Gross ecosystem product (GEP) accounting in Miyun County: supply and use

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Abstract

We aimed to evaluate the supply capacity and use status of the ecosystem in Miyun County. The potential and actual gross ecosystem products (GEPs), describing the background condition of an ecosystem and human demand for ecosystem products, respectively, were estimated. In 2020, the actual GEP of Miyun County accounted for 21% of the potential GEP. Water retention and climate regulation services were the highest in the potential and actual GEPs, respectively. The contributions of wetlands and forests were the highest in the potential and actual GEPs. Natural ecosystem area and vegetation coverage were the main factors affecting the potential GEP, whereas the actual GEP was mainly affected by gross domestic product (GDP) and population. Using Miyun County data, we quantitatively analysed the supply capacity and actual use of ecosystem products to clarify the interdependence between the ecosystem and human society to support decisions for regional eco-sustainability.

1. Introduction

The term "ecosystem services" was formally proposed in the early 1970s (Ehrlich & Holder 1974), and the Millennium Ecosystem Assessment (MA 2005) defined it as the benefits people obtain from the ecosystem (Zhao et al. 2007). Many studies on ecosystem services have been conducted since then, and preliminary research results have been documented (Li et al. 2022). Monetisation and quantification of ecosystem services have gradually garnered attention to assess the contribution of ecosystems to human welfare reasonably and guide the application of ecology in economic decision-making (Bayon 2004; EC 2008; Peterson et al. 2010; Roces-Diaz et al. 2015). However, because of the complex transfer process of ecosystem services from natural ecosystems to social and economic systems, the same terms have often been understood and applied differently, resulting in ambiguity in the concepts. For one example, the concept of ecosystem services proposed by Villamagna et al. distinguishes **supply** (ability to provide services) from**use** (depending on supply and demand) (Villamagna et al. 2013).

On the contrary, the System of Environmental-economic Accounting—Ecosystem Accounting (SEEA EA) manual equates the**supply** of an ecosystem with its **use** (United Nations et al. 2021). For another example, Crossman et al. have mixed-**use**and **demand** in the same term (often referred to as "demand") (Crossman et al. 2013). Nevertheless, in mapping and assessing ecosystems and their services (MAES) action, the European Union distinguishes between **use** and **demand** for ecosystem services (European Union 2020). Because the definitions in these studies are cluttered, we have synthesised these concepts into three categories:**supply** , **demand** , and **use** . We define the**supply** of ecosystem services as the ability of the ecosystem to provide services sustainably under existing ecosystem status and management conditions, regardless of human needs (Burkhard et al. 2012; Gómez-Baggethun et al. 2010; Haines-Young & Potschin 2010; Maes et al. 2016, van Oudenhoven et al. 2012), such as the ability of the ecosystem to provide water retention services.

Demand refers to the number of services that society requires or expects (Chaplin-Kramer et al. 2019; Fisher et al. 2008; Goldenberg et al. 2017; Maes et al. 2016; Villamagna et al. 2013), such as the number of water retention services that society expects. **Use** was determined based on the spatial relationship between supply and demand (Maes et al. 2016; Maes et al. 2020; European Union 2020: Vallecillo et al. 2019), which refers to the amount of services obtained and utilised by human society from the ecosystem, such as the total amount of water used in personal or economic activities. The supply of ecosystem services directly depends on regional ecological integrity, which is influenced by human actions and decisions such as land cover change, land use, and technological progress. Similarly, the use of ecosystem services is influenced by policies, population dynamics, economic factors, cultural norms, and governance influence. Therefore, the supply and use of ecosystem services must be distinguished and accounted for to guide the formulation of relevant policies for ecological restoration and protection (Curran & de Sherbinin 2004). Nevertheless, in previous assessments of ecosystem products, most of them did not distinguish between supply and use, instead choosing only one or the other in ecological studies or economic statistics applications (European Union 2020, García-Llamas et al. 2018, McDonald 2009, van Jaarsveld et al. 2005). For example, Song and Ouyang took Qinghai Province as an example to research potential GEP, accounting for an ecological benefit assessment (Song & Ouyang 2020). The United Nations Cooperation Project, NCAVES, calculated the actual GEP of Guangxi and Guizhou in China based on the SEEA framework in 2016 (NBS China et al. 2021), while the EU MAES report accounted for ecosystem products' supply and use (European Union 2020). However, in its accounting, the functional quantity index cannot be compared horizontally but only vertically. However, the supply and use of ecosystem products are interconnected and interact with each other, just like ecosystems and socioeconomic systems. We need to link the two for horizontal comparison to reflect the local ecosystem background and human utilisation of ecosystem products and formulate reasonable management policies.

The value quantity of ecosystem services is more widely used than the functional quantity because it converts different types of services into common weights before measuring them to facilitate horizontal comparison and comprehensive evaluation. (Boyd & Banzhaf 2007; Costanza et al. 1997). In 2013, Ouyang et al. from the Chinese Academy of Sciences proposed the concept of gross ecosystem product (GEP) (Ouyang et al. 2013). In 2021, the United Nations released the first international standard, the SEEA-EA manual, which cited the concept of GEP at an international level (United Nations 2021). The following year, the National Bureau of Statistics of China and the National Development and Reform Commission jointly issued the Standard for Accounting of the Total Value of Ecosystem Products (Trial) by referring to the SEEA-EA manual, emphasising the accounting of ecosystem products used by human beings (National Development and Reform Commission 2022). The 2013 concept emphasises the supply capacity of ecosystem products, while the 2021 concept emphasises humans' actual utilisation of ecosystem products. The different emphasis of GEP concepts also reflects the different focus of people in different fields: supply and use.

In summary, this study selected value indicators to calculate the supply and use of ecosystem products, namely potential GEP and actual GEP, to evaluate and compare the supply capacity and actual use of ecosystem products in Miyun County horizontally. In this study, we aimed to comprehensively understand the interdependence between the ecosystem and human society in Miyun County and provide decision support and policy guidance for ecological protection and sustainable development.

2. Materials and methods.

2.1. Study area

Miyun County is located in the Northeast of Beijing, with geographical coordinates of 116°39'–117deg30' E and 40deg13'–40deg47' N. It is flanked by the Pinggu, Shunyi, and Huairou Counties of Beijing in the Southeast to Northwest regions and Hebei Province in the North and East regions and has a total area of approximately 2229.45 km^2, making it the largest district in Beijing.

Miyun belongs to the Yanshan Mountains and North China Plain junction, and mountains surround the terrain of the entire area on three sides (East, North, and West). The Miyun area has a warm temperate monsoon continental semi-humid and semi-arid climate with four seasons and apparent changes in dry, wet, cold, and warm conditions. The annual average temperature is 6–19 degC; the frost-free period is about 150 d; sunshine is sufficient; and precipitation is mainly concentrated from June to August. The precipitation distribution generally decreases from Southeast to Northwest, giving an average annual of 300–700 mm.

In 2020, the main ecosystem types in Miyun County were forests (41.6%) and shrubs (22.9%), followed by farmlands (21.9%) and wetlands (6.6%). Natural ecosystems (forests, shrubs, grasslands, and wetlands) account for 72.4% of the total area of Miyun County. The quality of the ecosystem in Miyun County is good, and natural resources are abundant.

2.2. Data sources

The data from 2020 was used in this study for GEP calculation, and various data sources, including statistical and geospatial data, were integrated into this study.

Statistical data were obtained from the statistical survey information of the Miyun County Ecological Environment Bureau, Water Bureau, Meteorological Bureau, Cultural and Tourism Bureau, other industry departments, and the Miyun Statistical Yearbook. Ecosystem classification, vegetation coverage, biomass, evapotranspiration and other geospatial data were obtained from the Institute of Remote Sensing and Digital Earth, Chinese Academy of Sciences, with 10, 250, 250 and 500 m data resolutions. Rainfall data (Peng et al. 2019) were obtained from the National Earth System Science Data Center (http://www.geodata.cn) at a resolution of 1 km.

2.3. Methods

The GEP accounting of Miyun County includes three categories: material supply, regulation service, and cultural service. Material supply includes crop supply products and regulation services with seven types of products: products for water retention, soil retention, flood control, carbon sequestration, air purification, water purification, and climate regulation. Cultural services include nature-based tourism, recreation, and leisure. For these ten types of products, the potential (Ouyang et al. 2013) and actual GEPs (National Development and Reform Commission 2022) were calculated in this study, and the accounting indicators are listed in Table 1.

Bivariate correlation analysis was used to assess the degree of association between pairs of variables. According to the search results of the Web of Science (WOS), core set = "ecosystem service*" and "driving force*", the factors with the highest use frequency and no repetition were selected. Because of minimal spatial variation in climate factors such as precipitation and temperature in Miyun, these factors were not included in the analysis. Finally, the natural ecosystem area, built-up area, vegetation coverage, normalised difference vegetation Index (NDVI), slope, digital elevation model (dem), total population, and GDP were selected for the driving force analysis.

3. Results

In 2020, the potential GEP for Miyun County was 254.32 billion yuan. Among all kinds of ecosystem products, the water retention service contributed the highest (119.5 billion yuan), accounting for 47% of the potential GEP in Miyun County, followed by natural landscape (52.16 billion yuan). Wetland ecosystems were the main contributors to water retention services. The value of ecosystem products provided by wetlands was almost 4.5 times that provided by the other areas (per unit area) combined.

In 2020, the actual GEP in Miyun County was 53.28 billion yuan. Among all kinds of ecosystem products, the contribution of climate regulation service was the highest (17.46 billion yuan), accounting for 32.8% of the actual GEP in Miyun County, followed by water retention service (11.86 billion yuan). Forest ecosystems contributed the most to climate regulation. The value of ecosystem products contributed by wetlands per unit area was the highest at 96 yuan/m^2.

In 2020, among all types of ecosystems in Miyun County, wetlands contributed the highest potential GEP (141.92 billion yuan), followed by forests (61.19 billion yuan) and urban ecosystems (0.4 million yuan). Forests contributed the highest actual GEP (20.49 billion yuan), followed by wetlands (14.47 billion yuan).

The contribution of the urban ecosystem was the same as its contribution to potential GEP (0.4 billion yuan). Although the demand in urban ecosystems was theoretically high, owing to its low supply capacity, the ecosystem products provided by the urban ecosystem were utilised by residents and contributed to the actual GEP. The actual GEP accounted for approximately 21% of the potential GEP, indicating that the overall use intensity of ecosystem products in Miyun County remained low relative to the service supply capacity. The difference between the potential and actual GEPs shows the scope for vast exploitable space for water retention and natural landscape services in Miyun County and that the local government can further rationally promote local water resource utilisation and tourism development.

The spatial distribution patterns of potential GEP in Miyun exhibited apparent spatial heterogeneity. The potential GEP was high in the Northwestern region and the surrounding areas of the Miyun Reservoir, mainly distributed in PLT, SC, HWC, and MCY town. Areas with high values of ecosystem products were affected mainly by the Miyun Reservoir and Chaobai River systems, with rich vegetation, high water retention and climate regulation service values, and relatively complete ecological functions. Therefore, the supply potential was high. The potential GEP was low in the Southwest region, mainly distributed in KLC, KYC, and MYT town, and the low-value area is mainly distributed around the economic centre of Miyun County. Water and vegetation areas were small because of the extensive distribution of construction land. Therefore, the supply potential of ecosystem products was low.

The distribution pattern of the actual GEP in the Miyun area also exhibited obvious spatial heterogeneity. High actual GEP was primarily associated with the southwest region, such as KLC, KYC, and MYT town, with rapid economic and social development, high levels of regional economic development, dense populations, and high intensities of ecosystem product use. Areas with low actual GEP, such as HCT and PC towns, were mainly distributed in the Northeast. Owing to their low degree of development and utilisation, poor regional accessibility, and low population, the intensity of the use of ecosystem products was low.

The difference between the potential and actual GEPs in Miyun tended to be lower in the Southern region and higher in the Central and Northern regions, indicating some imbalance. From the perspective of spatial distribution, GEP surplus areas were mainly distributed in PLT and SC towns and other Northwestern regions. In the Southwest regions, including KLC, KYC, TY, and MYT towns, the regional economic development speed is fast, the construction land area is large, and the ecological resource utilisation intensity is high. Consequently, the potential supply of ecosystem products could not meet the needs of residents, as reflected in the GEP deficit. In addition, there is a trend of spatial expansion from the economic centre in the Southwest to the surrounding SLP, HNC, HTK towns, and other regions. The GEP surplus was high in the Northwestern region, with an excellent ecological environment and relatively low population density. The areas centred around the Miyun Reservoir, such as HWC, MCY, and TCT town, are close to the reservoir, rich in water resources and fishery products, and have strong climate regulation ability, which brings high tourism and cultural value. As a result, the potential GEP of the reservoir around the bank and the supply potential were high, differing substantially from the high-deficit areas outside the bank.

For natural ecosystems (forests, shrubs, grasslands, and wetlands), the potential GEP was positively correlated with the actual GEP ($R^2 = 0.61$). It follows that, within the scope of natural ecosystems in a region, the greater the supply intensity of ecosystem products, the higher the use intensity. However, due to human interference's intensity, farmlands, towns, and bare lands did not show apparent correlations. Correlation analysis of the driving factors with potential and actual GEP showed that the natural ecosystem area ($R^2 = 0.88$) and vegetation coverage ($R^2 = 0.73$) were the main driving factors affecting potential GEP in Miyun County. The GDP ($R^2 = 0.84$) and population ($R^2 = 0.82$) were the main driving factors affecting GEP in Miyun County.

4. Discussion

Taking Miyun County in Beijing as an example, ecosystem products' supply (potential GEP) and use (actual GEP) were calculated. The results show that in 2020, the potential GEP of Miyun County was 254.32 billion yuan, and the actual GEP was 53.28 billion yuan, approximately 21% of the potential GEP. Water retention services had a higher supply capacity among all the ecosystem products, whereas climate regulation services brought more welfare to human beings. Among all types of ecosystems, wetlands had the highest supply capacity for ecosystem products, which reflects the importance of wetland ecosystems in Miyun County, especially reservoirs, in the supply of ecosystem products. Therefore, when formulating policies, local governments should focus on strengthening the protection of the wetland ecological environment and maintaining its advantages. The actual GEP accounted for only 21% of the potential GEP, indicating that the overall intensity of the local use of ecosystem products is relatively low compared with the potential service supply. Therefore, local governments can consider further rational development and utilisation of ecological resources, promote local economic development under a sustainable model, and achieve a "win-win situation" between the social economy and the ecological environment. The potential GEP in the Miyun area positively correlated with the actual GEP concerning natural ecosystems, which means the greater the supply intensity of ecosystem products, the higher the use intensity. This correlation also suggested that the availability of ecological products was one of the factors promoting their use. Thus, increasing the supply of ecosystem goods through increased investment in protecting and maintaining ecosystems will directly benefit people. This finding was consistent with Aziz's study (Tariq Aziz, 2023).

The potential GEP depicts the background condition of the ecosystem, whereas the actual GEP reflects the human demand for ecosystem products. In previous assessments of ecosystem products, most did not distinguish between supply and use but only chose one for accounting (European Union 2020, Garcia-Llamas et al. 2018, McDonald 2009, van Jaarsveld et al. 2005). In our study, the supply and use of ecosystem products were distinguished and compared to fully understand the interdependence between the ecosystem and economic society in Miyun County. Simultaneously, value indicators were selected to compare potential and actual GEPs horizontally to understand the overall supply potential of ecosystem products and the relative situation of human use in the study area, providing a reference for decision-making.

This study has some limitations. From the perspective of ecosystem service flow, three components–supply, flow path, and demand–must be considered. Research on the framework of ecosystem products is still in its initial and conceptual stages, and the feedback mechanism between spatial attribute characteristics and location, such as the spatial flow path, flow, and degree of ecosystem product use, is still poorly understood. Although the total value of the supply and use of ecosystem products in Miyun County was calculated in this study, the spatial flow path of ecosystem products has not been determined. Therefore, we could not determine the flow direction of their supply and use and, thus, could not establish their spatial distribution or connection. Future studies could further explore the flow paths and ranges of ecosystem products between regions. Importance should be provided to applied research on ecosystem service flow, exploring the coupled relationship between ecosystems and human welfare, and promoting the continuous improvement of human welfare.

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6. Conflict of interest

The authors declare no conflict of interest.

7. References

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