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THE VIRTUOUS CIRCLE OF GEODIVERSITY: APPLICATION OF GEOSCIENCE KNOWLEDGE FOR SUSTAINABILITY IN THE FRAMEWORK OF THE INTERNATIONAL GEODIVERSITY DAY

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Abstract: Since geodiversity encompasses a broad spectrum of the earth's natural features and provides essential ecosystem services, it plays a critical role in environmental conservation, cultural heritage enhancement, and sustainable development of the territory. This paper presents possible geodiversity actions (use of digital knowledge, geosite inventory, sustainable geotourism, and legislative recognition) through global, regional, and local examples: a series of research and public engagement initiatives, including the themes of the International Geodiversity Day (IGD), a UNESCO celebration aimed at fostering public awareness of the contribution of abiotic nature to daily life and environmental stability. The paper uses a case study approach to present a virtuous circle of geodiversity model that shows how geodiversity can be used to improve environmental stewardship, sustainable resource use, and cultural identity. The interdependences of geological conservation, ecosystem services, and public education in meeting the sustainable development goals (SDGs) of the United Nations are stressed by this model. They underscore the importance of getting public and policy support from which geodiversity benefits can be sustained and suggest strategies for integrating geological diversity into conservation practice. Geodiversity is found to be a critical natural resource and a driver of sustainable development, thus serving communities, economies, and ecosystems.

Keywords: geodiversity, geosystem services, ecosystem services, Sustainable Development Goals, cultural geoheritage, UNESCO Global Geoparks

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Introduction

Geodiversity refers to the range of natural elements produced by Earth's geological processes, while biodiversity is the variety of life within an environment. After it was first recognised in the 1980s by the Tasmanian Forestry Commission (Houshold, Sharples 2008), geodiversity has evolved with definitions incorporating hydrology, landscapes, and scales. By 1992,

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both biotic and abiotic components of the ecosystems (dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit); United Nations (UN 1992) had been discussed in preparation for the Convention on Biodiversity at the Rio Earth Summit, but geodiversity gained prominence only later and was defined as a *variety of geological, geomorphological, and soil characteristics* (Sharples 1993, 1995). The Nordic geodiversity working group further emphasised its role in ecosystem support, advocating for its recognition by natural managers (Erikstad 2008). Over time, geodiversity has come to include the importance of landscapes and services provided to communities (Alexandrowicz, Alexandrowicz 1999, Sharples 2002, Kozłowski 2004, Zwoliński et al. 2018). According to the holistic view by Gray (2013), geodiversity encompasses the natural range (diversity) of rocks, minerals, fossils, soils, landforms, and hydrological features, alongside the processes shaping them. It also includes their assemblages, structures, systems, and contributions to landscapes. After this definition was internationally accepted at the beginning of the 21st century, the geodiversity concept grew in importance beyond the scientific world because of its strong relationship with cultural, environmental, and socio-economic issues. While Gray's (2013) definition of geodiversity has gained widespread recognition and is often cited as a comprehensive framework, earlier contributions, such as

Fig. 1. Examples of nature–human interactions within different geodiversity contexts of Italy. From top to down: the upper photos show different efforts for performing the viticultural activity in such geodiverse contexts: A – The Nebbiolo vineyards in the sedimentary context of Langhe Hills of central Piemonte; B – the Morgex vineyards at the foot of Mont Blanc in the framework of a metamorphic unit of the Western Alps; central photos show the similar metamorphic context of the SVUGGp in the Western Alps, with different landscapes due to the presence or absence of human activities: C – Extraction site at Montorfano quarry and D – wilderness area in Val Grande; the lower photos show the same environmental context of the Adriatic coastal area of northeastern Italy but with different human footprints: E – Venice lagoon vs F – Venice city. SVUGGp – Sesia Val Grande UNESCO Global Geopark.

Zwoliński (2004), which built on the framework established by the Australian Natural Heritage Charter of 2002, offer valuable perspectives on geodiversity's scope and relevance. It is essential to note that there are ongoing debates within the academic community regarding the precise definition, scope, and measurement of geodiversity. Some scholars argue which elements should be included under geodiversity, while others focus on the methodologies used to assess and quantify it (Németh et al. 2021, Stojilković, Gray 2024). These differing perspectives underscore the complexity of geodiversity as a concept and highlight the need for further research to reach a broader consensus.

Geodiversity is much more than a simple, static inventory of Earth's geological characteristics: it is a dynamic continuum that reflects millennia of geological processes and the history they tell humanity (Gray 2008). Moreover, in the last decade, Earth scientists demonstrated not only geological materials, landforms, and natural processes contribute to geodiversity but also human activities and culture (Ocelli Pinheiro et al. 2023). As shown in Figure 1, human–nature interactions within a particular geodiversity context create distinctive cultural landscapes.

Local human–nature interactions have been considered in the dynamic, comprehensive, and holistic view of geodiversity proposed within the UNESCO Global Geoparks territories (UNESCO 2015). The same view is yearly promoted globally thanks to the initiatives of the International Geodiversity Day (IGD), proclaimed by UNESCO at the 41st General Conference in 2021. Since 2022, on October 6th, an array of events has been locally organised worldwide to show the whole geodiversity values and the dynamic implications for the territory properly. Refer to Zwoliński et al. (2023) for a comprehensive discussion on the proclamation of IGD.

By communicating the most updated geoscience knowledge and human–nature interactions within a variety of geological environments, some initiatives of IGD provide adequate information on those processes making dynamic geological features, thus eventually causing geohazards and risks related to volcanic eruptions, landslides, glacial instabilities, etc. Some other IGD initiatives illustrate how geodiversity provides a variety of information on ecosystem services, including regulating, supporting, and provisioning services, and also cultural and knowledge ones, such as those offered by geoheritage. From this perspective, geological and geomorphological features with scientific values (Brilha 2016) can be attractive for tourist purposes, such as a glacier for its role in modelling the mountain landscape according to climate changes or a volcano for its eruptions, lavas, and related landforms.

On the eve of the Third International Geodiversity Day (2024), the Earth Sciences Department of the University of Torino, Italy (UniTO-DST), the Sesia Val Grande UNESCO Global Geopark (SVUGGp), and the Italian Glaciological Committee (CGI) jointly presented the results of the 'The Earth in your hands' initiative ('La Terra nelle tue Mani', in Italian language): a multiscale (global to local) effort for increasing public engagement on geodiversity, based on the presentation of good practices aimed at enhanced societal awareness of both georesources and geohazards related to dynamic geodiversity and of human activities impacting Earth system processes. The basic concept of this initiative is related to the fact that today, due to natural and anthropogenic factors, young and older generations have the Earth in their hands because of the substantial interactions between natural and human activities. Moreover, the widespread availability of geoscience digital data through personal electronic devices makes a larger audience capable of being informed on geodiversity contents, which is crucial for addressing informed decisions on sustainable development.

As shown in Figure 2, a coordinated series of public engagement activities has been included within 'The Earth in their hands' initiative. These allowed the presentation of targeted contents on the application of the geodiversity concept within selected UniTO-DST research and educational projects: H2020 ArcticHubs (Global drivers, local consequences: Tools for climate change adaptation and sustainable development for Arctic industrial and cultural hubs; CORDIS), ERASMUS+ project GEOclimHOME-PRO (Geoheritage and Climate Change for Highlighting the Professional Perspective), GeoDIVE (Full immersion on geodiversity, From rocks to stones, from landforms to landscapes; GeoDIVE), and PROGEO-Piemonte (PROactive management of GEOlogical heritage in the PIEMONTE region; ProGeo Piemonte).

Other than the single project's results, 'The Earth in your hands' initiative showed that a comprehensive research methodology is already available for enhanced use of the dynamic geodiversity concept within fragile environments such as the Alpine Region, deeply affected by climate change (Fig. 3): to map geodiversity for evidencing environmental change (at various time scales), to assess the drivers causing pressures and impacts on the state of the environment, and

Fig. 2. Selected activities being presented by the Earth Science Department of the University of Turin at the Third International Geodiversity Day: A – audiovisual recording, media interviews, and press releases; B – presentations to the general public and technical meetings with local stakeholders; C – field trips within geosites and geoparks; D – educational activities with schools (GeoDidaLab Ivrea, Italy), E – webpages activated for spreading digital geoscience knowledge on geodiversity (ProGeo Piemonte Turin, Italy).

to recognise human activities impacting Earth system processes.

Thanks to the participation in the IGD initiative, 'The Earth on your hand' suggested some possible steps towards the reinforcement of geosciences' fundamental role in promoting geodiversity within sustainable development policies. First, we must answer the research question: How can we raise public awareness of the variety of values and services geodiversity offers? To answer this research question, we first discuss targeted initiatives to analyse geodiversity components using precise geoscience digital data description and management. Second, we applied mapping and assessment of geodiversity within a geosystem service approach. Finally, we explored research methodologies and public engagement practices on geodiversity as possible contributions to enhancing natural and cultural heritage. The overall goal is to activate a virtuous circle of geodiversity, capable of boosting geoscience knowledge for achieving the legislative and regulatory recognition of geodiversity.

This article addresses critical aspects of geodiversity, including its role in sustainable development, public engagement strategies, and policy recommendations, through the lens of the virtuous circle of geodiversity. These themes are explored via case studies, conceptual frameworks, and practical applications.

Geodiversity data description: An ontology driven perspective

According to the approach by Gray (2013), the whole geodiversity can be divided into parts based on the related available geoscience knowledge. In addition to the identified geodiversity, which has been measured, coded, mapped, or inferred on Earth, there are two other categories: the conditional geodiversity, which is still being described, and undiscovered geodiversity, characterized by its hypothetical and speculative nature. The latter requires further exploration to gain knowledge and predict its potential locations. To identify geodiversity and facilitate data collection and spreading of knowledge, the UniTO-DST team performed a literature review on digital tools for enhanced geoscience knowledge and analysed regional data infrastructure on geodiversity in the Piemonte region.

The exploitation of digital tools is more and more rooted in the context of data management. The field of geodiversity is no exception to this trend, with more and more information managed

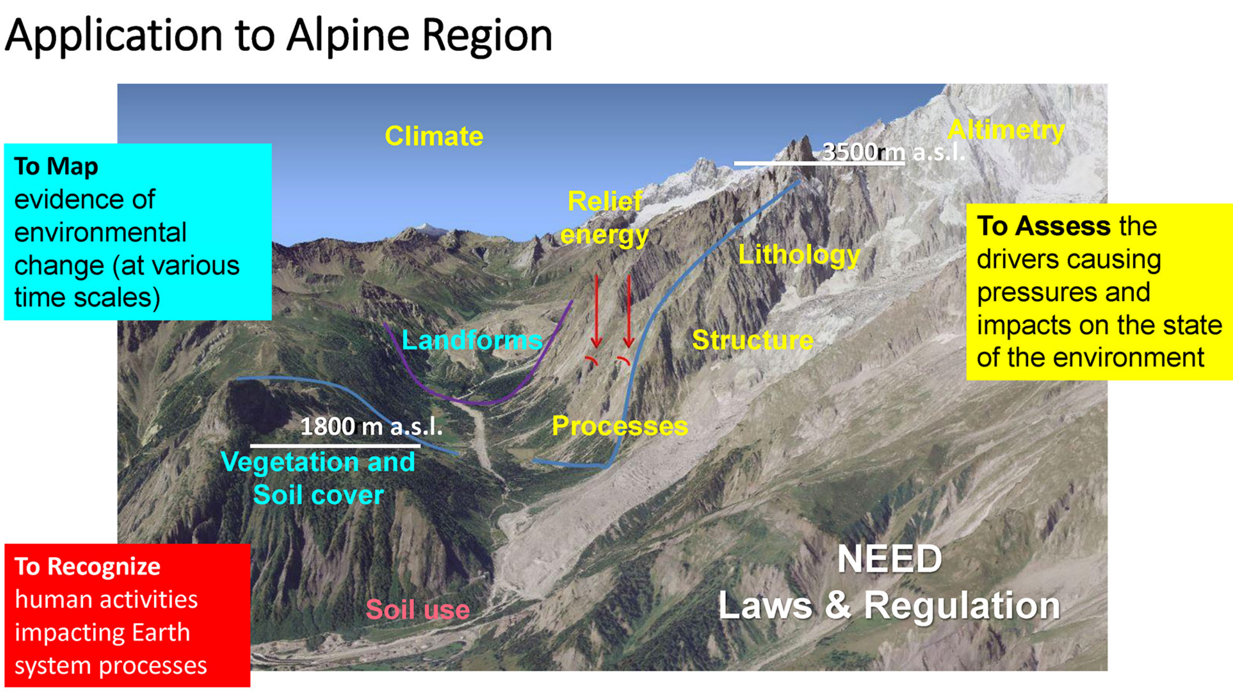

Fig. 3. Application of the dynamic geodiversity concept within the Alpine region for understanding environmental changes, human impacts, and the need for regulations.

in a digital format. This is a direct impact of using Geographic Information Systems (GIS) software to study, represent, and assess geodiversity. The digital management of the data should enhance its interoperability and information retrieval within and across informative systems. However, digital management is insufficient to ensure full communication among the data.

Recent approaches underline that the interoperability of the data is dependent on the harmonisation of the knowledge representation; in particular, the application of ontological and semantic studies could support a coherent representation of the data (Mantovani 2024). Previous studies reported that such a study model could also positively affect data representation within the geodiversity field (Zwoliński et al. 2018).

In geosciences, ontological and semantic approaches have been applied to provide a coherent representation of the knowledge domain. Some examples are the OntoGeonous Ontology (Lombardo et al. 2016, 2018), GeoCore Ontology (Garcia et al. 2020), and GeoScience Ontology (Brodaric, Richard 2021). Among these, OntoGeonous Ontology, based on the international standards of INSPIRE (INSPIRE TWG-GE 2023), GeoscienceML (GSML), and CGI vocabularies (CGI Data Model Working Group 2012), is modelled to satisfy the geological mapping data representation task. OntoGeonous is organised into four main classes: Geologic Unit, Geologic Structure, Geomorphologic Feature, and Geologic Event, all subclasses of the main class, named Geologic Feature. The Geologic Unit class represents the material part of the Earth; it represents the rocks that compose the Earth's crust, as represented in the geological maps. The Geologic structure class is the expression of the geometrical setting within the rocks, namely how the material is organised: for example, the foliation, the folds, and the faults. The Geomorphologic feature class is dedicated to classifying the landforms, i.e., the morphologies that model the Earth's surface. Finally, the Geologic Event class describes all the events that occurred in geological time and acted to create, destroy, or modify all the geological features. These concepts are inspired by the GSML standard (OGC 2017).

This ontologically designed structure has been applied to a cartographic project, namely the Geological Map of the Piemonte Region (GeoPiemonte Map 2021). Moreover, its knowledge model has been exploited to design an ontology-driven geodatabase to collect the data contained in the geological maps (Mantovani et al. 2020a, b).

As stated in the introductory part of this paper, the definition of geodiversity directly indicates the elements that contribute to geodiversity and that, consequently, are considered while assessing geodiversity. Recent works have attempted to model knowledge about geodiversity. For example, Hjort et al. (2024) proposed a taxonomy for the geodiversity elements, with four different hierarchies for the four main types of geodiversity elements (geology, geomorphology, hydrological features, and soil). In Mantovani (2024), differently, it was proposed an ontological approach for the description of the geodiversity by associating a class of OntoGeonous (or some classes from encoded international standards) to each geodiversity component:

- Geological (rocks, minerals, and fossils): Minerals and fossils are associated with the GSML standard, while the rocks (if considered as *in situ* formation and not *ex situ* samples) can be described with the Lithostratigraphic Unit class, a subclass of Geologic Unit identified by the lithology and the role in a stratigraphic section. *Ex situ* rocks, namely samples, can be identified through the Lithology vocabulary.
- Geomorphological (landforms, topography, and processes): The landforms can be described through the natural geomorphological feature, a subclass of geomorphologic features constrained by the relation with a natural process. In this part of the definition, also the processes are indicated: they can be described through the Geologic Event, features that are characterised by a precise age, environment, and process.
- Soils: Another subclass of the Geologic Unit is the Pedostratigraphic Unit, whose precise intent is the identification of pedologic horizons.
- The hydrological features are not encoded in OntoGeonous. However, they are treated in the Semantic Web for Earth and Environment Technology (SWEET) ontology; thus, they can be described following such organisation.

The final result can be represented in Figure 4; the geodiversity element class is the top class of a hierarchy that includes classes from different

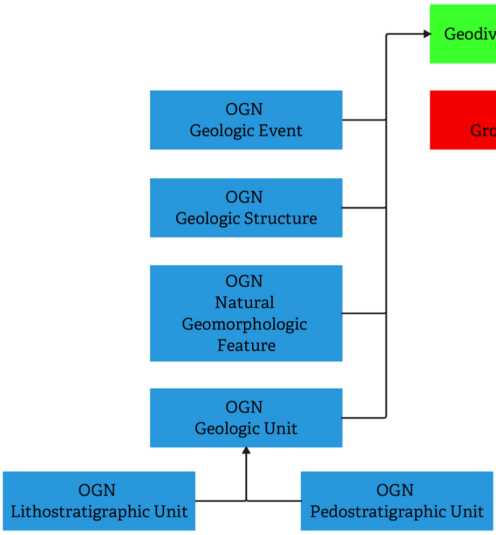

Fig. 4. A hierarchical representation of geodiversity elements: blue indicates classes from OGN, yellow from GSML, and red from SWEET. GSML – GeoScienceML; OGN – OntoGeonous.

ontologies. The impact of this representation is related to the harmonisation of knowledge. This knowledge is mutually integrated; hence, there cannot be incoherence in the knowledge representation. Since each class is identified by an axiom containing the necessary and sufficient conditions for an item to be included in a given class, each general element of geodiversity must possess some precise characteristics to be classified in a given way. For example, to describe a lithostratigraphic unit, it is mandatory to indicate the lithology (CGI 2020a) and its role within a stratigraphic section (CGI 2020b). The description of the geodiversity element based on such an organisation, which is inspired by the necessity of the geological mapping task, might be suitable to support the geodiversity assessment methods based on the mapping of geodiversity (e.g., the method applied by Najwer et al. 2016).

Mapping and assessment within a geosystem services approach

After being codified from an ontology-driven perspective, the knowledge of regional geodiversity should be updated and applied locally through further bibliographical research, field surveys, and laboratory activities. Mapping and assessment of geodiversity have been performed by the research team in Alagna Valsesia with the aim of inventorying geosites and enhancing geoheritage. These activities have been organised within the framework of the geosystem services approach to prepare for the favourable sustainable use of georesources.

Importance of geosystem services for geodiversity

Geosystem services are non-biological, Earth-based processes and elements, including soils, rocks, water, and topography, that underlie ecosystem functions, human well-being, and sustainable development (Gray 2004, 2013). The idea is similar to the concept of ecosystem services in that geodiversity is thought to support natural habitats, biodiversity, and human presence, extending the conservation programme to geological heritage beyond the biotic. Geosystem services support multiple dimensions of ecosystem services by regulating essential functions, provisioning materials, and providing cultural and scientific knowledge essential to society, and environmental management (Brauman et al. 2007, Frisk et al. 2022).

Acknowledging geosystem services acknowledges the centrality of maintaining geodiversity in the context of sustainable development. Similarly, the Millennium Ecosystem Assessment (2005) links ecological processes to human welfare. Nevertheless, such preservation of geosystem services is essential in the context of the Anthropocene, during which anthropogenic activities such as urbanisation, the activities linked to mining, and the activities associated

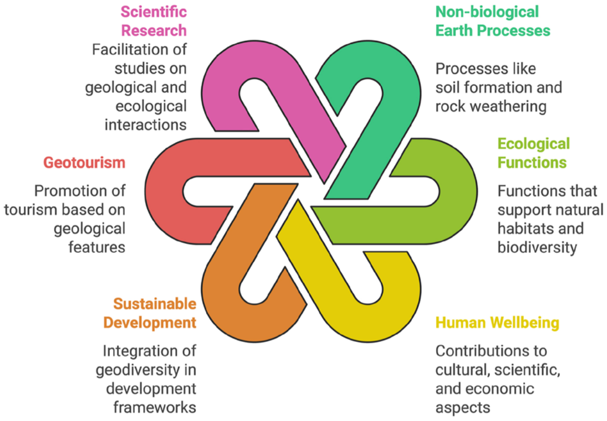

Fig. 5. The role of geosystem services.

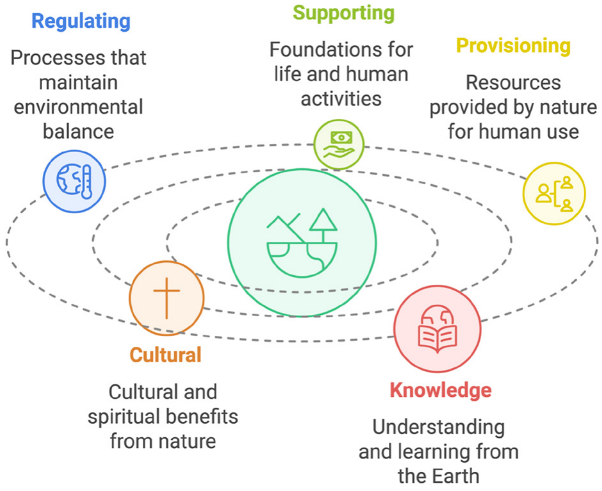

Fig. 6. Overview of the geosystem services.

with resource extractions have substantial effects on geosystem balance (Steffen et al. 2015, Silva et al. 2019). As illustrated in Figure 5, geosystem services serve geotourism, scientific research, and local economies to support biodiversity and ecosystem stability (Reynard et al. 2016, Tognetto et al. 2021). Starting from the geosystem services concept, various attempts at classification have been developed to define what is needed to be measured and communicated (Haines-Young, Potschin 2018). In recent years, two classifications have been the most accepted ones: (i) the classification provided by Gray (2011, 2013), maintaining the four categories proposed by the Millennium Ecosystem Assessment (regulation, support, provision, and cultural) with the addition of a fifth category (knowledge), to reach a total of 25 types of geosystem services and (ii) the Common International Classification of Ecosystem Services (CICES v5.1 led by Fabis Consulting Ltd.). In this version, it expands the abiotic section of ecosystem services and includes only three categories (provisioning, regulation and maintenance, and cultural) with 31 classes (Haines-Young, Potschin 2018).

Methods for mapping geosystem services

Geospatial mapping techniques are applied to geosystem services to assess and visualise geosystem services within frameworks of organised, effective, and represented geosystem functions and values. Within this mapping, geosystem services involve the classification of natural assets and their interactions with spatial analysis and GIS to quantify and spatially represent the contributions of geological resources to the geosystem (Gray 2004, Frisk et al. 2022). Figure 6 illustrates the method developed by Gray et al. (2013) and employed by Tognetto et al. (2021) for categorising geosystem services into groups, such as provisioning, regulating, supporting, cultural, and knowledge services.

The mapping process involves digitising datasets and overlaying geospatial layers to illustrate geosystem service distributions. For a detailed discussion of the geosystem service assessment methodology and results, refer to Khoso (2024). This taxonomy helps to systematically map these services to learn how their spatial distribution is coupled to social and geoecological roles in particular environments. As shown in Figure 7, the mapping process involves multiple stages:

1. **Data collection and classification:** The first stage involves collecting data from geological, geomorphological, pedological, topographical, climate records, and hydrological maps. Tools like GIS, which allow data to be brought together as geospatial layers, can integrate

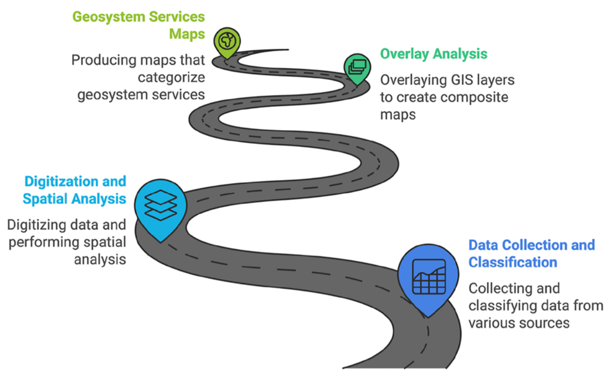

Fig. 7. Geosystem services mapping process.

these diverse data sources. An example would be translating geological maps, hydrographic networks, or sites into separate GIS layers (Khoso 2024).

2. **Digitisation and spatial analysis:** Geosystem services are produced from datasets digitised using GIS software and analysed to form spatial layers. Typically, these layers functionalise layers by using spatial units to indicate the presence and scope of each service, such as polygons for land cover and points for specific sites.
3. **Overlay analysis:** Various geosystem services are overlaid in GIS with multiple layers to incorporate a composite map showing their distribution. Through this mapping process, stakeholders and users can see where there are service concentrations, such as areas with high cultural significance or essential regulatory functions, which often cross over with conservation or tourism interests.
4. **Geosystem services maps:** The output includes the final map, which illustrates the spatial context of different service categories, such as regulatory and cultural. The map feeds back to stakeholders in the form of visual data to support policy and management decisions.

Example from Alagna Valsesia

An example is the Alagna Valsesia region, as shown in Figure 8, which demonstrates how geosystem services mapping can be applied through a structured approach combining several types of geosystem services (Khoso 2024).

Figure 9 shows a detailed GIS-based analysis that reveals several geosystem services that support the area's high geodiversity, a complex

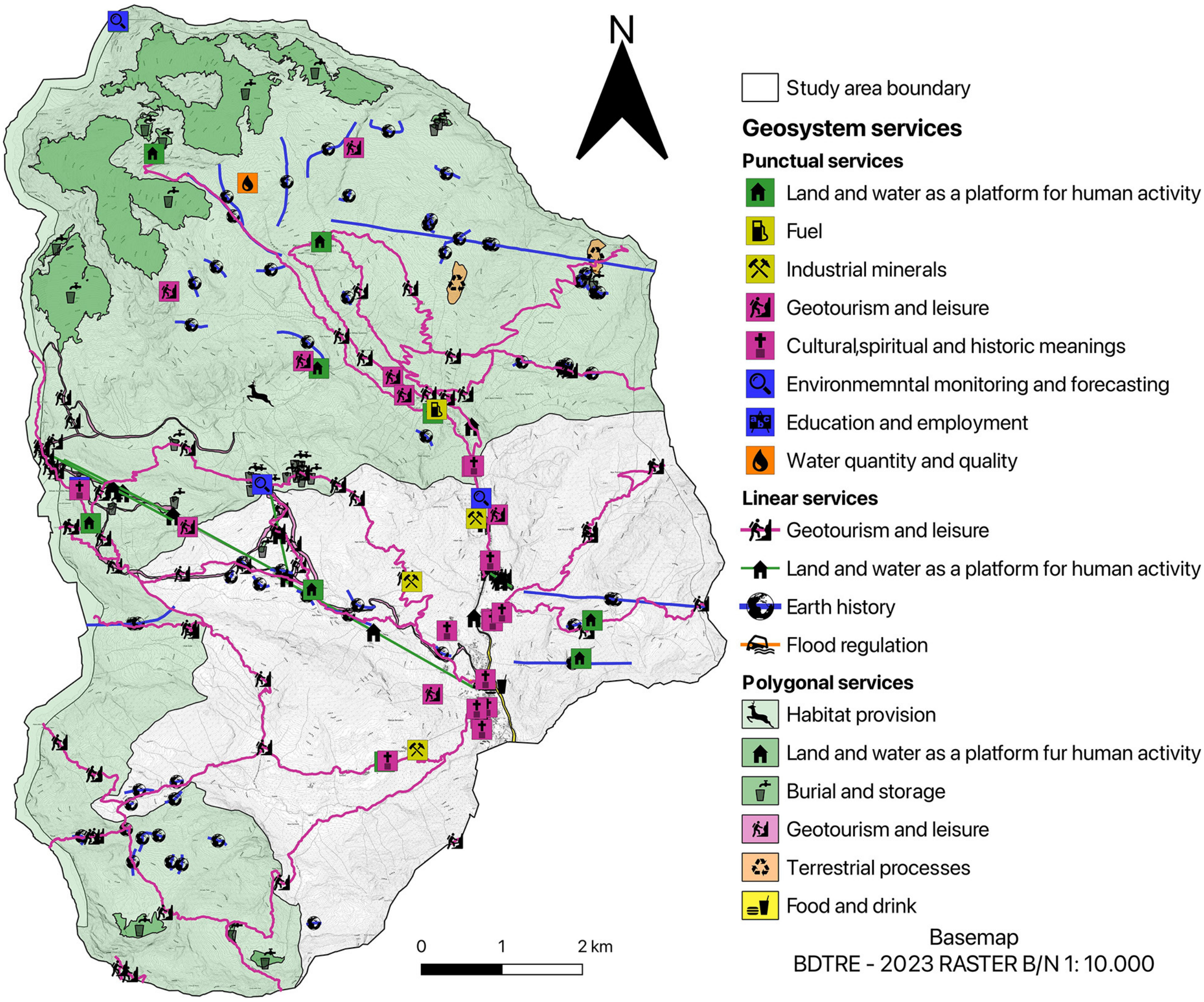

Fig. 8. Geosystem services map of Alagna Valsesia.

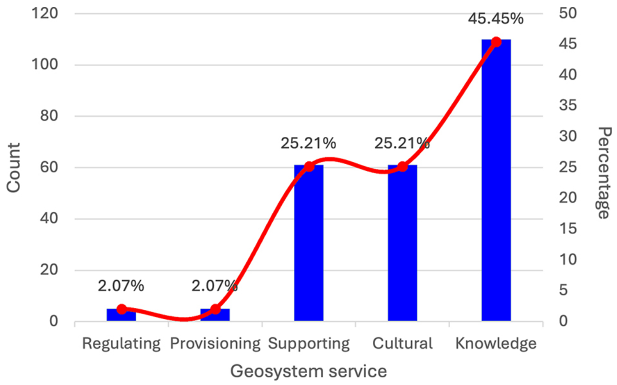

Fig. 9. Distribution of geosystem services in Alagna Valsesia.

amalgamation of geological formations and geomorphological features:

1. **Regulating services:** Geosystem services provided in Alagna Valsesia include water regulation, soil retention, and flood mitigation, but they represent a relatively small amount of the geosystem services. These services are critical to ecosystem balance, such as in valleys and water catchment areas naturally shaped by historical glacial and fluvial processes.
2. **Supporting services:** Around 25% of the area's geosystem services are supporting services. Without them, neither human activities nor ecosystem functions would be supported; they provide the foundation for both. This guarantee of local agriculture and local biodiversity is essential for the ecological integrity of the region because of the land's geological stability, which guarantees that the lands have minimal soil erosion.
3. **Provisioning services:** Although provisioning services are sparse, they provide tangible services such as freshwater and hydropower potential, which are crucial for local communities and industries.
4. **Cultural services:** They help the area serve as a recreational and spiritual value. Moreover, Alagna Valsesia's geomorphological features, rich in very diversified geosites, improve geotourism and educational components, constituting a typical cultural and economic pillar of local communities.
5. **Knowledge services:** Knowledge services comprise the most significant part of geosystem services in Alagna Valsesia and include scientific and educational benefits. However, geodiversity encompasses fields from climate change to geomorphology and provides rich research opportunities whose educative and scientific values cannot be denied by locals and visitors.

The mapping here categorises geosystem services in Alagna Valsesia to highlight their relevance across domains such as supporting ecosystem health, tourism, and education (Khoso 2024). Such services included in a spatial framework demonstrate the tangible benefits of geodiversity preservation and a need for targeted environmental and socio-economic resilience conservation policies.

Target solutions for promoting cultural geoheritage

Using geodiversity in the valorisation of geoheritage requires the consideration of the multiple dimensions (space and time) of geodiversity components; this allows us to evaluate their contribution to landscapes and assess their possible role in cultural heritage and geotourism. Therefore, to establish a proper application of geodiversity in enhancing sustainability within certain territories, it is necessary to introduce the concept of cultural heritage.

The cultural geoheritage concept

The concept of geoheritage cannot be divided from the notion of cultural heritage. The former presents a cultural component, with geological elements becoming geosites as a result of the socio-cultural interaction of scientists, administrations, tourism sectors, etc., for preserving and promoting such elements (Portal 2010, 2012, Reynard et al. 2011). Also, geomorphology has a vital cultural component, defined as cultural geomorphology by Panizza and Piacente (2003). Simultaneously, the cultural identity of a community can be influenced by the local geology, with natural stones strongly associated with cultural heritage (Tomás et al. 2021). Furthermore, landforms have served as migratory markers, rocks can be used as canvases for paintings, and minerals have affected the creation of historic mining towns (Andersen et al. 2015).

However, in the global framework, geoheritage is much less considered than cultural heritage, and the two concepts often do not intertwine. For instance, the UNESCO World Heritage List includes mostly ecological and cultural heritage sites. Still, it is essential to include geosites and geological heritage in conservation policies, including further attention from the administration at the international level (Boukhchim et al. 2018). However, cultural sites within UNESCO Global Geoparks (UGGps) are often not considered when managing UGGps themselves (Guerini et al. 2023), albeit the richness of these territories correlates with geological and cultural heritage.

If various elements of the local environment, such as natural elements, local economy, and education, are well balanced, cultural geoheritage can lead to the sustainable development of territories (Crofts et al. 2021) by promoting geotourism. To test the possibility of using local geodiversity elements to enhance the territorial values of geoheritage, the research group selected some specific areas where geoheritage is a relevant component of the cultural landscape. Here geodiversity has been mapped and assessed within its static and dynamic components to evaluate cultural georesources and possible threats to the geoheritage due to active natural processes and human activities. The overall goal is to propose sustainable geotourism activities offering proactive management of geoheritage.

The Chiusella Valley: A key study

In a context where outdoor activities are gaining increasing importance, small valleys within the Alps are the perfect places for developing cultural geoheritage events. Among all of these, there is the case of the Chiusella Valley, located in the North-West Italian Alps. The territory is a key area for the history of the alpine orogeny (Compagnoni et al. 1980). Human history is strictly connected to the geology setting of the area, especially the Traversella Pluton, with the renowned Traversella and Brosso Mining site, one of the most significant extraction points of iron minerals (magnetite and pyrite) in the Western Alps in the past centuries, leading to the development of a local community (Cima et al. 1984, Berattino 1988, Gallo 2007, Chiappino 2010).

Nowadays, the important geoheritage of the Chiusella Valley offers an excellent alternative to traditional mountain activities; it is possible to appreciate the astonishing environmental context

Fig. 10. Cultural geoheritage and educational activities in the Chiusella Valley: A – Some of the mineral collection of the Traversella mining site (source: Mauro Palomba); B – Torre Cives tower, on the top of Monti Pelati ridge (source: authors contribution; C – Canoe educational activity on the Morainic Area geosite – Lake Alice Superiore.

while experiencing a trip through the local geology and perceiving evidence of past and present climate change (Negri et al. 2024) through cultural and educational experiences (Fig. 10).

The cultural geoheritage of the Chiusella Valley is best represented by the Traversella Mining Site geosite (Costa et al. 2019). Visitors can explore the remains of historic mining buildings and, through guided tours, navigate the tunnels to learn about the site's mining history. Additionally, the Traversella Mining Museum showcases a collection of minerals and provides further insight into the area's rich heritage, as illustrated in Figure 10A. As shown in Figure 10B, other geosites have been identified within the Chiusella Valley: (i) Torre Cives and Monti Pelati, where the Torre Cives, an ancient tower erected in the XII century, is entirely built with local peridotite, a mantle rock that here outcrops originating the Monti Pelati relief (Rivalenti et al. 1981, Sinigoi et al. 1991, Mazzucchelli et al. 2010). This geosite is also recognised by the Regione Piemonte Geosites Inventory, developed after the approval of the Regional Law L.R. 23/23 (PRL 2023a, b); and (ii) Morainic Area, which includes a portion of the right moraine of the Ivrea Morainic Amphitheatre (Gianotti et al. 2008, 2015a, b); this site also contains two morainic lakes, one of which is a place of educational, environmental, and geological activities for schools as presented in Figure 10C.

The role of UNESCO Global Geoparks for geodiversity

UNESCO is actively promoting geodiversity through three main initiatives: International Geoscience Programme (IGCP) and the International Geoscience and Geoparks Programme (IGGP), which includes UGGp territories: UGGp are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development (UNESCO 2015). Geoparks actively promote sustainable local development, engaging local communities in activities linked to facing climate challenges; they became living laboratories for resilience to climate change and geo-hazards with a special focus on education toward potential natural disasters. With the establishment of the IGG Programme, education on geodiversity gained a recognised role through several initiatives, such as the establishment of IGD on 6 October 2021 by UNESCO.

GEOfood initiative overview

The GEOfood initiative was established in 2015 within the framework of UGGp located in various regions, led by Magma Geopark (Norway), Rokua UGGp in Finland, Odsherred UGGp in Denmark, and Reykjanes UGGp in Iceland. This initiative aims to enhance the visibility of these geoparks and foster greater public interest in geological heritage through local food offerings: by linking local cuisine with geological characteristics, the initiative seeks to promote awareness about the significance of abiotic services to local communities while supporting the achievement of Sustainable Development Goals (SDGs). The GEOfood initiative bases its quality criteria on community knowledge, where food and the connection with geological heritage play a crucial role (Thjømøe, Gentilini 2014). The initiative, now including 28 territories worldwide (status as of 2024) and represented by more than 120 companies, bridges gastronomy and geology, promoting sustainable practices while enriching cultural heritage through food. GEOfood has also been adopted as a best practice in several partner areas for the involvement of local communities (Norway, Finland, Croatia, Canada), attracting resources for local projects linked with its values and principles.

GEOfood and the United Nations' Sustainable Development Goals

In 2021, the International Geoscience Programme (IGCP) awarded the project as the best project proposal under the Sustainable Development topic. The cooperation with Naturtejo UGGP, Portugal, established the manifesto of values, including sustainability criteria for GEOfood companies, using references from the Food and Agriculture Organization (FAO 2018) and AGENDA 2030. The manifesto of values, now translated into 20 languages, includes information about the connection between the UGGp and the United Nations SDGs, with a specific focus on those related to food, climate change, and education, particularly with SDG nos. 2, 3, 4, 5, 8, 11, 12, 13, 14, and 17 (Gentilini et al. 2021).

The GEOfood contribution to SDGs target 2.3 is connected to the involvement of local small-scale producers, women cooperatives, empowering family farmers, and local enterprises towards innovative opportunities linked with non-farm activities such as food storytelling, tourism, and education. The empowerment of local farming relates to the supporting service Land as platform for human activity and provisioning service Food and drink, while innovative non-farm activities contribute to education and employment (Cultural Service). The GEOfood initiative contributes to target 2.4 by promoting traditional local agricultural practices aligned with natural cycles. These practices support various ecosystem services, including regulating processes such as terrestrial processes, flood control, and water quality regulation. They also enhance supporting services like land as a platform for human activities, provisioning services such as food and drink, and cultural services, including environmental quality and social development. Additionally, GEOfood addresses target 2.5 by valorizing wild species and encouraging the use of diverse seed types and genetic resources linked to traditional practices. This effort is connected to several ecosystem services, including habitat provision, food and drink, environmental quality, social development, and education and employment.

Public recognition of the whole virtuous circle of geodiversity

The concept of geodiversity has garnered significant attention among experts over the past decade, highlighting its ecological, cultural, and educational importance (Gordon, Barron 2013, Gray et al. 2013). Initiatives like IGD aim to increase overall knowledge of the importance of geodiversity in our daily lives, from the minerals in each smartphone to the extent of soil for agriculture. IGD significantly enhances the acknowledgement of the virtuous circle of geodiversity, highlighting four main circular steps with geodiversity as the primary driver (Giardino 2024). Being aware of the pivotal role of geodiversity in preserving biodiversity can help humankind face the biggest challenges for the future of our species. However, knowledge and recognition of geodiversity among the general public remain limited. People often perceive geodiversity as a distant and unfamiliar concept, a perception that hinders its wider societal recognition and appreciation (Ólafsdóttir, Tverijonaite 2022, Matthews et al. 2024). Addressing this disconnect requires more inclusive approaches that resonate with the general public.

Community participation through co-creation

Community engagement in geoscience through participatory research and co-creation of knowledge represents a promising path (Mauser et al. 2013, Lam et al. 2020, Wibeck et al. 2022). This approach promotes active community participation in research, helping them see geodiversity as a relevant and valuable part of their environment. In this way, we can gather local information, learn about their false beliefs/real knowledge, and understand missing information. Co-creation processes not only enhance the foresight of academics and the general public but also help non-academics prepare for future scenarios and help academics identify emerging research topics and challenges (Wibeck et al. 2022). Consequently, this approach in geoscience can enhance societal acceptance and appreciation of local geoheritage, thereby promoting sustainable management and conservation of local geodiversity (Henriques 2023). The concept of geodiversity can be shared more effectively by initiating a collaborative process of co-creating geoscientific knowledge with the local community and those who interact with the geosite at various levels. This approach makes it easier to evaluate the concept, provide targeted training, and carry out dissemination activities at the local and global levels.

One of the primary reasons for using co-creation methods is that as complexity and importance increase, it becomes crucial to involve an extended peer community from the outset of research projects to ensure practical and applicable outcomes (Nowotny et al. 2001). In this way, the co-creation approach to geodiversity, a complex and crucial topic that underpins ecosystems and influences biodiversity, can reduce the difficulty of communicating to the general public. Moreover, this approach of starting with people helps to understand the background of the audience, which is important before communicating anything. This way, we can learn who the audience is and their interests and needs.

Disseminating the knowledge and importance of geodiversity to the general public through the co-creation approach highlights the relevance of geoscientific knowledge for sustainability and helps communicate the importance of protecting and managing the geological heritage. In order to achieve wider recognition of the geodiversity concept and its protection, management, and valorisation, it is important to involve diverse communities in the co-creation process. This will make it possible to bring geodiversity into play for public acknowledgement of the virtuous circle and help recognise geodiversity at the administrative/legislative level.

Vernacular knowledge for enhanced geodiversity recognition

During the co-creation processes, vernacular knowledge (VK) has emerged as a valuable pathway for disseminating geoscientific concepts like geodiversity to a broader audience. In the existing literature, this type of knowledge is referred to by various names, including vernacular (Simpson et al. 2015), indigenous (Pásková 2018), or traditional (Todd et al. 2023) knowledge. However, it is a culture-dependent, community-based understanding of the environment, shaped by long-term observation and direct, lived experience in specific places, collectively forming a rational perception of reality (Ogawa 1995, Ellen, Harris 2000).

VK has deeply embedded indigenous cultures for centuries, each exhibiting its unique manifestations. Consequently, VK varies among distinct local communities, each with its traditions, customs, histories, and languages, and is influenced by the local and regional environment, which in turn is influenced by the communities. Despite this, all indigenous communities share a common worldview that all things in the natural environment have spiritual values, meaning, and deserve respect (Bauer 2007). As an example, within the Italian Western Alps, according to the Walser people (14th century colonists from Valais, Switzerland, who preserved ancient German language, culture, and architecture), natural elements of the landscape can hold a spiritual value; as testified by their oral traditions, Monte Rosa glaciers can host souls of dead men, or certain rocks were broken by the devil, or a northerly whispering wind represents the voice of dead persons. All these spiritual elements led the Walser people to perform respect to the environment (e.g. through public events, such as processions towards the Sesia Glaciers to give thanks for the compelling summer season spent in the mountain pastures and to remember, through prayer, the souls of deceased loved persons (Fig. 11) and to develop a sustainable approach to the local georesources (i.e. targeted use of lithological diversity within the Walser Architecture).

Practically, VK is conveyed through various forms such as language, artistic expression, dance, music, toponyms, remedies, architecture, environmental practices, stories, and more. This knowledge often spans multiple disciplines, including earth sciences, social sciences, architecture, and health, blending them into a unified, holistic framework typically passed down orally or through everyday activities (Hoagland 2017, Smythe, Peele 2021). This integrative nature underscores the holistic values embedded in VK, which makes it valuable to the virtuous cycle of geodiversity. UGGps, in particular, aim to promote geoscience and geodiversity by emphasising a holistic approach to land protection, conservation, and sustainable development. In this sense, VK can be an important resource.

While Western science often emphasises pure scientific methods and may struggle to integrate VK into its frameworks, VK can offer effective solutions to complex scientific challenges precisely because of its adaptability and deep local connections (Bocco, Winklerprins 2016). To realise the total value of both knowledge systems, it is essential to abandon hierarchical views prioritising Western science over VK and foster two-way communication with local communities instead. This approach supports the goals of UGGp, as VK can enhance geoscientific communication that more directly addresses local challenges, strengthens a sense of community belonging, and promotes sustainable land development (Pásková 2018).

Local communities have developed adaptation strategies based on their extensive knowledge of

Fig. 11. Since the 17th century, with the Rosario Fiorito procession to the Sesia Glacier, Monte Rosa (source: Alagna Valsesia Tourism Office).

the area, which has accumulated over centuries. Without presuming its inferiority, the utilisation and integration of this knowledge present two significant pathways for advancement:

1. The application of historical knowledge, which encompasses millennia of experience, enriches research by providing essential environmental and cultural context. This approach enhances geoscience communication and enables communities and visitors to fully appreciate the area's geological, historical, and cultural dimensions, thereby rediscovering the potential of indigenous storytelling in conservation practices (Fernández-Llamazares, Cabeza 2018).
2. The potential for valuable insights that can inform more effective land management solutions tailored to address specific challenges (Bocco, Winklerprins 2016).

Activation of the virtuous circle of geodiversity

Using the Piemonte Region (northwest part of Italy) as a learning case study, the abovementioned concepts and methodologies for geodiversity actions have been applied within a series of research and public engagement initiatives, thus introducing an innovative – conceptual and operational – circular approach to geodiversity, here proposed as the virtuous circle of geodiversity (Fig. 12), including:

1. the use of digital knowledge for assessing geodiversity, functional for
2. inventorying geosites and enhancing geoheritage, therefore allowing
3. growth of sustainable use of georesources and geosystem services
4. public recognition of the whole virtuous circle of geodiversity.

According to this methodological scheme, as illustrated in Figure 12, ontological studies and comparative analyses of scientific literature on the rich Piemonte geodiversity (1) lead to the identification of the most representative geothematic areas and related geosites (Ferrero et al. 2012, Lombardo et al. 2016), (2) including landforms, geological units, and processes of different ages and environments (Giordano et al. 2015, Rolfo et al. 2015). Creation of description and interpretation forms on scientific and additional values of geosites related to educational, cultural, aesthetic, and other interests allowed

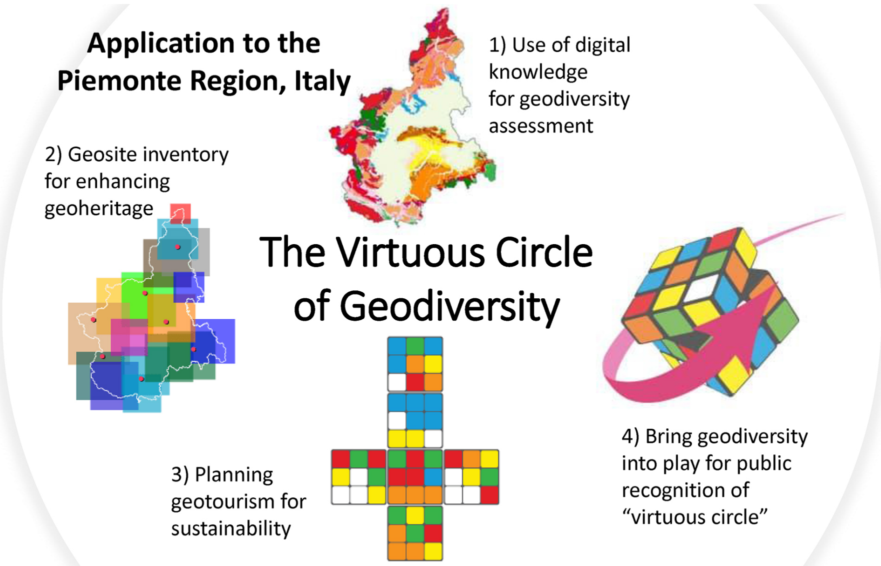

Fig. 12. The four steps of the virtuous circle of geodiversity.

comprehensive assessments of natural and cultural heritage; these are supporting promotion and management initiatives in the regional territory (Giardino et al. 2014). (3) To ensure a balance between the protection of nature and the need for local economic development, we propose a sustainable use of geosites of high scientific value for educational activities, geotourism itineraries, and cultural proposals, thus enhancing their local economic resources (Magagna et al. 2013, Lozar et al. 2015). The virtuous circle of geodiversity (4) can be strengthened by territorial policies that develop geoheritage assessment and, at the same time, promote sustainable use of the environment, particularly through environmentally friendly geotourism.

The Regional Law 23/2023 issued by the Piemonte Region government for the provisions for the conservation, management, and valorisation of the geological heritage recognises the public interest of geodiversity and geological heritage; it identifies elements of particular scientific, cultural, and landscape value within geosites and geoparks; it promotes the conservation, improvement of knowledge and management, and scientific, educational, cultural, and tourist valorisation of geosites in compliance with the principles and state and community provisions on the matter. The full text of the Piemonte Regional Law 23/2023 is available as Supplementary Material, providing a model for other regions and administrative units (Appendix no. 1: Piemonte Regional Law 23/2023). Thanks to this law, the territories of the Sesia Val Grande UNESCO Global Geopark (SVUGGp) (NW Alps, Italy) can also be better valued and protected. The Department of Earth Sciences of the University of Turin, together with various institutions of the Piemonte Regional government, including Arpa Piemonte (Environmental Protection Agency) and the Regional Museum of Natural Sciences, is grateful to the International Day initiative for having acted as a booster of the public recognition of the virtuous circle of geodiversity.

Besides the top-down approach of legislative directions, a useful tool for integrating the geodiversity and geoheritage concepts in the population is the Public Participatory GIS (PPGIS). PPGIS is a relatively new methodology with a bottom-up approach that engages the public and stakeholders in decision-making processes and territorial management plans, including local knowledge and contextualising various and complex spatial information (Sieber 2006, Dunn 2007). Specifically, PPGIS can be adapted to local territories, being context-specific. The most effective usage of PPGIS is the creation of online surveys, which are useful in collecting values, knowledge, and preferences of the general public because respondents can answer the questionnaires wherever they are and at any time (Jankowski et al. 2016, Kantola et al. 2023). The idea of using a PPGIS allows a better comprehension of the territory itself, including local population knowledge and perception of the geodiversity of the territory, with two goals: (a) using the information in the management plans and (b) understanding the lack in the knowledge of communities and trying to communicate with them about the potentiality of geodiversity and the geosites.

Alternatively, the mapping and assessment of geosystem services give essential insights for sustainable geodiversity management and reveal the necessity of spatially informed policies integrating geo-ecological and socio-economic benefits. The example of Alagna Valsesia illustrates how spatial analysis can help define the kinds and locations of geosystem services and, more generally, provide an understanding that guides policy and community mobilisation. By identifying the multi-functional roles of geosystem services, stakeholders can focus conservation efforts supporting these services that help maintain biodiversity, local economies, and preserve geological and cultural heritage in geodiversity-rich regions.

Finally, through co-creation and the inclusion of VK, geoscientists and local communities can work together to develop conservation and management strategies that are both scientifically sound and culturally resonant. This collaborative approach respects, incorporates, and fosters a shared commitment to sustainable practices. Such a collaborative approach is a tool for reinforcing the virtuous circle of geodiversity. In fact, by valuing both scientific and traditional perspectives, we can ensure that geodiversity remains a vibrant foundation for ecosystems, cultural identities, and future generations.

Conclusions

Geodiversity is important because of its multidimensional (geo-ecological, cultural, and educational) contribution. The research and public engagement actions presented for IGD within the 'Earth in your hands' initiative provide evidence of essential functions for geodiversity to go beyond Earth's inventory in physical characteristics and dynamic processes. The paper illustrates targeted initiatives to raise the public's awareness of the variety of values and services geodiversity gives to humanity. By stressing the importance of geodiversity protection, these initiatives point to geodiversity as necessary for maintaining ecosystem stability, supporting biodiversity, and promoting sustainable local development. At a global scale, the GEOfood initiative brings geological heritage into local economies through sustainable food production. Within this framework, several UGGps link food practices to geological features, engaging local communities and visitors alike to promote sustainable practices that support specific SDGs. At a local scale, the presented initiatives on cultural geoheritage and geotourism show that geodiversity is indeed something that can play an active role in sustainable tourism, community identity, and environmental resilience. Moreover, Regional Law 23/2023, the first legal document explicitly addressing geodiversity, sets a precedent for policy development. It includes provisions for the conservation, management, and valorisation of geological heritage.

As demonstrated by applying the virtuous circle of geodiversity approach, geological conservation, use of natural resources, and their preservation from cultural heritage are connected. Home for this approach is a model of public engagement and education in geodiversity's essential importance and a sense of stewardship in local to global communities. Geodiversity provides geosystem services, including regulating, provisioning, cultural, and knowledge services, which drive environmental stability and economic resilience.

Conclusively, geodiversity underpins geological, ecological, and human welfare and argues for the necessity and development of integrated and sustainable conservation and management options. Initiatives like IGD, the Earth on your hand showcase how geodiversity can be a component of a development strategy that creates sustainability in ways that also protect culture. This foundation can serve as a catalyst for future initiatives to enhance public awareness and legislative backing for geodiversity, ensuring its sustainable utilisation for future generations. Consecutively, examples provided in this study, such as the GEOfood initiative, geosystem services mapping in Alagna Valsesia, use of co-creation, VK for public engagement initiative through IGD, and the conceptual framework of the virtuous circle of geodiversity, collectively illustrate the multidimensional role of geodiversity in fostering sustainable development, public awareness, and environmental resilience.

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Author's contribution

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. The authors declare no conflict of interest.

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Appendix no. 1

Piemonte Regional Law 23/2023

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Art. 1
Purpose

1. The Region, within its competences and, in implementation of the art. 9 of the Constitution and art. 6 of Statute:
   a) recognizes the public interest in geodiversity and geological heritage;
   b) identifies particular elements in geosites and geoparks scientific, cultural and landscape value;
   c) promotes the conservation, improvement of knowledge and management, scientific, didactic, cultural and cultural enhancement tourism of geological sites in compliance with the principles and state and community provisions on the matter.

Art. 2
Definitions

1. For the purposes of this law, the following definitions shall apply:
   a) geodiversity: the variety recognizable in nature of geological, geomorphological and characteristic elements hydrological, mineralogical and paleontological;
   b) geological heritage: the set of places and singularity where testimonies of history are preserved and of the geological, geomorphological and pedological evolution;
   c) geosite: any site where it is possible to identify a geological interest of significant value for conservation;
   d) geopark: a territory with defined boundaries with a heritage particular geological and a sustainable development strategy.

Art. 3
Classification of geosites

1. For the purposes of this law and for the subsequent evaluation and enhancement, geosites are classified according to the following classes and types:
   a) scientific interests grouped by field:
      1) geographical-physical, geomorphological, karst, geopedological;
      2) mineralogical, petrographic;
      3) structural geology, geophysics, geochemistry, volcanology;
      4) geological, stratigraphic, sedimentological;
      5) paleontological;
      6) geological-environmental, hydrological, hydrogeological, glaciological;
      7) applied glaciology, geomining, geohistory, geological-economic and geotouristic;
   b) interests that are contextual and complementary to the scientific one define the context of the environmental or territorial relations of the geosite in the following areas:
      1) artistic, cultural, historical, archaeological, architectural and religious;

2) naturalistic, landscape, botanical and faunal;
3) educational and informative;
4) hiking and sports;
5) socioeconomic, touristic and food and wine.

Art. 4
Regional geosites inventory

1. Within twelve months of the entry into force of this law, the Regional Council establishes at the regional structure the regional land registry of geosites is competent, hereinafter referred to as land registry.
2. The land registry referred to in paragraph 1 is made up of the lists of geosites and an archive accessible and consultable online, integrated with the regional geographic infrastructure referred to in the regional law December 1, 2017, no. 21 (Regional infrastructure for information geographical) and divided into the following sections, in accordance with the national repertoire of geosites of the Higher Institute for environmental protection and research:
   a) location and classification, containing information on geographical-administrative location, size, type of geosite, bibliographic, cadastral, cartographic references and photographic;
   b) geodiversity, containing the information that characterizes the geosite, defining the type and scientific name of the elements described, the genetic process and age, taking into account the geological units, i.e. lithology, deformational structures, the geomorphological elements;
   c) scientific and contextual interests, associating each one geosite a degree of interest based on the number and quality of scientific publications;
   d) relations with the environment and the territory, detecting the any phenomena of instability that may produce danger and natural vulnerability, and the human activities that can generate impacts on the geosite;
   e) use of the geosite, containing the description of accessibility, visibility, state of conservation, any degradation factors;
   f) evaluation of the geosite, containing considerations qualitative-quantitative based on parameters useful for defining the integrity, rarity, representativeness of the geosite and the scientific, didactic, popular and aesthetic importance, ecological, historical-cultural, as well as to evaluate its accessibility'.
3. The Regional Council regulates the acquisition, updating, the methods of management and disclosure of the collected data. The information referred to in this article is collected in a manner systematically through specific cards.
4. The list resulting from the census provided for by the regional law October 21, 2010, n. 23 (Promotion and conservation of boulders erratics of high landscape, naturalistic and historical value) flows into the regional register of geosites referred to in paragraph 1.
5. The Regional Council, for the creation of the land registry referred to in paragraph 1, promotes forms of collaboration, through agreements, with universities, research institutes, regional agencies, instrumental bodies, territorial bodies, professional orders, companies and associations active in promoting the environmental geological heritage recognized at regional and national level and makes use of mainly of the documentary contents on the geosites present at the documentation center on geodiversity and geoconservation present at the regional museum of natural sciences.

Art. 5
Provisions for conservation and access to the geological heritage

1. The Region supports the conservation of the geological heritage also through initiatives promoted by the owners or managers of the assets and properties subject to conservative recovery.

2. Access to geosites and geoparks is free, except for rights of the owners of the land in which the sites are located, as well as any prohibitions or limitations provided for by more detailed provisions restrictive.

Art. 6

Provisions for the management of geosites and geoparks

1. The Region supports and sustains the management of geosites and geoparks, as well as the activity on the territory of the geoparks which obtain the recognition awarded by UNESCO.
2. The Region, in order to enhance the geological heritage of the Sesia - Val Grande geopark belonging to the Unesco world network Global Geopark, pursuing the quality requirements and parameters of functioning indicated by UNESCO, supports its activities conservation of the geological singularities present in its territory and education, training and research activities scientific and promotional activities related to the geopark, promoting specific agreements between the management body, local and research bodies and third sector associations.
3. For the purposes referred to in paragraph 2, it is provided for the year 2023 a one-off, non-repayable contribution equal to Euro 253,000.00 in favor of the management body of the Sesia - Val geopark Large, which is covered by the financial resources referred to in paragraph 1, letters a) and b), of art. 12.

Art. 7

Enhancement and promotion interventions of geosites and geoparks

1. The Region contributes to the valorisation and promotion of geosites and geoparks through:
   a) support for conservative recovery referred to in art. 5, therein including access paths;
   b) the installation of information tables on geodiversity, on characteristics of the geological heritage, on the value of geosites and geoparks;
   c) the planning and implementation of thematic itineraries for their geotouristic use;
   d) the creation of structures that facilitate accessibility, with particular attention to disabled people;
   e) the installation of signs concerning the rules and behaviours to be observed adopt for the respect and care of the geological heritage;
   f) specific training activities on geoparks;
   g) the educational valorization of geosites and geoparks.
2. For the purposes referred to in paragraph 1, the Regional Council, having heard the competent council committee, by 30 September each year, approves the annual program of interventions for the conservation, promotion and enhancement of the geological heritage.
3. The annual intervention programme contains:
   a) the objectives of the conservation, promotion and enhancement of the geological heritage;
   b) the specific initiatives to be financed and intended for protected area management bodies, territorial bodies, agencies regional, instrumental bodies, non-profit foundations and third sector associations that develop projects and pursue purposes in support of the geological heritage;
   c) the priorities of the interventions and the territorial areas;
   d) the financial plan of the budgeted funds.

Art. 8

Implementing rules

1. Within ninety days of the entry into force of this law, the Regional Council, having heard the council commission competent, adopts a regulation which governs, in particular:
   a) the criteria for the recognition and classification of geosites referred to in art. 3;

b) the methods of acquisition, updating, management and disclosure of data collected for the creation of the land registry in art. 4.

Art. 9
Monitoring

1. The Regional Council, two years after the entry into force of this law and subsequently every three years, submits a report to the competent council committee containing the main data and actions related to the application of the same, as well as the amount and recipients of the benefits provided.

Art. 10
State aid notification

1. The bodies established in application of this law which provide for the activation of actions that can be classified as State aid, except where such aid is granted in accordance with as provided for by the Community exemption regulations and/or in de minimis regime, are subject to notification pursuant to Articles 107 and 108 of the Treaty on the Functioning of the European Union.

Art. 11
Repeals

1. On the date of entry into force of this law, the following is repealed: regional law 21 October 2010, n. 23 (Enhancement and conservation of erratic boulders of high landscape value, naturalistic and historical).

Art. 12
Financial standard

1. In the first application phase, the charges arising from the implementation of this law, quantified in total Euro 538,000.00 for the years 2023, 2024 and 2025, of which Euro 268,000.00 in current expenditure and 270,000.00 euros in account expenditure capital, we face:
   a) for the year 2023 with an increase in resources equal to euros 40,000.00 allocated to mission 09 (Sustainable development and protection of the territory and the environment), programme 09.01 (Defence of the soil), title 1 (Current expenditure), with an increase in resources equal to €183,000.00 allocated for mission 09, program 09.02 (Environmental protection, enhancement and recovery), title 1 (Expenditure current) and contextual reduction of the sums referred to in mission 20 (Funds and provisions), program 20.03 (Other funds), title 1 (Current expenditure) of the 2023-2025 financial budget forecast;
   b) for the year 2023 with an increase in resources equal to euros 70,000.00 allocated for mission 09, program 09.02, Title 2 (Capital Expenditure) and the related reduction of amounts referred to in mission 20, programme 20.03, title 2 (Expenditure in capital account) of the 2023-2025 financial budget forecast;
   c) for the year 2024 with an increase in resources equal to euros 20,000.00 allocated for mission 09, program 09.01, Title 1 (Current expenditure), with an increase in resources equal to Euro 10,000.00 allocated for mission 09, program 09.02, Title 1 (Current expenditure) and consequent reduction of the sums referred to mission 20, program 20.03, title 1 (Current expenditure) of the financial budget forecast 2023-2025;
   d) for the year 2024 with an increase in resources equal to euros 100,000.00 allocated for mission 09, program 09.02, Title 2 (Capital Expenditure) and the related reduction of amounts referred to in mission 20, programme 20.03, title 2 (Expenditure in capital account) of the 2023-2025 financial budget forecast;

e) for the year 2025 with an increase in resources equal to euros 10,000.00 allocated for mission 09, program 09.01, Title 1 (Current expenditure), with an increase in resources equal to Euro 5,000.00 allocated for mission 09, program 09.02, Title 1 (Current expenditure) and consequent reduction of the sums referred to mission 20, program 20.03, title 1 (Current expenditure) of the financial budget forecast 2023-2025;

f) for the year 2025 with an increase in resources equal to euros 100,000.00 allocated for mission 09, program 09.02, Title 2 (Capital Expenditure) and the related reduction of amounts referred to in mission 20, programme 20.03, title 2 (Expenditure in capital account) of the 2023-2025 financial budget forecast.

2. For the financial years after 2025, the charges arising from the This law is addressed within the scope of spending authorizations annually established by the budget approval law, pursuant to the provisions of art. 38 of Legislative Decree 23 June 2011, n. 118 (Provisions on the harmonization of accounting systems and budget schemes of the Regions, local authorities and their bodies pursuant to Articles 1 and 2 of the law 5 May 2009, n. 42).