a forward-looking scenario.

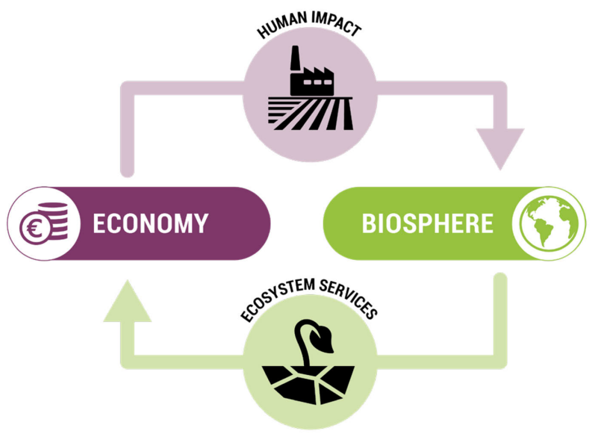

Figure 1 *Sustainability requires considering the entire bio-economic system*
Source: Own work.

Gross Ecosystem Product: a monetary index on the aggregated value of ecosystem services

GEP as an indicator summarises the value that final ecosystem services provide to society in an area as a single monetary metric (Ouyang et al., 2020). Natural capital is the stock of renewable and non-renewable resources (e.g. plants, animals, air, water) that generate in interaction with other capitals (human, social and produced capital) a flow of goods and services, 'ecosystem services', that create value through the benefits they provide to business and society (Figure 2). Ecosystem services can benefit people in many ways, either directly, by providing services or goods such as food, timber, fibre, or indirectly as inputs of the natural system providing fundamental services such as generation of habitats, water cycle regulation, pollination or flood defence. There has been a growing need over the years to assess ecosystem services, which are fundamental to our wellbeing. It is estimated that a significant proportion of global GDP depends on them. Human interactions and politics have a strong impact on the provision of ecosystem services (Guerry et al., 2015). A better understanding of how policy decisions affect the contribution of ecosystem services to the economy, now and in the future, enables evaluation.

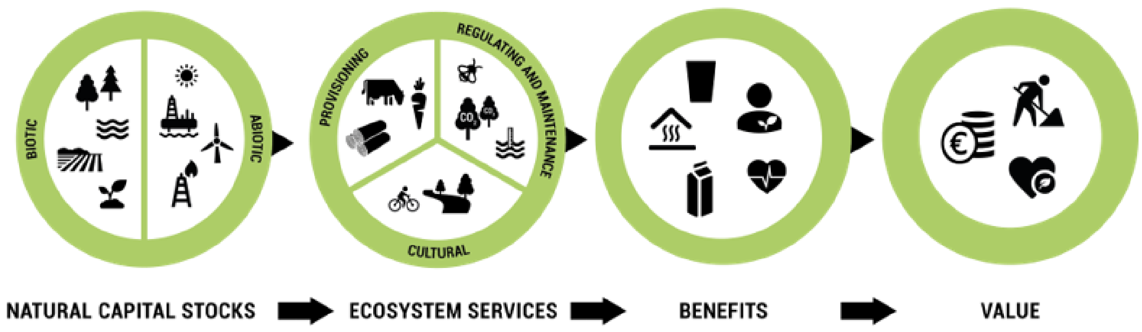

Figure 2 *Natural Capital Stock, Ecosystem services, Benefits and Value*
Source: Own work.

The ecosystem services are categorised under the common international classification of ecosystem services (see e.g. www.cices.eu) and include provisioning services (e.g. food, timber, water), regulating and maintenance services (e.g. water purification, carbon sequestration) and cultural services (e.g. ecotourism, nature experience for mental health) (IPBES, 2023).

Table 1 *Definition and examples on the three major sections in CICES V5.1*

Section in CICES	Definition	Examples
Provisioning services	This section covers all nutritional, non-nutritional material and energetic outputs from living systems as well as abiotic outputs (including water)	Crop provisioning, Timber provisioning
Regulating and maintenance services	All the ways in which living organisms can mediate or moderate the ambient environment that affects human health, safety or comfort, together with abiotic equivalents	Water purification, carbon sequestration, flood control, crop pollination, natural pest control
Cultural services	All the non-material, and normally non-rival and non-consumptive, outputs of ecosystems (biotic and abiotic) that affect physical and mental states of people	Nature based recreation

Source: cices.eu.

To calculate the GEP, flows of final ecosystem services need to be quantified and translated in monetary terms. Estimating this economic value of ecosystem service flows can be complex as many of these services do not have well-established volumes, prices or markets. Here, the SEEA EA provides necessary guidance. This international statistical framework developed by the United Nations provides a uniform approach for integrating environmental and ecosystem information into economic accounting systems (UN, 2021). Since humans only benefit from the final ecosystem services, GEP is calculated as the sum of all final ecosystem services. Thus, following the GEP definition where all ecosystem services are simply additive, the final GEP value is a summation of the aggregated valuations of the provisioning, regulating and cultural services.

An important feature of the GEP is that, alongside other data sources, national accounts are used for the calculation, so it can be compiled in parallel with GDP. This in turn allows these measures to be interpreted alongside each other. It is noteworthy that the GEP indicator incorporates nature’s contributions to the economy including marketable ecosystem services such as crop and wood provisioning. As shown in Figure 3, this leads to an overlap between the two indicators (Polasky et al., 2023). For these and other reasons, the interpretation of the ratio of the two indicators is not straightforward. We suggest focusing not on the GEP/GDP ratio itself, but on the overall trend of the ratio, which provides more meaningful information for decision-making.

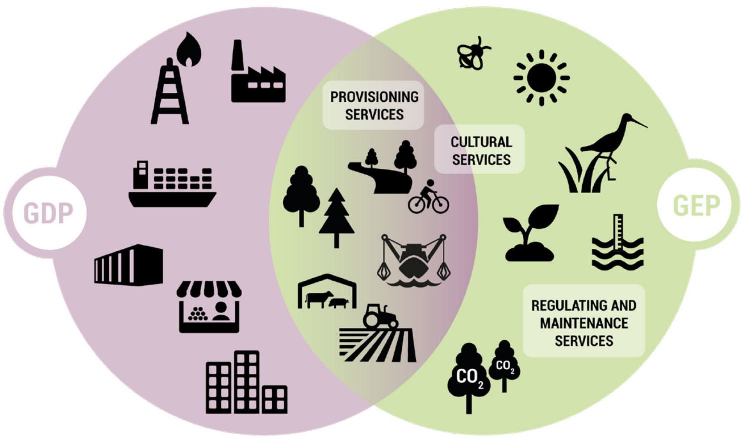

Figure 3 *Illustration of GEP and GDP partly overlapping*
Source: Own work.

The GEP indicator and its component provide valuable insights, since quantifying the contribution of ecosystem services to the economy helps highlighting their importance. In this way, the performance of ecosystem services can be assessed and reflected in statistics, providing information for policy evaluation. An application of the GEP is not limited to environmental policy. The GEP indicator applied in policy-making ensures that policy impacts associated with nature are taken into account as well when considering policy options. Assessing these impacts against metrics is a prerequisite to put them on a par with other conventional metrics and show the broader picture of the implications. However, it should be stressed that the complexity of capturing the contribution of nature in data does not yet make this indicator fully suitable for integration between national accounts and nature. For example, a valuation method may suggest that the economic value of an ecosystem is zero or low, or an ecosystem service may have an intrinsic value that, by definition, cannot be captured in monetary terms. It would be irresponsible to conclude that these ecosystem services truly have no value, but this value is not included in GEP when comparing alternatives in decision-making. This underestimation should be taken into account when interpreting GEP outcomes.

While GEP provides valuable insights into sustainability issues through the impact on and trade-offs between ecosystem services flows, for sustainable development additional measures are required to track ecosystem assets. Ecosystems are considered assets (forests, wetlands, agricultural areas, rivers and coral reefs), that generate flows of various ecosystem services. Their measurement is taken from two perspectives (1) ecosystem condition and (2) ecosystem extent. There is a linkage between the condition of ecosystems and the services they provide, with any change in the condition of ecosystems affecting services and thus benefits to the economy and society (La Notte et al., 2022b). The monitoring of condition (health) of ecosystems as indication of sustainable development requires parallel and separate measures (UN, 2021a). Systems of national accounts include measures of wealth and of income, and GDP and GEP are similar in that they are not characterised as wealth measures but as measures of ‘income’ (Polasky et al., 2023). The GEP is an annual flow measure, reflecting the economic value of ecosystem service contribution for a specific period, but does not provide an estimate of the cumulative worth of natural assets over time.

Policy application of the GEP concept, especially in forward-looking policy analysis, is still at an exploratory stage. Despite the potential of the concept and prospective possibilities for policy application, recent research shows that there are two main challenges in making GEP a complementary measure to GDP (Hao et al., 2022). First, the accuracy of GEP accounting needs to be improved. No ecosystem services valuation technique is perfect, and uncertainty is always a critical issue. There are several areas for improvement to achieve even better valuation measures globally (Brander et al., 2023; Hao et al., 2022). The optimal valuation method for different ecosystem services requires a unique approach for each ecosystem service, which poses a challenge when adding up the different ecosystem services. Second, consideration should be given to how GEP results can be applied as part of policy decision-making (Hao et al., 2022). Regarding this challenge, this study takes a step by linking GEP with macroeconomic models and policy scenario analyses. In addition, this study shows that the components of the GEP indicator are also useful for policy evaluation purposes.

The *GEP module*: connecting ecosystem services values to macroeconomic variables

The *GEP module* is implemented as an extension to the CGE model MAGNET (www.magnet-model.eu), using an external source, the Integrated Natural Capital Accounting (INCA) dataset, to determine the initial quantities and prices of ecosystem services (Vysna et al., 2021). INCA (Integrated system for Natural Capital Accounting)[1] is a project funded and supported by the European Commission to test and implement the SEEA EA in Europe and whose first round of applications generate a number of lessons learnt on the operational procedures to be applied for ecosystem services accounting (La Notte et al., 2022a). The INCA dataset represents the economic value of ecosystem services for EU member states in 2021 and is particularly suited for the calculation of GEP indicators.

In the *GEP module*, the economic value indicators from INCA are linked and updated with economic change variables (such as land use and production) in MAGNET via so-called postprocessing of the quantitative forward-looking scenario results of the model. Currently, the *GEP module* contains only a subset of ecosystems and related services. Due to their strong linkage to economic sectors and land use variables available in MAGNET, three ecosystems were chosen: cropland (61,441 million euros), grassland (29,071 million euros) and woodland/forests (81,414 million euros). In this way, we were able to include more than 90% of the monetary value of all ecosystem services available in the INCA database, see Figure 4. The INCA data were used to compute the GEP indicator based on the assumption that the value per ecosystem service per hectare of ecosystem is constant over time.

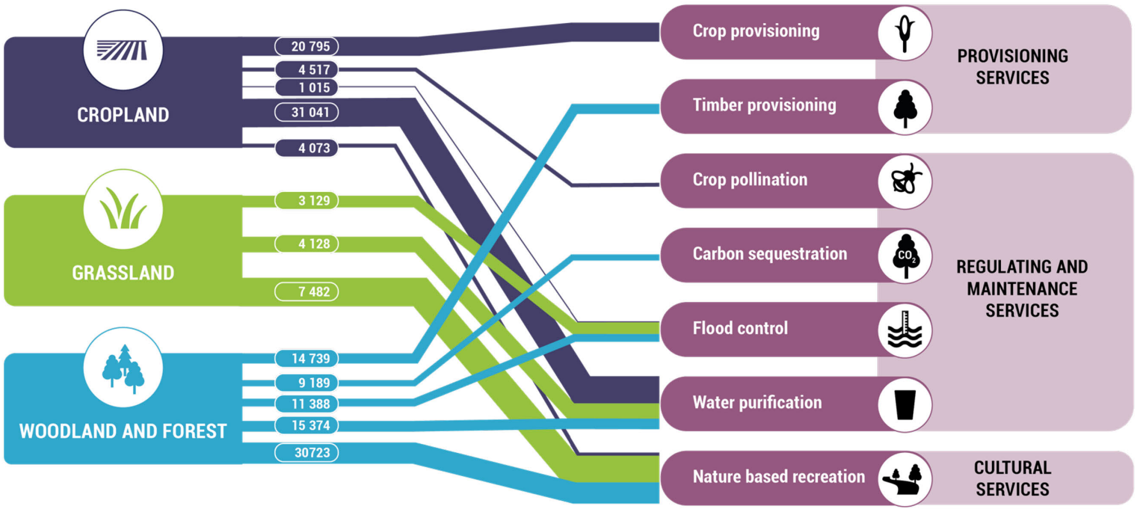

Figure 4 *Economic value provided by ecosystem services in the EU in INCA database (2012, million euros). The data are available at the member state level from the INCA platform.*

The *GEP module* updates the input variables for the GEP calculation by linking them to changes in related MAGNET economic variables. For example, the calculation of the water purification service depends on the amount of fertilisers that enter soil and eventually freshwater when applied to cropland. In the case of cropland water purification, we start in the base situation with the INCA

[1] https://ecosystem-accounts.jrc.ec.europa.eu/

value for that ecosystem service (see Figure 4) and update that value with the percentage changes of inputs of fertiliser into the crop production sector. A useful aspect of the MAGNET model with respect to GEP, besides its international dimension, is its capability of calculating land use change endogenously, as many parts of the *GEP module* depend on those outcomes. For example, the flood control ecosystem service depends (as of yet) solely on changes in land demand, where, e.g., a certain increase of forest area directly updates (as percentage change) the flood control ecosystem service value.

Following up on SEEA-EA guidance, the analysis starts from the ecosystem services actual flow that is accounted in supply and use tables, where, according to accounting logic and rules, supply equals use. The authors are aware that there are some inconsistencies and simplifications relative to reality in how expected ecosystem services flows are calculated in the *GEP module*. For example, the crop pollination ecosystem services are initially implemented simply as the increase of the crop production output (i.e. the ecosystem service actual flow) as we do not have any additional explanatory variables in the MAGNET model (as yet) that would influence the supply of the pollination service. Another example for possible future improvement is that carbon sequestration is now calculated using a fixed price of 30 euro/tonne CO_2, where it could be potentially be linked to exogenous or endogenous CO_2 prices in a MAGNET model simulation. The *GEP module* will be continuously updated to reflect new insights on ecosystem service valuations, as well as expanded with additional ecosystem services as data availability allows.

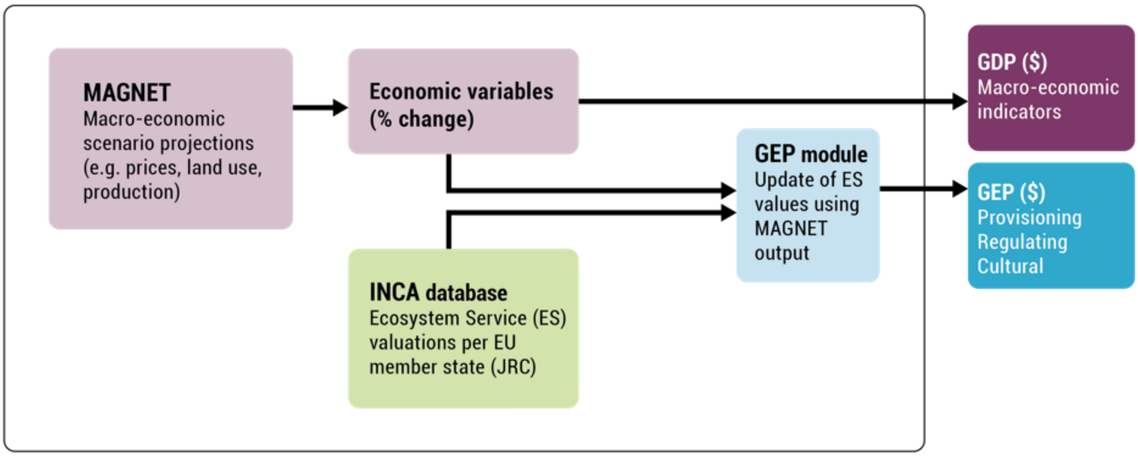

Figure 5 *Model setup GEP module*
Source: Own work.

Exploratory illustration of the *GEP module* scenario results

In this section, we illustrate the measurement of GEP through an application to a macroeconomic scenario to showcase the new module and its potential application in decision-making. The data presented here is preliminary and only provides insight into the way GEP results can be interpreted, and the outcomes presented are not conclusive in this illustrative scenario. The module is still under development and has various limitations, e.g., in relation to data completeness.

The scenario discussed below is the plant protein scenario, in which consumption in the EU gradually (in steps of 10 years; 2030, 2040, 2050) changes towards more plant protein. This scenario is simplified and only covers one aspect of the multi-faced topic of economy and land use. The scenario assumes a gradual shift in consumer preferences over several decades and reflects a macroeconomic change that could be brought about by policy intervention. No other assumptions besides the consumer preference shift are made, the main effect will be an overall decrease in livestock demand which will translate in changes in land use. The scenario analysis is compared against the baseline or 'unchanged policy' scenario, which follows a path in which social, economic and technological trends do not shift markedly from historical patterns.

Results: The change in consumption patterns has a very small (but positive) impact on EU GDP in 2030 (+0.01%) compared to the reference scenario. However, the GEP index increases by **1.5% or 2.3 billion euros** compared to the reference scenario, with the components of GEP increasing by 1 to 2% depending on the type of ecosystem service: cultural services, provisioning services and regulating and maintenance services, see Figure 6.

Figure 6 *Policy scenario result EU 2030, GEP % change vs. baseline*
Source: Own work.

In the European Union, the main effect of this scenario is a slight decrease in grassland area due to decrease livestock demand (-36,000 ha, -5%) and related services, but an increase in forest area (1,300 ha, 3%) in 2030. Also crop production increases (17,500 ha, 4%). All this means that ecosystem services related to cropland and forest generally increase, these are; nature based recreation, crop provisioning, water purification, crop pollination, flood control, wood provisioning and carbon sequestration. As the ecosystem services related to grassland decrease (nature-based recreation, water purification and flood control). Note that in this illustration there are no provisioning services (e.g. fodder provisioning) related to grassland; this is the result of using the currently available INCA data that does not include them.

In terms of ecosystem service trade-offs, nature-based recreation as an ecosystem service is negatively affected by the decrease in grassland, which is fully offset by the increase in forests ecosystem services, since forests have a higher recreational value; net nature based recreation increases as a result of this scenario.

Furthermore, as a result of this scenario, carbon sequestration increases due to the increased forest area. This net increase in carbon sequestration due to changing consumption patterns is fully assigned to forests here, as the INCA data (following LULUCF reporting guidelines in the EU) consider only forests as net sinks of atmospheric carbon, see Figure 7.

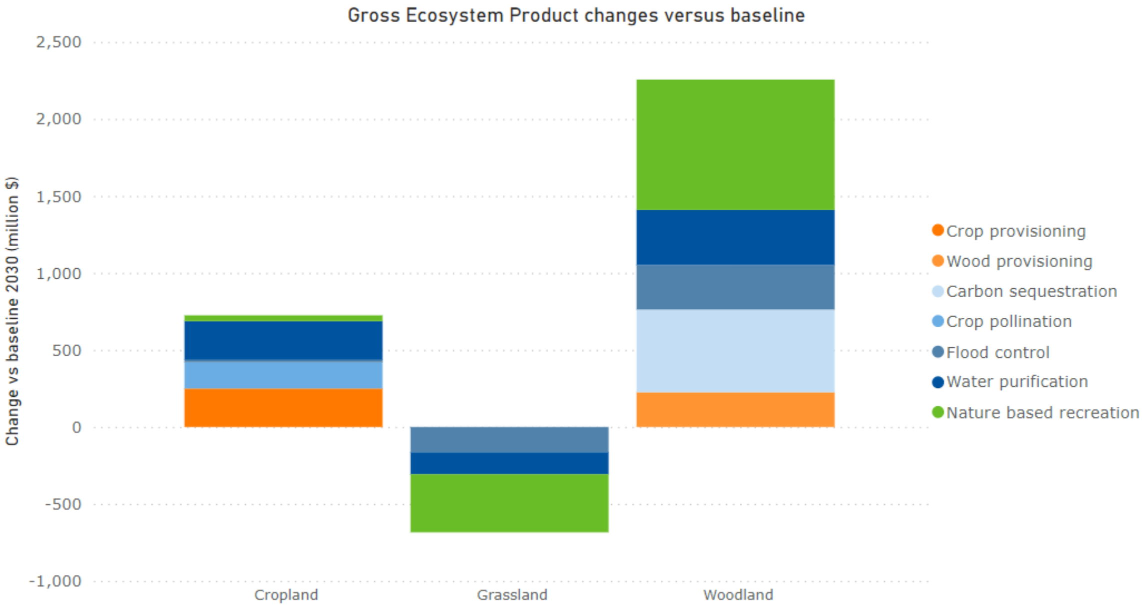

Figure 7 *Scenario result EU 2030, GEP absolute change in million euros versus baseline*
Source: Own work.

The *GEP module* and nature-inclusive decision-making: assessing scenario analyses and ecosystem services trade-offs

To achieve truly integrated decision-making, we need to move beyond environmental policy evaluation, and use GEP insights to help policymakers in choosing the optimal policy design. The *GEP module* presented here allows for analysing potential impacts of different policies on both, GDP and GEP, and thus gives decision makers an analytical approach to manage natural capital as part of broader economic strategies in a consistent way. The structure of GEP, and its coherence with SEEA EA, ensures that the accounts are directly applicable to these macroeconomic decision contexts (UN, 2021a). In addition to the other forms of capital, produced and human capital, the GEP index can be included as an additional dimension in macroeconomic models already in use by policymakers. In this way, natural capital can be part of ongoing analyses and integrated in economic decision-making, in the same way it is done for other forms of capital.

This distinguishes the *GEP module* application from other applications of GEP, which more often involve more isolated analyses and, more importantly, retrospective policy evaluations, rather than future assessments of the effects of various policies on the contribution of ecosystem services (see Ouyang et al., 2020 and de Jongh et al., 2021). For example, the Chinese government applies the GEP to evaluate the effectiveness of policies, provide a basis for the assessment of the performance of policy implementation, and uses it as a reference for programmes. Examples are ecological fiscal transfer (EFT) programmes, in which the GEP indicator serves as the basis for redistribution of public revenues between governments within a country, and payments for ecosystem services (PES) programmes, where beneficiaries of environmental services provide payments to private resource owners (Hao et al., 2022). The focus here is on encouraging and evaluating environmental policies.

One of the applications of the *GEP module* is the ex-ante modelling of scenarios with a medium to long-term time horizon. By linking GEP outcomes to the outcomes of a macroeconomic model, the *GEP module* also allows insights into indirect effects and spillovers. Using a multi-country model such as MAGNET provides understanding of international trade-offs and the systemic effect of policies across national borders. This makes it possible to show the influence of different trade-induced shocks on GEP, e.g. eating less meat in Europe leads to lower meat imports, less deforestation and thus a higher GEP value in Brazil.

The *GEP module* also provides insights into trade-offs and synergies among ecosystem services. Economic development that benefits from ecosystem services often involves ecosystem services trade-offs, and it is pivotal for sustainable development that this is done in a way that protects the natural capital needed to provide services for future generations. Trade-offs among ecosystem services occur, for example, when the contribution of one ecosystem services decreases due to an increased use of another ecosystem services or when a policy decision achieves an ecosystem services advantage at the expense of another (Le et al., 2023). The *GEP module* helps evaluate co-benefits and minimise conflicts between various ecosystem service flows, and with GDP and other indicators.

The development of the *GEP module* is an ongoing process

Accurate metrics are vital for integrating nature into policy decision-making. Using GEP to value ecosystem services within the decision-making process could improve the quality of new policies and stewardship, allowing natural capital to be better managed which ensures a flow of vital goods and services. While we note that GEP falls short as a measure of the value of nature, GEP, as a monetary metric, reflects that nature provides a considerable contribution to our well-being and economy to inform decision-making. This novel metric is in the spotlight around the world, and there is development and uptake of SEEA EA consistent ecosystem accounting across broader scales and including multiple ecosystems. Despite this, for various reasons, real world policy applications of GEP in its full potential as a metric alongside GDP, are still pending. This can be partly explained by technical limitations, especially with regard to data availability and the complexity of ecosystem service valuation in relation to aggregation across regions and ecosystems. Yet it should be noted that the EU with its INCA dataset provides a unique basis for analysis.

Nature-inclusive decision-making requires extensions of the current macroeconomic models used for policymaking. This helps to improve the policy instrumentality of GEP, as macroeconomic analysis is already in use by researchers, analysts and policymakers, with GEP enriching the analysis in parallel with other macroeconomic indicators such as GDP or employment rate. For instance, we can show the impact of trade-induced shocks on GEP, e.g. less construction with timber in Europe means less deforestation and thus a higher GEP in wood-supplying countries. Our analysis shows that for correct interpretation of the GEP indicator, the components of the GEP indicator enrich the analysis. For example, if less wood is harvested, the provisioning service decreases but the regulating services increases, resulting in a net increase in GEP value.

The *GEP module* can be a tool to assess and compare the contribution of ecosystems to the economy for specific regions. It is worth considering the spatial distributional effects of GEP when further developing the *GEP module* and incorporating it into the decision-making process. For example, in the application of GEP in China, we see that a region within China, being a net exporter of ecosystem services, is facilitating the provision of ecosystem services without receiving all the benefits (Ouyang et al., 2020). These regional differences should be taken into account when assessing policy decisions.

There is potential in further development of the *GEP-module* in MAGNET as a tool for policy evaluation; further improvements are identified in the section below. We suggest that the development of the *GEP module* should be a continuously evolving process with both long-term and short-term improvement aims. Possible improvements could include principles for screening indicators or inclusion/exclusion of ecosystem services. It may also involve enriching GEP accounting with perspectives of the link between biological and human production, or including harm to the ecosystem carrying capacity (Zhang et al., 2022). In addition, in terms of interpretation and explanation, there is a risk of misinterpretation the meaning of GEP results if the underlying assumptions are not made explicit or GEP is interpretated in a different context. In parallel with these technical developments, further elaboration of the policy applications of the *GEP module* that facilitates intuitive interpretation by policymakers is important.

Further development of the *GEP module*

With a view to future scenario applications with the MAGNET model, Wageningen Economic Research and JRC plan to update the *GEP module*, mainly to improve the applied ecosystem service valuation methodology as well as updating the reference year of the INCA data. This includes improving the link to the INCA database, including price effects and increasing the scope of ecosystem services in the *GEP module*.

Furthermore, there is work ongoing in collaboration with the Foundation for Sustainable Development (FSD) on improving the ecosystem service valuation data extraction of the Ecosystem Service Valuation Database (ESVD). Hereby, the focus is on global level (expand beyond the EU) and on further refinement of the spatial component of some ecosystems, e.g. forest and woodland.

Further steps also include the implementation of 'sustainable flows-approach'. For example, by including the self-sustaining and regenerative capacity of ecosystems or the critical retention measures for ecosystem service flows. As a result, sustainable flows of ecosystem services will be better reflected in economic valuation. Related to this would be the possible inclusion of ecosystem stocks in an environmentally extended social accounting matrix and the inclusion of these sectors in the production function of dependent sectors. For example, pollinators could be considered an integral part of the production of crops, competing with labour and capital inputs. In that way, ecosystems and their services can become an integral part of macroeconomic policy analysis for nature inclusive decision-making.

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