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The role of Ecosystem Services in the assessment of abiotic nature within two UNESCO Global Geoparks.

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"Le donne che hanno cambiato il mondo
non hanno mai avuto bisogno di mostrare nulla,
se non la loro intelligenza"

Rita Levi-Montalcini

"Carissimi tutti, penso di aver fatto la mia parte.
Cercate di fare anche voi la vostra per questo nostro difficile Paese."

Piero Angela

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Table of Contents

Abstract

Over the last 20 years, there has been an increasing interest in environmental issues − particularly those related to sustainable use of natural resources − and the solutions adopted are often linked to performing analyses of ecosystem services and finding indicators for biodiversity assessment. However, while the biotic aspect of nature has been deeply explored and discussed by the scientific community, the abiotic side has not received the same attention.

Only recently Geodiversity assessments have received scientific attention and specific ecosystem services have been discussed in connection with abiotic nature; however, a specific assessment regarding abiotic indicators hasn't been developed yet. Nevertheless, through their management strategies, UNESCO Global Geoparks can play a very important role in this matter: they raise awareness and understanding on geodiversity, they add value to geological heritage, thus representing potential strategies for holistic and sustainable development in rural areas through proper assessment and use of abiotic ecosystem services. At present the Geopark´s managers are not provided with specific classification methods which take into consideration abiotic nature and the services provided to the society.

This PhD research focuses on the detection of common data systematizations and on developing provisional indicators for abiotic nature in two UNESCO Global Geoparks: Magma Geopark in Norway and Sesia Val Grande in Italy.

The methodology applied to this research stems from the collection of desk and field data, which compares existing geosite classifications − with a focus on the method developed by the Department of Earth Science of the University of Torino − and the system for geosite assessment in use at the Geological Survey of Norway. Eight geosites have been selected following common characteristics and the final geosite classification schema has been tested and compiled as a first research product.

The geosite registration database provides a tool for geopark managers, supporting them in choosing, monitoring, and developing the geosite, before and after obtaining the designation within the UNESCO Global Geoparks initiative.

The second part of the research stems from the analysis of the scientific baseline of biotic and abiotic ecosystem services and their assessment. The methodology for the development of abiotic ecosystem indicators followed and adapted the Biodiversity Indicators Development Framework.

Four geosites were selected for this research phase: the analysis of the geological processes influencing different abiotic ecosystem services and their connection within the spatial dimension of the geosite and its buffer zone supported the development of variables and provisional indicators for abiotic nature.
Through the attribution of specific values and a common scale, the four geosites were assessed for all the 25 abiotic ecosystem services proposed by Gray (2013).

The outcomes of this PhD research thesis offer contributions to the effective recognition of the value of geodiversity within nature protection and sustainability and show the need for an abiotic ecosystem service assessment methodology for developing accurate management strategies in UNESCO Global Geoparks.

Furthermore, the achievements of this Phd would contribute to the development of both 726 IGCP project, " GEOfood for Sustainable Development in UNESCO Global Geoparks" and the project n. 731: "Geological Heritage Sites project" thanks to the analysis of the geosite classification and the connections between abiotic nature and human development.

Chapter 1 - Introduction

1.1 Foreword

In November 2015, the UNESCO General Assembly approved the new International Geoscience and Geoparks Programme (IGCP) to be implemented by the International Geoscience Programme (IGP) and the UNESCO Global Geoparks (UGGp); thus, the third and the only UNESCO Programme where sites and landscapes of international geological significance are managed with a bottom- up approach, holistic concept of protection, education and sustainable development, was established.

The IGCP consists of two pillars: the International Geoscience Programme and the UNESCO Global Geoparks network initiative. The first one is based on a "network of geoscientists focusing on the environmental resource extraction, natural hazard resilience and preparedness, and adaptability in the era of a changing climate". The second is based on the values of the UGGp seen as "laboratories for sustainable development by following a bottom-up approach that promotes the recognition and management of Earth heritage" (UNESCO, 2015). Since 2015, all territories which have successfully applied to the UNESCO Global Geopark have become members of the International Geoscience and Geoparks Programme.

The main missions of the UNESCO Global Geoparks (UGG) are the protection of geological heritage, the valorization of geodiversity, support to local communities and education on climate change and geo-hazard issues. To become a member of the UGG, a territory must demonstrate that its geological heritage has international value; but also needs to apply a bottom-up approach with local communities, working on educational programs providing a strong management structure and a solid budget.

The data requested on behalf UGGp for membership application is standardised; however, the methodology for the classification and description of the geosites depends on each country's classification and in several cases the knowledge/methodologies developed by those responsible for the application.
Furthermore, the IGCP Programme does not provide the applicants with tools for pre-assessing their abiotic heritage and eventually selecting the geosites which could be further valorised within their development plan after the UNESCO designation is obtained.

As a result, over the last 20 years, a variety of different criteria have been applied to the Geoparks territories for the classification of the geosites and their valorisation; It is also important to point out that the services provided by the geodiversity to the Geopark communities are not assessed at the time they apply to become a UNESCO Global Geopark. The lack of homogeneous data in the classification of geosites (Reynard, 2008) within Geoparks makes it difficult to compare geosite development within different UNESCO Global Geoparks, or to analyse and to compare different local strategies; moreover, the absence of abiotic factors assessments could lead to a lack of tailored and effective geoheritage management strategies.

The focus of this PhD research is the development of a methodology for assessing Geopark geosites and their abiotic ecosystem services, by assessing two UNESCO Global Geoparks: Magma in Norway and Sesia Val Grande in Italy. The research aims at contributing to the development of "abiotic service"-based strategies for the enhancement of geoheritage within UNESCO Global Geoparks, supporting them with a common preliminary tool for the Geopark geosite assessment.

1.2 Research questions, aims and objectives

The main aim of this doctoral thesis is to provide managers and policy makers with a preliminary tool for assessing Geopark geosites and their contribution to the abiotic services within UGG territories.

The PhD's main investigator has been supported by Rolv Dahl, Senior Adviser at the Geological Survey of Norway, Dr Tom Eldal, Dr Lars Eikstad, Pål Thjømøe, Magma UNESCO Global Geopark Manager, and Prof. Marco Giardino, Scientific Coordinator of Sesia Val Grande UNESCO Global Geopark.

The two main research questions and outcomes are the following:

1. How can the Geopark evaluators and the UNESCO Global Geoparks Council compare geosite classifications around the world, since different territories use a range of criteria for the assessment of international significance?

The actual procedure for a territory aiming at becoming a UNESCO Global Geopark consists in sending an application dossier, to be prepared by following the Statute Guidelines (UNESCO International Geoscience and Geopark Programme, 2015). The application includes supporting material to demonstrate that the area has already been functioning as a de facto Global Geopark for at least one year.

The aspiring UNESCO Global Geopark must have geological heritage of international value and be managed by a body having legal existence recognized under national legislation that has a comprehensive management plan, covering governance, development, communication, protection, infrastructure, finance, and partnership issues (UNESCO IGCP, 2015).

The entity responsible for the acceptance of new UNESCO Global Geoparks is the UNESCO Geoparks Council, which is the "*decision-making body for new UNESCO Global Geopark applications and revalidations and it is responsible for advising the Director-General on the strategy planning and implementation of the Global Geoparks activity of the IGGP. The Council is composed of 12 ordinary members, with the right to vote, who are individuals appointed by the Director-General of UNESCO on recommendation of GGN and Member States"* (UNESCO IGCP, 2015).

The adopted criteria by the UNESCO Geoparks Council to evaluate the geological international value of an aspiring UNESCO Global Geopark is based on the number of scientific peer-reviewed publications related to that specific area. This aspect is crucial for a successful application, together with the ones listed above which are all equally as important. However, it is easy to argue that territories having very important geological heritage are not necessarily objects of research or scientific studies. Conversely, it is also possible to prove that territories where extensive scientific research has taken place and where there is a strong management structure in place, where holistic approaches have applied and with specific sustainable bottom-up strategies have not been accredited UNESCO Global Geoparks status due to lack of scientific publication.

The Geopark concept is based on a holistic approach involving several interconnected disciplines and membership to the UNESCO Global Geoparks requires the ability to follow strict quality criteria; however, there are no common guidelines provided for geosite selection or assessment.

At the time of application, the UNESCO Global Geopark Council does not provide aspiring geoparks with any specific guidelines concerning the criteria needed for the selection of future Geopark geosites: the team of geoscientists in the aspiring Geopark has the responsibility for choosing geosites, the measures carried on are checked by re-evaluators every 4 years, together with other important issues. However, the lack of shared criteria for geosite selection could lead the aspiring Geoparks to select too many geosites: this could result in the impossibility of appropriately valorising and protecting these sites. The case could also be the selection of geosites having only or mostly "geological" interest, while neglecting the combination of other features in the interpretation such as culture or nature, with a consequent lack of holistic approach which is one of the requested criteria for becoming UGGp.

Furthermore, the absence of set guidelines for geosite selection and assessment makes it difficult to apply an objective comparison between different territories applying for the same Geopark status.

Consequently, the first PhD outcome is the suggestion of a preliminary database for the creation of a common framework for UNESCO Global Geoparks geosite classification (see 4.2.5); said database could support the development of a more holistic evaluation for the definition of the "international" significance of geosites and support the UNESCO Geoparks Council in comparing different territories.

2. How and to what extent could the abiotic ecosystem services contribute to the creation of a management tool for UNESCO Global Geoparks?

The UNESCO Global Geoparks are territories based on a bottom-up approach and the holistic interpretation of geological, cultural, and natural heritage; they are like open air laboratories for educational activities and community engagement. UNESCO Global Geoparks actively work on the valorisation of natural and cultural features, emphasising the connection with the geological heritage recognized as having international value. (Zouros 2004; Henriques & Brilha, 2017).

Ecosystem services and indicators for biodiversity have gained popularity since the adoption of the Millennium Ecosystem Assessment (Layke *et al.*, 2012); however, the abiotic ecosystem services linked with geodiversity are still lacking interpretation and specific indicators (Gray, 2021).

The assessment of both biotic and abiotic ecosystem services in a whole is not included as assessment criteria for becoming UGG member, and there are no example of Geopark strategy which taking them into account, except of the Northwest Highlands Geopark which is the only UNESCO Global Geoparks which considers Geodiversity and its related ecosystem services in the whole Geopark strategy(Scottish Natural Heritage, 2013).

Geodiversity, which characterises every UNESCO Global Geopark, is considered as one of the assessment criteria for becoming a UGG member, but it does not include assessment of biotic and abiotic nature.
The present thesis aims at proving that the assessment of abiotic ecosystem services could support UNESCO Global Geoparks and policy makers to set up specific plans for the development of the geosites, taking into consideration each single service and its peculiar advantages provided to the community. The assessment, if properly included into development plans, could lead for example to a better use of non-renewable resources, to a proper valorization to the best geosites for education, and to develop more effective policies against climate changes and resilience.

At present, there are no specific tested methodologies which could support Geoparks' understanding of the importance of abiotic ecosystem services in reaching the UN's 2030 Agenda Sustainable Development Goals (SDGs). As a response to the second research question, this PhD thesis aims at setting up a preliminary methodology for the assessment of 25 "abiotic ecosystem services" (Gray, 2013) within selected geosites of the UNESCO Global Geoparks.

This PhD research is based on the analysis of eight geosites selected in two UNESCO Global Geoparks (UGG): Magma UGG (south-west of Norway) and Sesia Val Grande (north-west of Italy). When applying to the UGG Network, the two Geoparks territories implemented different methodologies for geosite classification. As a result, the Geoparks also developed different geosite valorisation strategies.

After the data gathering stage, the research focused on establishing a common framework for geosite classification between Italy and Norway.

The comparison of different adopted solutions led to the first research outcome: the preliminary database which has been populated with information from the eight geosites selected. (Annex 1)

During the second stage of the research, the focus shifted to the analysis of "abiotic ecosystem services" (Gray M. et al., 2013) and during the final research phase, it was possible to finalise the second research outcome: provide provisional indicators to assess each of the 25 services within the 4 selected geosites. (Annex 6)

Lastly, through a detailed analysis in chapter, the hypothesis will be tested and validated; it is expected that the results could contribute to supporting the valorisation of geodiversity and its service to society.

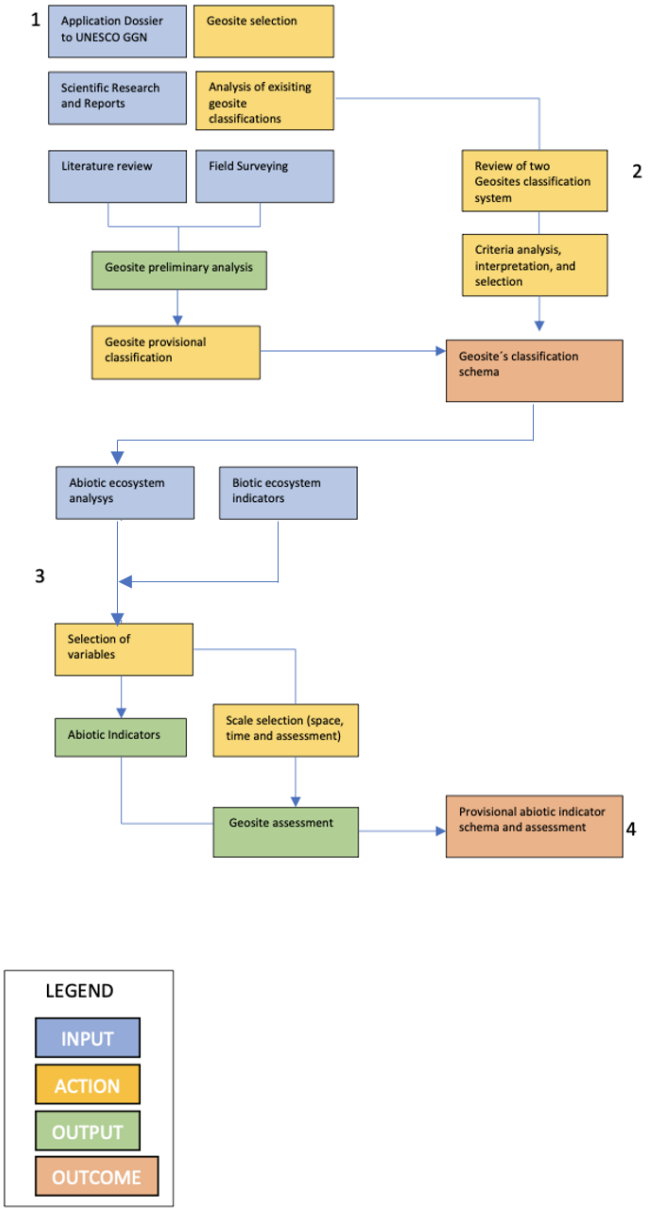

Table 1 – Workflow and organisation of the PhD Research, with the related operational phases. (Gentilini, 2022)

1.3 Outline

This thesis is organised into seven chapters:

Chapter 1 briefly introduces the research foreword, the aim of the study, the objectives and the outline.

Chapter 2 gives a brief overview of the basic definition of the terms geosite, geodiversity, and geoheritage. It provides a brief overview of the concept of Geoparks, the 'International Geosciences and Geoparks Programme' (IGGP), the general UGGp operational rule and the procedure to become a UNESCO Global Geopark territory.

Chapter 3 describes the two pilot areas and the applied geosite classification approaches.

Chapter 4 summarises the research framework. Starting from the baseline, the analysis of already developed geosite classification methodologies, this chapter provides a description of every single phase which brings to the geosite inventory schema development, as the first outcome of the research.

Chapter 5 describes the different existing abiotic and biotic ecosystem services classification and the process of adapting the indicators for biotic nature to abiotic natural resources, the selection of factors influencing each services and their final assessment methodology, as the second outcome of the research.

In **Chapter 6,** the GEOfood initiative and the IGCP- 726 Project are described as examples of applied actions for the valorisation of abiotic ecosystem services within UNESCO Global Geoparks.

Chapter 7 includes conclusions and final remarks.

Chapter 2 - The Background

2.1 Basic definitions

2.1.1 Geoheritage

The definition of Geoheritage varied throughout history, adapting to the different cultural values people give to nature: from a Romantic view of the physical landscape in the 18th and 19th centuries as an aesthetic experience, to a scientific view of nature in the latter half of the 20th century as a focus for study and conservation in protected areas; and more recently, to a recognition of the need for sustainable use of natural resources that combines both the aesthetic and the scientific viewpoints and provides benefits for people, and embodied now in geoconservation and geotourism activities like in the UNESCO Global Geoparks. (Gordon, Crofts, Díaz-Martínez, 2018).

In 2008, Brocx defined Geoheritage as *"the heritage value assigned to features of a geological nature encompasses globally, nationally, state-wide to regionally, and locally significant features of earth science that are intrinsically important or culturally important, offering information or insights into the evolution of the earth or into the history of earth science, or that can be used for research, teaching, or reference"* (Brocx, 2008).

One of the most comprehensive definitions of Geoheritage comes from José Brihla: "*Geoheritage, or geological heritage, is a term used to describe minerals, rocks, soils, fossils, and landforms having a significant value that justify their conservation and proper management. This includes the ongoing geological processes that produce these especially significant physical objects. Despite what can be an apparent appearance of robustness, such objects can be at risk, particularly due to human actions. Therefore, the conservation of geoheritage needs specific policies, both at the international and national levels, for their preservation and conservation*" (Brilha J., 2021).

According to the definition by José Brilha, Geoheritage represents a relevant part of natural heritage, and includes all elements resulting from geological processes, whether objects, features, landforms, or structures, important to any field of geology, such as: geomorphology, stratigraphy, tectonics, petrology, mineralogy, palaeontology, hydrogeology, etc. Each of them has its peculiarities, but all form part of geoheritage in its widest sense. Like any other type of heritage, Geoheritage has both an objective component (i.e., the elements that make it up) and a subjective component that can change (i.e., the value of the elements).

As mentioned above, the type of heritage is determined by the type of element. Thus, for example, a fossil with high value is palaeontological heritage, and a landform with high value is geomorphological heritage. Both are different types of geological elements and part of nature, so both are geoheritage and part of natural heritage (Carcavilla & Vegas, 2019).

This research focuses on geotourism and geoheritage, since Geoparks apply best practices in this field. However, abiotic ecosystem services embrace all types of geoheritage, which provide services to human communities. In 2015 the set-up of the IGCP International Geoscience and Geoparks Programme established global recognition for Geoheritage, giving visibility to its importance, conservation, and related management strategies.

2.1.2 Geodiversity

The term "geodiversity", first used by Federico Daus in 1940, defines geodiversity as: "*mosaics of landscapes and cultural diversities of geographical space and territorial complexities at different scales related to human habitats*" (Daus F., 1940). From its initial definition, the concept of: "geodiversity" has been part of the debate to define its clear and independent role in human society compared with "biodiversity", and their co-related impacts on human development.

The term "Geodiversity" refers to the spatial diversity of elements resulting from geological processes and events that have occurred during Earth's history, while biodiversity is defined as: "*the variety of plant and animal life in the world or in a particular habitat, a high level of which is usually considered to be important and desirable*" (https://www.lexico.com/definition/biodiversity) .

The concept of geodiversity first appeared in the 1980s, when it was associated with biodiversity by the Tasmanian Forestry Commission (Sharples, 2008) who drew parallels with biological concepts; from the beginning the 21st century, several definitions have been coined based on themes and areas, with inclusions of different factors such as hydrology, landscapes, seas, oceans, and scale factors.

Since 1992 − after its inclusion in the international agreement on the Convention on Biodiversity at the Earth Summit in Rio de Janeiro – geodiversity's most common definition in use within the scientific community has become: "Geodiversity as an expression of the variety of geological, geomorphological and soil characteristics". (Sharples, 1993, 1995).

Thanks to contributions from the Nordic Geodiversity Working Group, since the 2000s, the role of geodiversity within environmental studies has become more relevant. The group started to consider geodiversity as "*the support of ecosystems and biodiversity"*; furthermore, its importance started to be discussed in the scientific community as a group of important values, which "*must be taken into account by natural managers*" (Erikstad - *et al.*, 2019).

Alongside these developments, a broader conceptual vision of geodiversity has also developed; said vision includes several aspects linked with the importance of landscape interpretation for a better understanding of the services provided by geodiversity to the communities (Alexandrowicz, 1999; Kozlowsky, 2004; Serrano & Ruiz-Flaño, 2012; Sharples, 2002; Zwolinski, 2004), leading to the final agreement on the "variety of the abiotic nature" (Gray, 2004). One of the most comprehensive definitions comes from Kozlowski who define geodiversity as "*the natural variety of the Earth surface referring to the geological and geomorphological aspects, soils and surface waters, as well as to other systems created because of both natural processes and human activity*" (Kozlowsky, 2004).

Another important step towards the recognition of the role of "geodiversity" came from the Report of the Nordic Council of Ministers in 2001, where it strengthened the idea of geodiversity and its relevance for nature management, connecting the concept with landscape diversity, ecosystem, and biodiversity. In the mentioned Report, geodiversity was defined as*: "the expression of different geological environments and describes the variation of geological phenomena and processes in a* defined area" (Johansson, Alapassi 2001; Wimbledon & Smith-Meyer,2012).

Gray (2008) considers geodiversity to be the abiotic equivalent of biodiversity and describes the variety of geological, geomorphological, pedological and hydrological features and processes, giving a comprehensive overview of all services provided by nature to human development. His definition of geodiversity includes all the natural range of "*geological (rocks, minerals, fossils), geomorphological (landforms, topography, physical processes), soil, and hydrological features"*. but it also includes "*their assemblages, structures, systems and contributions to landscapes."*

This innovative approach underlines the benefits of geodiversity, which consists of providing many fundamental goods and services (geosystem services or abiotic ecosystem services) to society, on which human well-being and prosperity depends as a natural complement to biodiversity (Gray, 2018). However, at present there are no National or European Directives, international agreements, or conventions focusing on the exclusive value of Geodiversity, while scientists come to a clear acceptance of the connection between biodiversity and geodiversity "*in the context of the overriding framework for natural resources assessment and management through the Ecosystem Approach and ecosystem* (Crofts, 2014).

This research aims at encouraging the dialogue towards the better integration of "geodiversity" as an overall concept into the European and Global Geoparks Network, international legislation, and policies worldwide.

2.1.3 The Geosites

There is a long tradition in the name chosen by scientists to describe the site of direct physical representations of geoheritage (Wimbledon *et al*., 1995; Reynard *et al*., 2004, Fassoulas *et al*., 2012; Brilha, 2016 and reference therein). In a broad sense, a "geosite" is a site containing one or more distinctive elements of abiotic nature (such as a rock outcrop with distinctive lithological characteristics, minerals or fossils; a geological structure resulting from a tectonic event; a landform related to a geomorphic process; etc.) whose significance is primarily due to its scientific value, but it can also have educational, aesthetic, and cultural values. In this sense, geosites are considered as the expression of a heritage of geological content, i.e., geoheritage elements (Brilha, 2016).

In the literature, there are many definitions of geosite, from Wimbledon who define it as a *"structure such as a group of rocks, minerals or fossils, stratum, ground formation or geological structure resulting from an event during the creation or evolution of the earth's crust, that put a process or formation into existence, that has a need for scientific documentation and in some cases visual attraction qualities"* (Wimbledon, 1995); (Johansson *et al*., 1999), to Grandgirard (1999), who describes a geosite as a " *single or multiple formation, it is not possible to define a standard size nor a minimum or maximum size*".

More specifically, two schools of thought have evolved since the scientific community began to deal with geological heritage and, consequently, two main concepts for "geosites" have been developed:

1) The first one is more restrictive, and it considers geosites from a scientific perspective as: "geological objects that present a particular interest for the comprehension of the Earth, climate and life history" (Grandgirard, 1995).
2) Other authors developed a broader definition considering geosites as sites ("geotopes"), including four main components for their evaluation: a) scientific, b) aesthetic, c) cultural/historical and d) economic values (Panizza & Piacente 1993,2003).

Within the first definition, the evaluation of the geosite is based on its scientific quality (rarity, exemplarity for the Earth sciences, etc.), while following the second definition, the scientific interest concerns four types of values: scientific, aesthetic, cultural/historical, economic, and ecological. The use of one definition or the other depends on the operational context:

1) for conservation purposes, it is preferable to use a scientific approach,
2) for tourism or dissemination purposes, the second approach preferable.

Reynard (2009) subsequently recommended distinguishing the values of geosites into the central geological value (scientific) and the additional four values (ecological, aesthetic, cultural and economic). The geosite in fact can be used for further purposes not directly linked to their scientific values, like tourism or education (Pralong & Reynard, 2005). The several different concepts can be grouped into categories of restricted and broad definitions: this approach will apply to the present research (Reynard, 2009), (Reynard et al., 2012) (Reynard & Brilha, 2018).

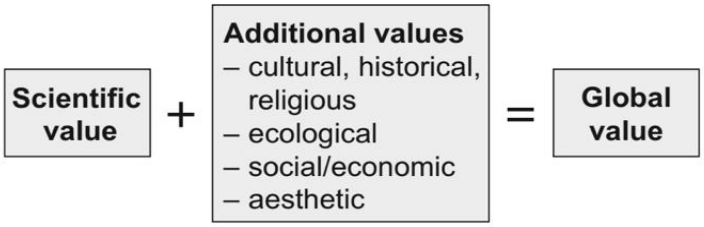

Figure 1 Central and additional values of geosites. (Reynard, 2009).

2.2 Geoconservation

The definition of "geoconservation" and geodiversity conservation has been developed as its own discipline over the years. (Sharples (2002), Prosser (2002a, b) Gray (2004), Prosser et al. (2006))

For a broad definition of "geoconservation" it is firstly necessary to distinguish between "conservation" in general which can be considered as the '*active management of something to ensure its quality is retained*' with no major changes required to the object , and conservation of geological items which very often can lead to some concrete actions more similar to preservation. Geoconservation can be defined as "*action taken with the intent of conserving and enhancing geological and geomorphological features, pro- cesses, sites and specimens*". (Burek & Prosser, 2008).

Following Sharples (2002) he defines geoconservation in protected areas as the practice of conserving, enhancing, and promoting awareness of geodiversity and geoheritage. Geoconservation is, therefore, concerned primarily with conservation of features and/or elements that have special geological or geomorphological value. Geoconservation can help to maintain biodiversity and the functioning of healthy ecosystems, as well as the conservation of geoheritage (Crofts, Gordon, Brilha, *et alia*, 2020).

History of geoconservation started in Europe during the Seventeen century in Germany, at the start of the twentieth century the geoconservation was connected with the geological heritage and modern specific legislation started to be developed (Erikstad, 2008).

It was only after the 1990s that geoconservation acquired global scale importance, especially after the First International Symposium for Geological Heritage Conservation (Digne-les-Bains, France, 1991) and the creation of the European Association for the Conservation of the Geological Heritage (ProGEO), in 1992 (Moura, Pamella & Garcia, Maria da Glória & Brilha, José & Amaral, Wagner,2017).

In fact, at present geoconservation is very important in the PROGEO Association and in the UNESCO Global Geoparks which became an UNESCO Programme in 2015, as well as in the World Heritage selected sites which are focusing on geological outstanding value.

2.2.1 Why conserve geosites?

Geosites are a part of the Earth's memory "book": they have been recording all the past events on Earth and preserving this information for future generations, there is a clear responsibility to be followed by scientists, policy makers, and managers.

If carried out with preliminary guidelines, man-related activities such as the opening and infilling of quarries, irresponsible specimen collecting, reprofiling or stabilising road and rail, river engineering works, or the construction of buildings could, in fact, lead to geosite degradation.

On the other hand, natural processes like weathering or vegetation encroachment may also result in geosite destruction, so these also need to be considered in setting up specific conservation plans.

In some cases, a geosite can be threatened by both anthropogenic and natural phenomena, occurring at the same time or during different phases.

One of the main threats is a general lack of knowledge about geoheritage and appropriate geosite management. Following Borba *et al.* (2013), geoconservation aims at the interaction between geoscientists with social issues such as environmental protection, sustainable development, education, and territorial planning.

Consequently, engaging key actors and increasing the awareness of geological heritage are essential to ensure proper nature conservation strategies, while preserving geosites is a duty in order to understand the future of our planet through its past and to be able to use these spaces as "open air laboratories" for training the new generation of scientists (Erikstad 2008, Carcavilla 2012, Henriques *et al.* 2011, Gray 2019).

For the detection of which geosites are worthy of protection and which are not, several parameters should be taken into consideration, depending on the context we are acting in and following the geoheritage definitions given in the paragraph above. For "scientific" purposes, so-called "scientific" parameters may apply, based on the knowledge and study of the Earth's evolution, while in case of the valorisation and cultural approach of the overall landscape, a broader definition is recommended (Panizza M. & Piacente S., 2003).

To facilitate the global comprehension of a geosite's overall natural complexity, its natural aspect should be considered in terms of both its biotic and abiotic features.

In Europe, the first public institution devoted specifically to geoconservation was created in Great Britain in the mid-twentieth century. In 1949, the conservation of geological and geomorphological features was included in the approval of the National Parks, and Access to the Countryside Act was the first step toward the establishment of the Nature Conservancy, the world's first statutory non-voluntary conservation body.

In 1966, it was incorporated into the newly created Natural Environment Research Council (NERC). The Nature Conservancy separated from the NERC in 1973 and became the UK Nature Conservancy Council. (Prosser, 2012)

The UK also played an important role in the establishment of the first methods aiming at the national-scale systematic inventory of geosites of scientific value, influencing European and International institutions during the 1970s. In 1977, the Nature Conservancy Council established the Geological Conservation Review, setting the background for the implementation of geosite conservation by means of a scientific-based methodology (Cleal *et al.*, 1999). The aim of this Review was to: "*assess systematically the scientific part of the geological heritage of Great Britain and to select for conservation those localities that exceed a minimum threshold in their national (British) value to Earth science*" (Ellis, 2008).

In Paris in 1972, the UNESCO "Convention Concerning the Protection of the World Cultural and Natural Heritage" was the first international effort to select sites of paramount world importance due to their natural characteristics. (Brilha,2016). Still, the selection and assessment of sites of geological nature that justify conservation and proper management was long to be established.

Sharples (1993), a pioneer of Australian geoconservation, reports that during the 1993-1994 period, the Forestry Commission of Tasmania prepared several reports with preliminary inventories of landforms in the state forests of Tasmania to facilitate "the conservation of Earth systems ('Geoconservation')":this is the first time that the terminology had been used.

Since 1992, till the present days ProGEO (The International Association for the Conservation of the Geological Heritage) has developed many initiatives concerning geoheritage, one of the first organisational aims of ProGEO, was the creation of an European inventory of geosites (ProGEO Wimbledon *et alia*, 1998).

In 1993, the first attempt for a common Global Indicative List of Geological Sites (GILGES) was established by the working group on Geological and Palaeobiological Sites as cooperative effort between UNESCO (Cowie, 1993, 1994; Dingwall, Weighell & Badman, 2005**)** and IUGS: the aim of the project was to define sites of international importance. GILGES supported the works of the UNESCO World Heritage Committee and was under the leadership of UNESCO, IGCP, IUGS and IUCN, the main outcome of the revision of criteria selection was the so-called "Trondheim " database (Díaz-Martínez,Brilha, Brocx,Erikstad, García-Cortés. & Wimbledon, 2016).

The Global Geosites Working Group (GGWG) of IUGS, in 1995 started the development of a database of global geological sites (IUGS GEOSITES) establishing a global principle for a common methodology focusing on enumerating thousands of sites in order not to be forgotten or overlooked (Wimbledon, 1996). The project was supported by UNESCO, ProGeo, IUCN and since then it contributed to enhance site conservation and geoscience awareness. It also supported Countries to "*identifying the corresponding geological frameworks and geosites of international relevance".* Due to lack of common objectives and scarcity of funds the project was abandoned.

In 2003, IUGS created the GOSEE initiative, to set the strategic position of IUGS to coordinate and to insert geoscientist knowledge into geoscience education, culture, communication and sustainable development. (IUGS, 2006), the initiative was considered over-ambitious and in 2006 at the IUGN EC Meeting in Punta Arenas, the initiative was closed.

Geoconservation practices linked with geological heritage have increased during the last 20 years, even though some countries have more developed policies, while others have only recently developed protection measures. However, it is worth mentioning that, from the Rio Earth Summit (United Nation, 1993) to the decisions taken by the United Nation in 2015 with the 2030 Agenda (United Nations, 2015), the terms 'geoheritage', 'geodiversity' or 'geoconservation' have been never used, while reference to geology is limited to three pages within the official statements.

In fact, during the last decade, the scientific community has carried out several studies and initiatives around geoheritage and geoconservation-related activities: all theories are based on the protection of geosites as a foundation for geoconservation, as "nature conservation". Preserving geosites enable humankind to understand the evolution of Earth, the processes that shape our landscapes and environment today, and the location of natural resources; this is and will be crucial for human development. (Gray, *et al*., 2013).

Following the need for a broader approach to geoconservation and geodiversity and their contributions to a range of ecosystem services, a broader concept for geodiversity is emerging. This recognizes the links between geodiversity and several services provided by abiotic nature to humanity, such as different landscapes and biodiversity, economic development, climate change adaptation, management of land and water, historical and cultural heritage, people's health, and well-being, geotourism, etc. (Prosser *et al*., 2013).

In 2014, the International Union for the Conservation of Nature (IUCN) and UNESCO gave importance to the concepts of geoheritage and geodiversity, which have become strategically relevant, after decades of focus on the protection of biological heritage. IUCN in 2015, recognised the importance of geological features as integral parts of nature at the same level as biological elements within the establishment of a Geoheritage Specialist Group within the World Commission on Protected Areas (WCPA).

In 2016, the International Union of Geological Science (IUGS) reactivated the GILGES project described above, important geoheritage initiative, as an evolution of the former Global Indicative List of Geological Sites (GILGES), associated to the Global Database of Geological Sites of IUGS, aimed at a systematic selection of geosites based on specific geological frameworks, enabling their comparison on several scales (Cleal C. J. et al., 1999).

In 2020 the IGCP financed the IUGS Geological Heritage sites (with the project number 731) led by Dr. Asier Hilario Orús from Spain with scientists from Brazil, Colombia, Greece. The project aims to open a new opportunity for the global recognition of Geological Sites of International Significance (IUGS Global Geosites) bringing together the experience and knowledge of different actors like geological surveys, UGGp and scientific organisations. The project is expected to increase the international cooperation between scientific organisations, geological surveys and UNESCO Global Geoparks towards a common goal: a world inventory of geological sites of international significance (IUGS Global Geosites); define procedure and protocol for IUGS recognition, to implement the new methodology in case study sites in several UGGp and protected areas around the World; sustainability plan for the overall Geosites database.
At today, after several months of discussion the main standards have been defined and participants are already working on the selection of "The First 100 IUGS Global Geosites" (UNESCO 2021).

2.3 Conservation and management in practice: the International Geoscience and Geoparks Programme- IGGP

In 1997, in response to the 'Declaration of the Rights of the Memory of the Earth' (signed on June 13th, 1991, by 150 scientists at the First International Symposium on the Conservation of Geological Heritage, Digne Les Bains, France) the Division of Earth Sciences of UNESCO introduced the concept of a UNESCO Geoparks Programme to support national and international endeavours in Earth heritage conservation (Martini 1993, Patzak & Eder 1998).

The Geoparks initiative started in 2000 when four territories in four European countries (France, Germany, Greece, and Spain) shared the idea that sustainable territorial development could emerge from the protection and enhancement of geological heritage: they established the European Geoparks Network with the main aim to

protect the geological heritage and the promotion of sustainable development (Martini & Zouros 2001,2003; Mc Keever & Zouros (2005).

In 2004, the European geoscience community adopted the European Manifesto on Earth Heritage and Geodiversity and laid down that Europe's natural heritage is an essential part of Earth heritage, including landscapes, landforms, rocks, sediments, soils, minerals, fossils, and waters. The document says that the EU should incorporate Earth Heritage and Geodiversity in policy, planning and related procedures (Rec (2004)3).

In February 2004, the UNESCO international group of experts discussed the establishment of a Global Network of Geoparks following the Operational Guidelines for application on the global Network. The "First International Conference on Geoparks" was also held in Beijing, China from 27 to 29 June 2004, to promote the establishment of a worldwide network of national Geoparks with contributions from the international governmental and non-governmental community (Zouros, 2004).

In 2015, to achieve better cooperation between Geoparks and to strengthen their capacity, UNESCO's General Conference merged the existing International Geoscience Programme and the Global Geoparks Network initiative into the International Geoscience and Geoparks Programme (IGGP) and established the UNESCO Global Geoparks (Fig. 2).

The IGGP, directly related to the International Geoscience Programme (IGCP), was established in 1972 to bring together scientists focused on resource extraction, natural hazards, and adaptability to climate change, and strengthening international cooperation while supporting projects, meetings, and joined research.

According to the original definition, *UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed within a holistic concept of protection, education, and sustainable development. Their bottom-up approach of combining conservation with sustainable development while involving local communities is becoming increasingly popular*. (UNESCO, 2015).

Within this PhD, the UNESCO Global Geoparks have been considered as "*laboratories for sustainable development which promote the recognition and management of Earth heritage, and the sustainability of local communities*" (see Chapter 2.2.3).

The two initiatives − International Geoscience Programme and the Global Geoparks − shared the UNESCO Secretariat and joint coordination meetings of their respective bureaus, which were convened as necessary. The chairpersons of the two respective Councils co-chair the IGGP. (https://en.unesco.org/international-geoscience-and-geoparks-programme)

"This new International Geoscience and Geoparks Programme (IGGP) with its two pillars, focusses on UNESCO's contribution to implementation of the 2030 Agenda for Sustainable Development and the Paris Agreement on Climate Change, and the pursuit of its two global priorities -Africa and gender equality, applied to Earth sciences since UNESCO is the only United Nations organisation with a mandate to support research and capacity building in Earth sciences" (UNESCO, 2016).

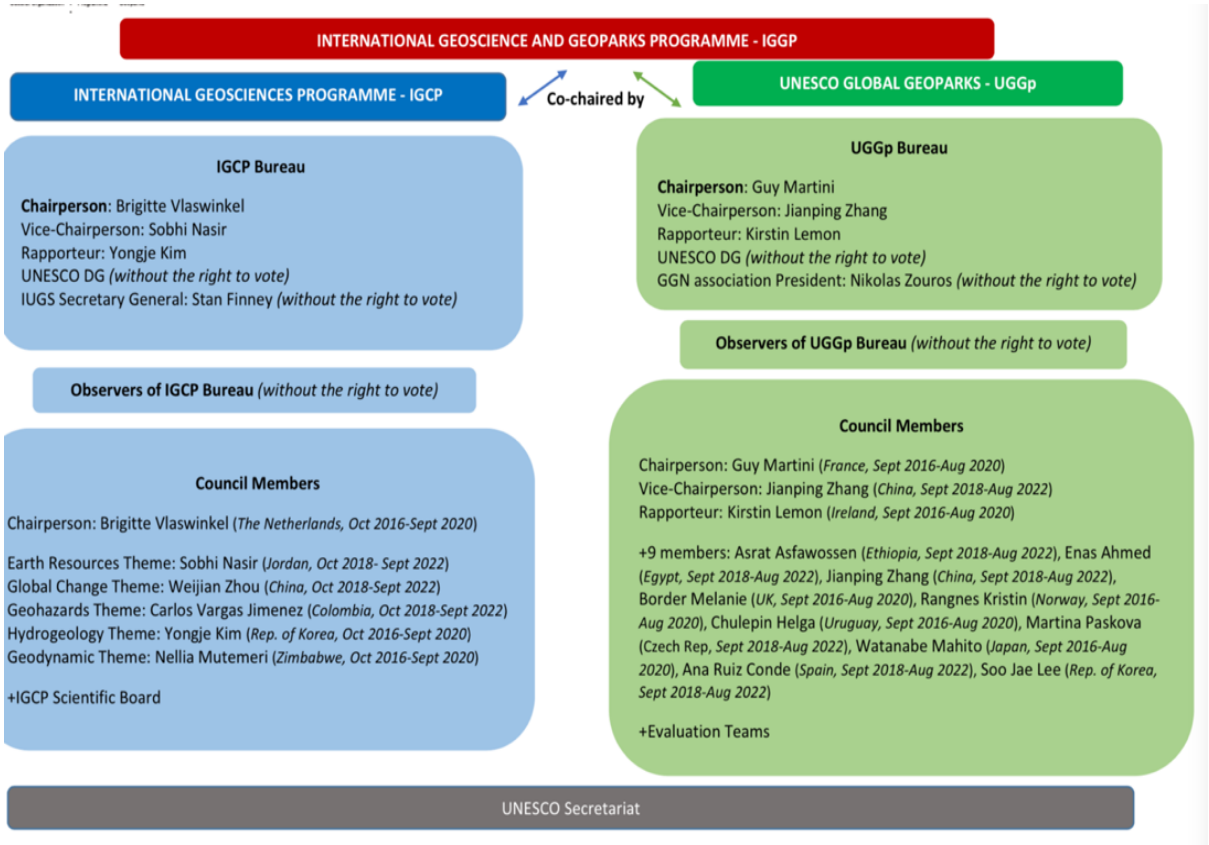

Figure 2 -UNESCO (2019) International Geoscience and Geoparks Programme structure [online]. Available at: https://en.unesco.org/international-geoscience-and-geoparks-programme.

The International Geoscience and Geoparks Programme is the third official UNESCO Programme, together with the World Heritage Sites Programme focusing on the protection of cultural and natural sites of outstanding international values, (https://whc.unesco.org/en/list/) and the Man and Biosphere Reserve Programme (https://en.unesco.org/mab) focusing on biodiversity and human development.

2.3.1 The UNESCO Global Geoparks

On 17 November 2015, the 193 Member States of UNESCO ratified the creation of a new label, the UNESCO Global Geoparks. This expresses governmental recognition of the importance of managing outstanding geological sites and landscapes in a holistic manner.

The Global Geoparks are laboratories for sustainable development which promote the recognition and management of Earth heritage, and the sustainability of local communities. Their bottom-up approach of combining conservation with sustainable development while involving local communities is becoming increasingly popular. As of November 2021, there are 169 UNESCO Global Geoparks within 44 Member States. (https://en.unesco.org/international-geoscience-and-geoparks-programme)

The UNESCO Global Geoparks Council is responsible for assessing revalidated and new UNESCO Global Geopark nominations and it performs a key role for the Director-General of UNESCO in advising on the strategy, planning, and implementation of UNESCO Global Geoparks.

The UNESCO Global Geoparks Council is composed of 12 ordinary members with the right to vote, who shall be individuals appointed by the Director-General of UNESCO on recommendation of the Global Geoparks Network (GGN) and of Member States (Fig.3), and four members without the right to vote: the UNESCO Director General, GGN President and one representative from the International Union of Geological Science (IUGS), and

one from International Union for Conservation of Nature (IUCN) (Fig.2). Council members need to fulfil specific selection criteria. (https://en.unesco.org/global-geoparks/council)

2.3.2 The Global Geoparks Network Association

The UNESCO Global Geoparks territories are also member of the Global Geoparks Network which was initially founded in 2004; in 2015 the Network established the Global Geoparks Association developed as interlocutor with UNESCO to develop models of best practices and set quality standards for territories that integrate the protection preservation of Earth heritage sites in a strategy for regional sustainable economic development (Zouros, 2017).

After the official recognition of the International Geoscience and Geoparks Programme, in 2015 the Global Geopark Network Association became officially partner of UNESCO for the operation of the UNESCO Global Geoparks promoting the brand UNESCO Global Geopark as a label of excellence for areas that validate, protect, and promote their Earth Heritage and other related natural and cultural heritage as a tool for sustainable local development. (https://en.unesco.org/global-geoparks)

The Global Geoparks Networking Association acts as a networking initiative, sharing good practices and common values, it includes five Regional Networks worldwide:

- European Geoparks Network
- Asian Pacific Geoparks Network
- Canadian Geoparks Network
- African Geoparks Network
- Latin America and Caribbean Geoparks Network

The Global Geopark Association is in charge of developing strategic guidelines including actions and goals for the overall Global Geopark Network (GGN). According to the GGN directives (Global Geoparks Association, 2021), the goals for 2022-2023 are:

1) Continuous networking and communication between all UNESCO Global Geoparks and effective operation of the Global Geoparks Network and its Regional Geoparks Networks.
2) Promotion of the UNESCO Global Geoparks as a quality label for sustainable tourism, as safe and sustainable territories where Earth heritage is protected and managed properly supporting the sustainable development of local communities.
3) Support to the organization of Geopark initiatives, meetings, and events at Regional and National levels.
4) Review and implementation of the Communication and Marketing Strategy to elevate global awareness of UNESCO Global Geoparks and the Global Geoparks community, focusing on the value and mandates they bring or can bring to the territories.
5) Implementation of a strategy for legal protection and security for the protection of the members of the GGN for their duties in the Network. (Global Geoparks Association, 2021)

The Governance structure of the Global Geopark Association includes:

- The General Assembly consists of all individual, supporting, and honorary members and the designated representatives of institutional members.
- The Executive Board, i.e., the decision-making body of the GGN; it consists of 13 elected members, as well as the Chairperson of the Advisory Committee and a UNESCO Secretariat representative as ex-officio members. Members are elected by the Ordinary General Assembly and serve a four (4)-year term of office.
- The Advisory Committee is the advisory body of the GGN. It consists of the Chairpersons (or their appointed representatives) of the National Geopark Fora / Committees, and the designated representatives of the Affiliated Organisations.

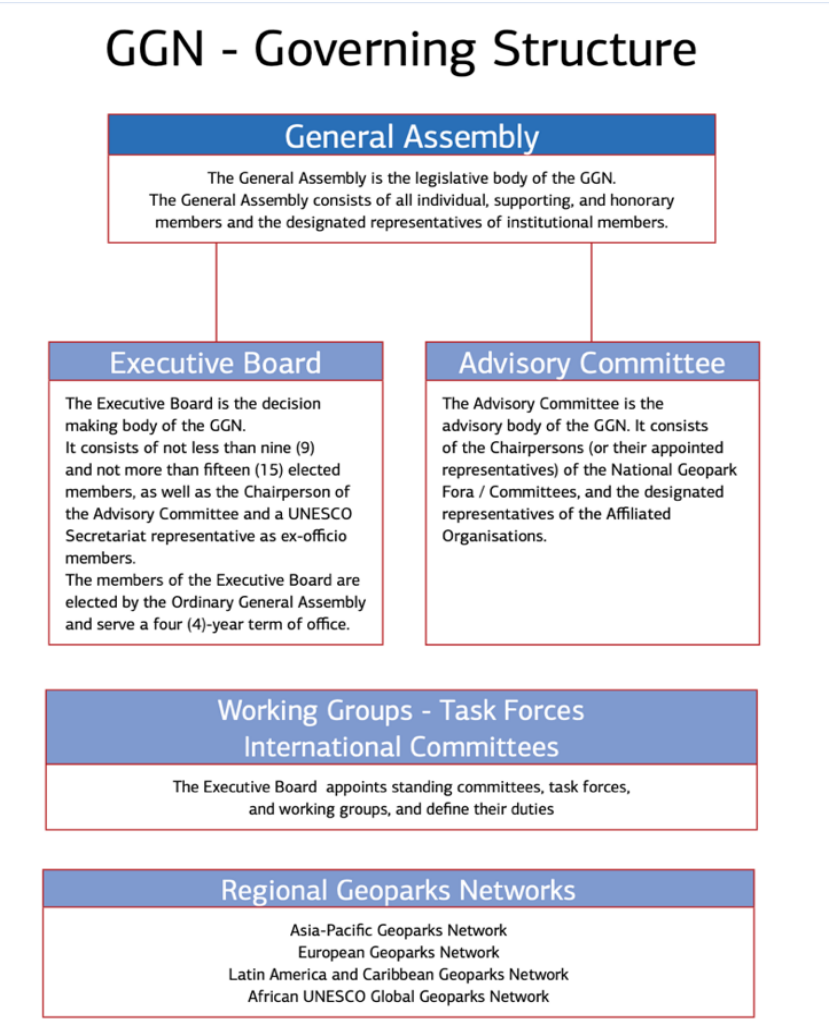

Figure 3 - UNESCO (2019) Global Geoparks Network Managing Structure [online]. Available at: https://en.unesco.org/international-geoscience-and-geoparks-programme.

2.3.3 Procedures to become a UNESCO Global Geopark

The UGG Application Process follows the Guidelines defined by the IGGP (UNESCO International Geoscience and Geopark Programme, 2015).

The first expression of interest needs to be submitted to the National UNESCO Commission, involving, where applicable, the National Geoparks Committee. The application dossier and the document showing that the candidate area already operated as a Geopark for at least one year should be delivered to the UNESCO Secretariat in the interval between 1st October and 30th November each year.

The International Union of Geological Sciences (IUGS) (https://www.iugs.org/history) oversees an assessment of the geological part of the application dossier. Two members of the UNESCO roster of evaluators are assigned by the Geoparks Bureau to evaluate the area. The evaluator's report is available to the Council for review.

The Council will review each application, the desktop assessment of the geological heritage, and the field evaluation report on the basis of criteria as explained on the website (https://en.unesco.org/global-geoparks/how-to-become-geopark).

The Council may accept an application, reject an application, or defer it for a maximum of two years to allow for improvements to be made to the quality of the application. Each UNESCO Global Geopark is subject to a re-validation mission every four years to check the quality of the management and the overall Geopark development.

Evaluators deliver a report and propose “green” or yellow” cards:

- “green” if the quality and management of the area have improved or at least continues to be “satisfactory”,
- “yellow” if the Geopark needs to undertake actions for keeping the Geopark status within two years.

In any case, the evaluators apply recommendations to the Geopark that would need to be fulfilled in the following four-year period by the Applicant. The final decision concerning the admission or rejection is taken by the UNESCO Global Geoparks Council.

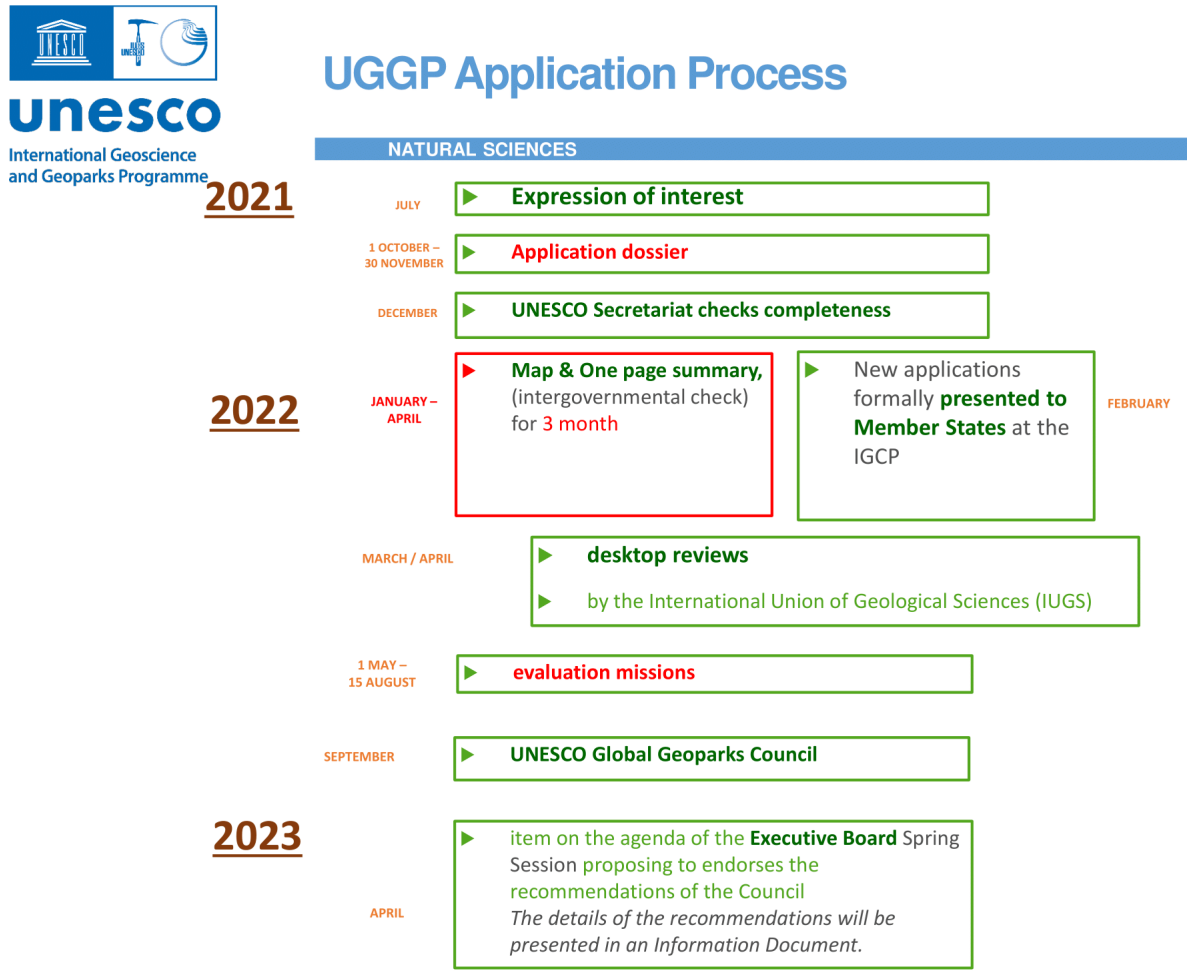

Figure 4 - UNESCO 2015, *Application process to UNESCO Global Geoparks* [online] Available at: *https://en.unesco.org/global-geoparks/how-to-become-geopark)*

Chapter 3 - The study areas: Sesia Val Grande and Magma UGGps

3.1 Introduction to the study areas

This research focuses on two European UNESCO Global Geoparks (UGGps): Sesia Val Grande UGGp (in Northwest of Italy) and the Magma UGGp (located in Southwest of Norway) (Fig.5).

Figure 5 -Gentilini, S. 2021, Location of the two studied UNESCO Global Geoparks.

The Magma UNESCO Global Geopark (MGp), located in south-western Norway, includes a surface of about 2329 km2, five municipalities and about 33 thousand inhabitants. The Geopark includes Rogaland and part of the Vest-Agder counties, its boundaries following the administrative borders of the municipalities of Bjerkreim, Eigersund, Flekkefjord, Lund and Sokndal. The geomorphological landscape represents an ancient peneplain that slopes gently down to the coast, gradually reaching sea level in the western sector of the geopark, whereas in the east there are steep coastal cliffs.

The Sesia Val Grande UNESCO Global Geopark (SVGGp) is located in the Northeast of the Piemonte Region (NW Italy) and encompasses areas of the Verbano Cusio Ossola (VCO), Biella, Novara and Vercelli provinces. The territory of the Sesia Val Grande Geopark includes a surface area of about 2000 km2, 106 municipalities, and about 190 thousand inhabitants.

Concerning the geological contents and scientific importance, both Geoparks show a magmatic bedrock with relevant crustal processes: in MGp, deep crustal processes prevail, while the SVGGp displays both deep and superficial crustal processes. Even from the geomorphological point of view both Geoparks show glacial

landscapes: in Magma mainly of the Pleistocene age and in Sesia mainly Pleistocene landforms and/or present-day glaciers.

The geosite classifications and the management structures adopted in the two geoparks are based on quite different approaches, which makes them interesting case studies for the development of indicators for geodiversity and the related analysis of abiotic ecosystem services in connection with management tools.

The SVGGp is jointly managed by three partners − Val Grande National Park, the Regional Parks of Sesia valley and the Sesia Val Grande Geotouristic association − under a governance determined by a Memorandum of Understanding (2012) recognized by the Italian Ministry of the Environment) and an Operating Agreement (2016) under the Piemonte Region Government. The operative leader of the SVGGp is the National Park and the official headquarters are based there. The Management Board is composed of two official representatives of the three organizations, chaired by an appointed professional with proven experience in the field of geological and cultural heritage management and sustainable development. The Operative Team is coordinated by the director of the National Park with the support of the director of the Regional Park. At present, there is no specific Geopark budget and Management Team. Interventions are guaranteed by agreements between all the Parks and the Association Sesia Valgrande Supervulcano. The scientific support is guaranteed by internal resources and researchers of the scientific committee coordinated by the University of Turin.

In terms of the management structure, MGp AS is a private share company that was established before applying as UGGp and is responsible for the management and development of the overall area. The biggest challenge it has faced throughout the years is engaging owners and stakeholders, keeping them informed and motivated with regard to the Geopark's actions and mission. MGp is financed directly by the owners, which are both private and public entities: municipalities, counties and, in the last two years (2019-2020), the National Government. The General Assembly, which is made up by all the owners, elects the Board of Directors, composed of six members, every two years. The function of the board is the fulfilment of the Geopark's strategy and Action Plan, revised every four years. The Scientific Committee is composed of the Norwegian Geological Survey, the Norwegian UNESCO Commission, and members of the Environmental Department; they provide the Geopark with mentoring and effective scientific research.

3.2. Sesia Val Grande UNESCO Global Geopark

The SVGGp area is characterised by a diversity of alpine mountain and Piedmont landscapes and by different management models (Perotti *et al.*, 2020). In its northern sector , the Geopark includes the entire territory of the Val Grande National Park plus surrounding territories for a total of 26 municipalities. In the southern sector, the Geopark covers most of the mountain range of the Sesia Valley basin over an area of about 800 km², including the whole Sesia Valley and portions of neighbouring territories such as Valsessera, Prealpi Biellesi, Val Strona and Alte Colline Novaresi with more than 80 municipalities (Fig. 6).

This large area is bordered to the west by the Valle d'Aosta Region along the Monte Rosa Massif (4634 m a.s.l.); to the north, by the Ossola and Vigezzo valleys and the Swiss border; to the east and south, by Maggiore Lake; and to the south, by the Alpine Piedmont and the Po plain.

The Geopark includes the Val Grande National Park, two regional parks (Alta Valsesia and Monte Fenera), now under the jurisdiction of the Management of Protected Areas of the Sesia Valley, and the Special Nature Reserves of Sacro Monte di Varallo and Santuario di Ghiffa. The Geopark features other protected areas: Riserva Naturale Orientata delle Baragge, the Riserva Fondo Toce, and three "Oases": the Oasi Zegna, the Oasi Naturale Bosco Tenso, the Oasi Naturalistica Pian dei Sali. (Fig.7)

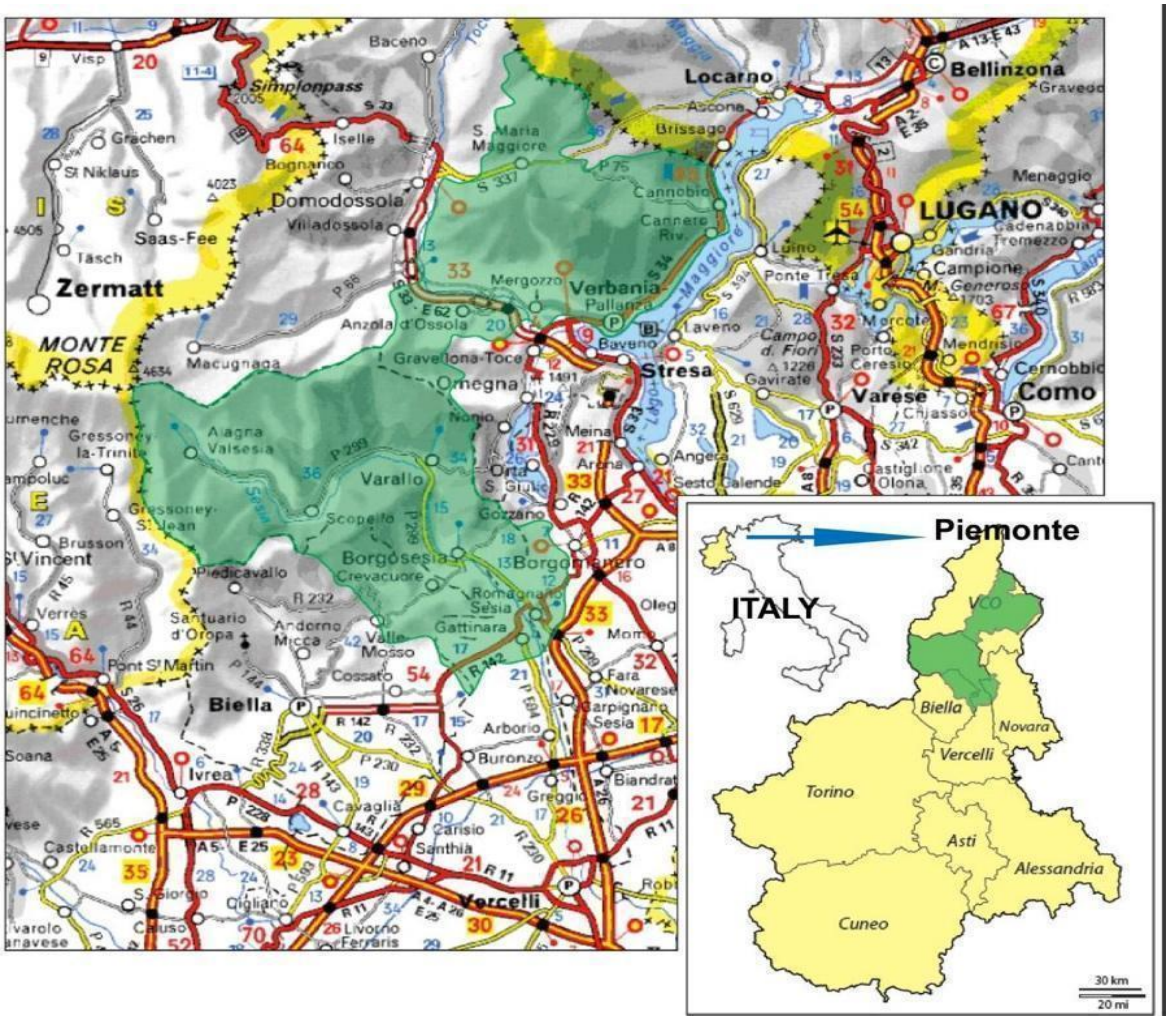

Figure 6 - Location of Sesia-Val Grande UNESCO Global Geopark (from the Application Dossier to UNESCO, 2012).

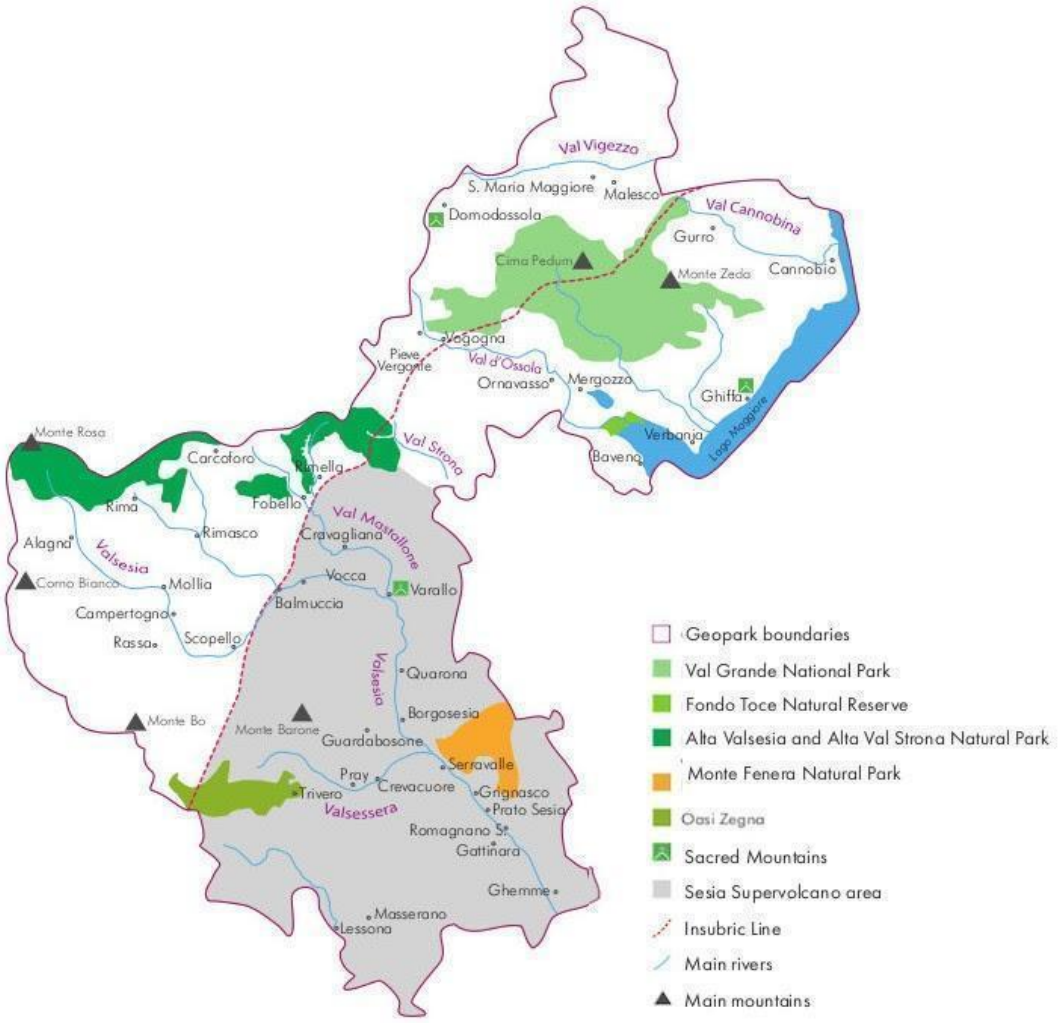

Figure 7 – Boundaries and subdivisions of the Sesia Val Grande UGG territory, including: national and regional parks, cultural sites, main geological, hydrographic and orographic features (from the Second Revalidation Dossier to the UGGP, 2021).

The importance of the geodiversity in the SVGGp is linked to the extreme variability of its altimetry and the complexity of its lithological and structural setting (Fig. 8) within the geological framework of the Northern Piemonte region (Lombardo *et al*., 2016; Piana *et al*., 2017). These make it possible to detect several ancient orogenetic processes (see below) and recent geomorphologically diverse features: glacial, hydrological, gravitational and also karstic phenomena, in the southern part of the Geopark (Perotti *et al.*, 2019). Since the Sesia Val Grande UGGp extends from the Mount Rosa massif to the Po plain, it also shows the record of past and present climate changes related to morphogenetic processes, which continuously shape the landscape (Giardino *et al*., 2017).

From a geological point of view, the SVGGp straddles the Canavese segment of the Insubric Line, a major tectonic boundary of the Alps (Milnes, 1974; Platt & Lister 1985). North and westward of the Insubric Line, the Austro-Alpine domain consists of piles of nappes, which were assembled and affected by a poly metamorphic event during the Alpine Orogeny (Laubscher, 1985).

South and eastward of the Insubric Line, South-Alpine rock units were not affected by this metamorphic event. They preserve an older history, despite experiencing substantial Alpine tectonic deformation. These are the original rocks of the northern margin of the Adriatic Plate, an exceptional record of metamorphic and igneous events preserved with a virtually intact section of the pre-Alpine crust. These rocks are a study model for the scientific data's interpretation on continental crust (Boriani *et al*., 2016).

Geological relations in the SVGGp are internationally renowned and of world-class scientific significance. Accessible outcrops display the effects of dramatic geological processes that shaped the continental crust through a wide range of crustal levels, from high-grade metamorphism, magmatism, anatexis and ductile deformation at depths as great as 25 to 30 km, to the explosive eruption of a supervolcano at the surface of the earth 282 million years ago (Quick *et al*., 2009). For more than 40 years, this area has served scientists as an unprecedented crustal reference section in which geophysical observations and physical processes may be interpreted in the context of geology that is observable on the ground (Bagnati T. *et al*., 2012). The scientific importance of the Sesia Val Grande Geopark is testified by the recent DIVE Project for deep Drilling into the Ivrea–Verbano Zone in the Sesia and Ossola valleys, which aims at unravelling the architecture of the lower continental crust towards the Moho discontinuity (Pistone *et al*., 2017).

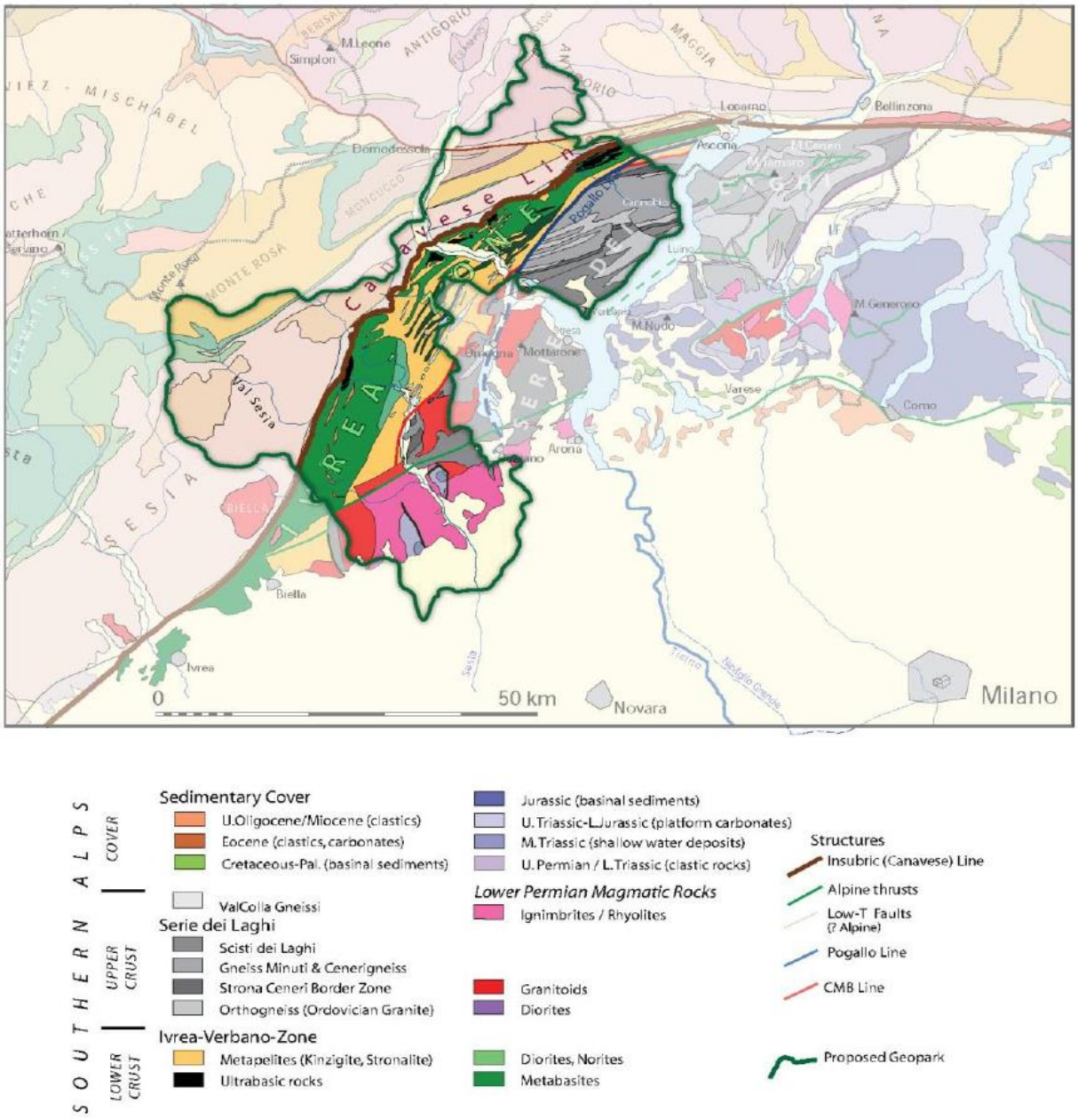

Figure 8 - Simplified geological map Sesia-Val Grande Unesco Global Geopark (Brack et al. 2010).

3.3 Magma UNESCO Global Geopark

Water and ice played a major role in the MGp landscape − the ancient peneplain having been deeply incised by rivers and glaciers − giving the hilly topography that is visible today and creating hundreds of small valleys and more than 6,000 lakes.

There are only a few islands off the Geopark coast, most of which have no protection against the ravages of the North Sea. The landscape is dominated by bare, rounded, rocky hills where crystalline rocks form the surface. Vegetation has, however, taken hold in areas with glacial and river deposits. The natural vegetation consists mainly of heather, juniper, marshlands, and small birch forests.

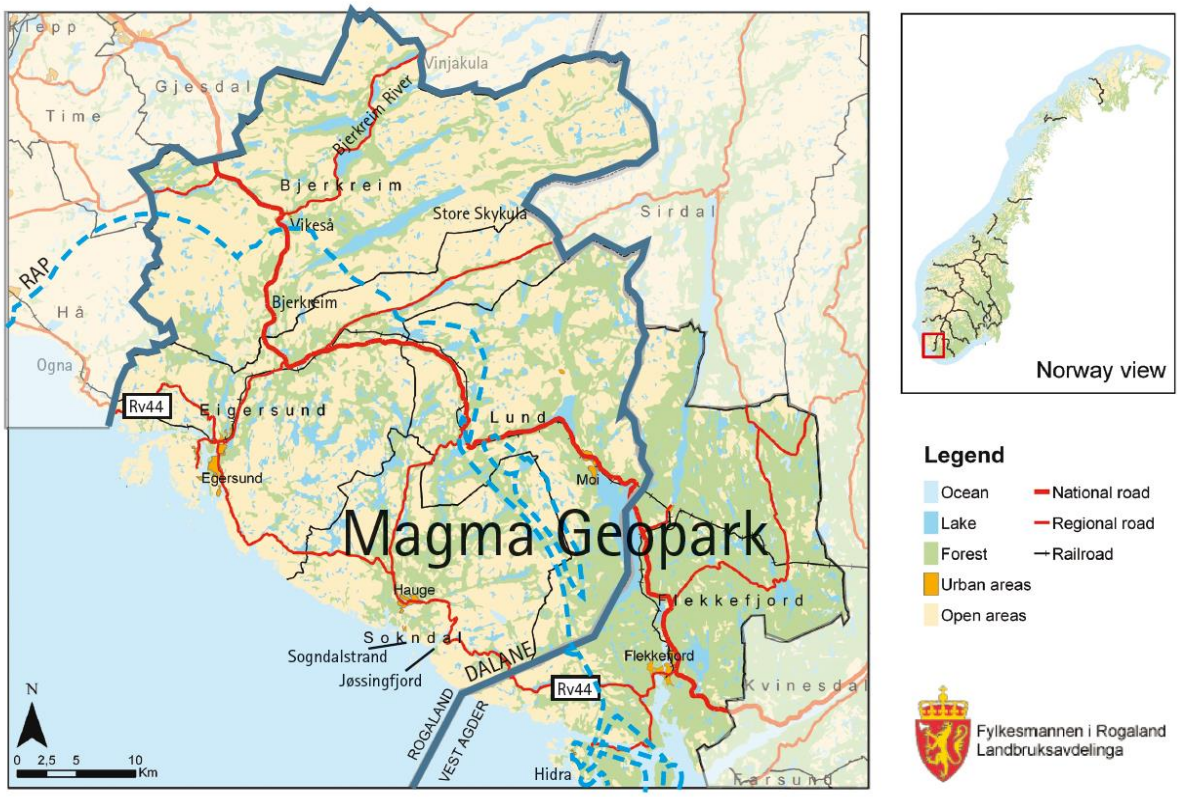

Figure 9 - In black, area of Magma UNESCO Global Geopark, (MGp Application Dossier, 2008).

Apart from some Quaternary deposits, all the rocks in MGp were formed in Precambrian times during the Proterozoic Eon, or more specifically, in the Meso- and Neoproterozoic.

Infact, the area of the Geopark consists largely of igneous rocks that crystallised about 930 million years ago in large magma chambers that were approximately 20 kilometres below the surface. Large bodies of anorthosite, a rare rock-type that consists almost entirely of mineral plagioclase, dominate much of the area. (Charlier et al., 2006; Schzrer et al., 1996).

Some of the western parts of the area were metamorphosed during the Caledonian Orogeny (late Silurian Period) and the entire area was strongly affected by glaciation and deglaciation processes (i.e., the onset, pulsations and retreat of a continental ice sheet, and the related post-glacial crustal rebound) during the Quaternary. All the rocks in the area are formed in the Eon Proterozoic (2,500 – 542 mill years ago).Proterozoic is divided into three eras: Paleo- Meso- and Neoproterozoic. The Magma Geopark rocks was formed in Meso- (1600 – 1000 mill y) and Neoproterozoic (1000 – 542 mill y)Each of these Eras is divided into three geological periods: Calymmian, Ectasian, Stenian, Tonian, Cryogenian and Ediacaran.Calymmian 1600-1400 y: Banded gneiss Ectasian 1400 – 1200 y, Granitic gneiss Stenian, 1200 – 1000 y; Augengneiss Tonian, 1000 -850 y: Anorthosite, Bjerkreim Sokndal Layered intrusion, Tellenes Ilmenite Norite Cryogenian 850 – 630 y: Monzonoritic dyke swarm Ediacaran 630 – 542 y: Egersund basaltic dyke swarm.

As a result, at least 8 geological intervals are therefore represented, (Falkum, Petersen,1987; Duchesne, 2001). The largest layered intrusion in Western Europe is also present and contains a very wide range of rock types as well as a variety of sedimentary-like structures that formed from crystallising magma (*Fig.8*).

Glaciation and deglaciation

For several thousand million years, the large mountain ranges that covered the Magma Geopark were worn down by hot and cold periods. Many of the cold periods were so cold that we call them ice ages. During these periods, the whole of Norway was covered by ice. There have been about 200 such ice ages. As the last ice age approached its end, about 10,000 years ago, the ice and the enormous amounts of meltwater left their last traces in the landscape. The ice left, among other things, exciting sculptures made of stones of all sizes and shapes. Some balance, others stand on top of each other and some, like Trollpikken, protrude from the mountain.After the last ice age came the Stone Age. During this period, people came across the ice from Denmark and settled at the ice front. These first humans were engaged in fishing and hunting. Later, in the Bronze Age, people began to settle in more permanent settlements. Here they built homes and cultivated the land. In Magma Geopark we find traces of people from the Stone Age, Bronze Age, Iron Age, Viking Age, Middle Ages, modern history and World War II, and these different periods have affected the landscape and the area in different ways.ng history of mining, mostly for iron and titanium, and a considerable amount of cultural history in the area is related to early mineral exploitation. The resistant rocks that dominate the area are responsible for the bare, rounded outcrops that characterise the unique landscapes of the MGp.

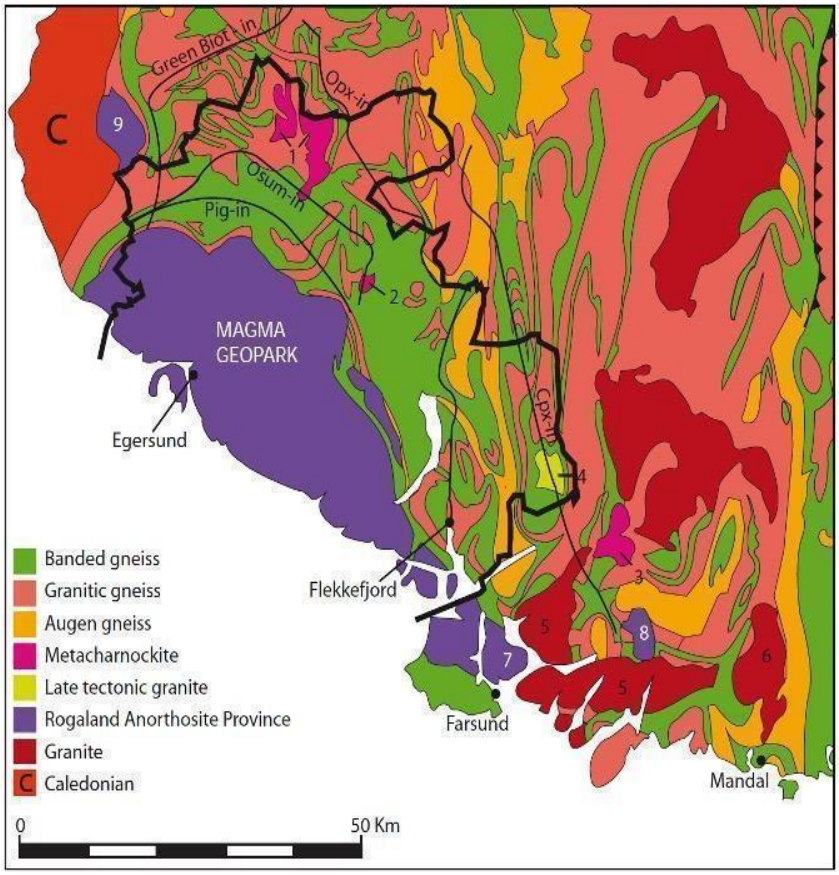

Figure 8, Magma Geopark simplified geological map (MGp Application Dossier, 2008).

3.4 The geosite classification adopted in the Sesia and in Magma UGGps

The research on geosite classification is based on desk analysis of the Sesia Val Grande and Magma Geoparks' Application Dossiers to UNESCO Global Geoparks, the first one delivered in 2012 and the second in 2009 (Annexes 2 and 3).

The two applications and the additional data provided by the two territories after the pre-evaluation done by external experts are the baseline for this research desk analysis.

3.4.1 Geosite classification in the Sesia Val Grande UNESCO Global Geoparks

The SVGGp application dossier introduced a total of 124 geosites of interest. 33 of those are labelled as "*geological sites within the proposed Geopark, categorized according to their international, national, regional or local value*", while the other 46 are considered to be "*under preparation at present or for future development*"; no further description is provided. (Bagnati T. *et al.*, 2012).

The 46 SVGGp geosites selected are classified under international, national, regional or local ranking based on their scientific value, and a single short description is provided for each of them.
Within these 46 geosites, five have been defined as having "International" value; ten are classified as having "National" value; ten as having "Regional value" while nine as having "Local" value.

Only 33 geosites are fully described and are classified following these parameters:

- State
- Region
- Province
- Municipality
- Coordinates
- Quote (Elevation)
- Rank (scientific relevance at an international, national, regional, local level)
- Scientific interest (Main, Secondary): one "main" interest and one "secondary" interest are indicated.
- Other Interests
- Conservation Issues: the geosite conservation statute and eventual issues.
- How to reach this site (e.g. accessibility by car).

Of these 33 geosites, 25 have been described as having "International value", 3 as having "National" value, 5 as having "Regional value", while none of the 33 has been classified as having "Local value".

Scientific Interest includes the following categories and is written in order of importance from the complier's perspective: Petrography (P), Structural Geology (ST), Geology of the Basement (G), Geomorphology (GM), Cultural Heritage (CH), History (H), Metamorphic Petrology (MP), Glacial Morphology (GM), Structural Geology (SG), Permian Magmatic Activity (PMA), Alpine Geology (AG), Glaciology (GL), Mining (MI), and Peculiar Morphology (PM) (Bagnati T. et al, 2012).

The analysis of the "Scientific" interest of SVGGp geosites gives the following results:

- 30 geosites are considered representative of "Structural Geology";
- 27 are of "Petrographic" interest;
- 22 are connected to "Geology of the Basement";
- 7 geosites are classified as having "Glacial Morphology" characteristics;
- 3 feature Alpine Geology;
- 2 geosites are related to Cultural Heritage;
- Each remaining geosite has one interest related to: "Metamorphic Petrology", "History", "Permian Magmatic Activity", "Peculiar Morphology", "Glaciology" and "Mining".

Concerning the "Other interest" category, the following subcategories are included in the SVGGp application: Science-Education (SE); Environmental (E), Archaeological (A); Historical (H); and N = Naturalistic (N). Results of the analysis indicate:

- 32 geosites have "Environmental" interest;
- 31 have "Naturalistic" interest;
- 28 have Science Educational interest;
- 3 have Historical interest;
- 1 has "Archaeological interest".

Only four geosites present a conservation risk due to their exposure or human threats which are not further specified.

The final geosite database from the SVGGp Application lists 45 non-geological sites divided into 5 categories of which 6 listed as "Ecomuseums", 9 considered "Religious Sites", 2 classified as "Stones and Mines Heritage" sites, 6 in the category "Castles and Fortifications", while 22 are Museums. (Annex 2). This list includes sites of value from the point of view of nature, art, history, and culture, such as Val Grande National Park, the Natural Parks of Alta Valsesia and Monte Fenera, and Sacro Monte di Varallo: the 16th century Sanctuary is listed as a UNESCO World Heritage Site within the "Sacri Monti" site (Fig. 9).

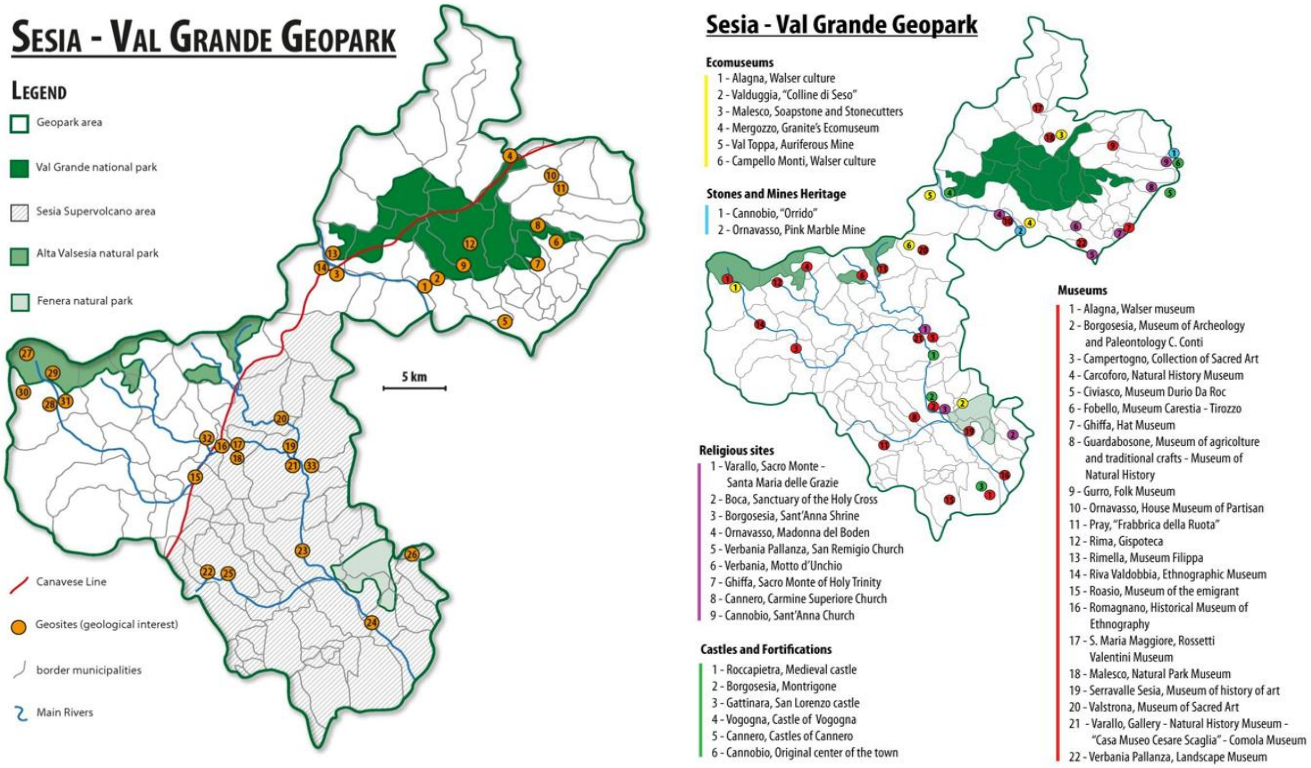

Figure 9 -SVGGp geosites: "geological interest" and: "non- geological interest". (Application Dossier to the UGGp, 2008).

The overview of the geosites in the Application appear rather chaotic and it is quite difficult to get a clear outline. In the main dossier, several geosites are classified according to their scientific-geological importance without taking into consideration the 45 criteria listed in the separate Annex of the application, which are also double-listed; furthermore, no consideration is given to the "other value" they may have.

22 of the 124 geosites considered in the application are listed twice: 10 are described under the "geological value" category, while 12 are listed as having "geological value"; but are in fact the same geosite under the same classification, which is, in fact, doubled.

Only 102 geosites of 124 listed would need to be considered for further Geopark's valorisation plans and activities; the review of the geosite list is available in Annex 2, with indication of possible amendments:

- Example: the "Varallo" geosite is described as a geosite having geological scientific interest; there is also specific mention of the fact it is a "paleoglacial valley". Following the description in the Annexes of the application, it is also listed as a Museum and a Religious Site. Three different values have been given to the same geosite, but no overview describing its various aspects has been provided.

- Another example is the "Ornavasso" geosite which has been listed as "Stone-Heritage", "Museum" and "Religious Site"; all values are listed separately in the Application without a coherent analysis of the site from different perspectives.

At present (May 2022), even if a preliminary analysis of the geotouristic contents of the SVGGp has been performed (Perotti *et al.*, 2020), the management plan and the plan for the development of the geosites in SVGGp is not yet available. So far, the selection and re-validation of the geosites is under processing by the scientific Committee in view of the next EGN Conference (2022), which will be hosted at the SVGGp. Therefore, within this PhD research thesis, it was not possible to proceed with further analysis of the present status of development of the Geopark geosites.

3.4.2 Geosite classification in Magma UNESCO Global Geoparks

In the application to UGGp (Wilson. *et al*. 2008), MGp manager and working group, while selecting the site "having geological, cultural and natural values" defined two main categories: the first include the so- called "geosites" and the second is the sub-category defined as "geopark localities".

In the classification, the distinction between "geosite" and "locality" is the result of an internal survey and analysis of several successful applications (including the one by Gea Norvegica; the other Norwegian territory which applied to UGG in 2004) delivered to UNESCO before the MGp dossier.

The working group define the geosite as the sites having "*high interest from the geological, natural, cultural and scientific point of view*": they are sites which are important for education and science activities within the Geopark but are of less interest for the public and tourist due to their limited accessibility and/ or due to their vulnerability.

MGp scientific Committee selected 89 geosites in total, classified within the following criteria:

- Interests (regional, national, or international)
- Use (main field of use of the geosite: Geotourism, Education, Science).
- Protection status: the level of protection of the geosite, according to one of the following Norwegian laws: 1) Act related to nature conservation (NatP), 2) Act related to the cultural heritage (CulP) and 3) Act related to outdoor recreation (LNF = agriculture, nature, and recreation)
- Availability limitations (categorizes if the geosite is included in private properties or if there are any issues pertaining to safety).
- Presence of actual threats at the site (Natural or Artificial threats to the site)
- Other information is listed, such as: historical, viewpoint and archaeological info (Table 2).

Theme	Abbreviation	Category
Rank	Int	International
	Nat	National
	Reg	Regional
Use	Edu	Education
	Tour	Geotourism
	Sci	Science
Protection status	NatP	Nature Protection
	CulP	Cultural Protection
	LNF	LNF area
	Awl	Agreement with Landowners
	NoP	No Protection
Availability limitations	Priv	Private property
	Saf	Safety
Threatened	Yes	Yes (possible)
	No	No
Other Information	Vwp	Viewpoint
	Hist	Historical interest
	Arch	Archaeological interest

Table 2 Geosite's Abbreviations and Categories in the Magma Geopark, (Wilson R., 2008).

In the MGp application, 58 of the 89 Geosites are also classified as "Geopark localities" which are defined as: "*places that illustrate interesting geological features for the public, sites that have archaeological and cultural value strongly connected with geological heritage, having a signed landowner agreement with the Geopark management, marked trails, parking places and a pamphlet/leaflet/booklet describing the locality*", while 31 sites are listed as geosite (Annex3).

The MGp dossier also includes a list of 27 "non geological sites and geosites with minor geological interest but where rocks often have been used in one way or another; some of them are linked to sites of geological interest while some are not. These "non-geological sites" are described using the same parameters for geosite and geopark locations.

In the further integrations, sent in 2010, MGP presented the 46 geopark localities (instead of 58) which have been selected by the scientific committee and the 5 municipalities; 29 of the 46 geopark localities overlap with the first application choice, while 17 localities are introduced as new.

The choice of the final 46 localities, made by the scientific committee and local stakeholders, reflected the scientific importance; they are representative of balance within different interests (cultural, geological or both) and the need for increasing the tourist business of the overall area.

Only the 29 localities chosen in the Application have been described with the following parameters: the Rank (international, national, regional), Use (Educational, Geotourism, Science), Protection Status (Nature, Cultural, LNF area, Agreement with the landowner, "no" protection needed), Availability (Private Property, Safety), Threatened status (Yes, No), and Other information (Viewpoint, Historical Interest, Archaeological interest).

The 17 localities introduced afterwards have not been classified following those parameters, so it is not possible to do an overall homogenous analysis of all 46 geosites.

The following statistics can be deduced from the 29 localities:

- **"Rank":** 5 are classified as having "International" value, 11 as "National" value while 13 as "Regional" value.
- "**Use":** 23 have "Educational" use, 25 "Geotourism" use and 7 "Scientific" Use. Following the classification, 4 localities can be used for all three purposes.
- "**Protection Status":** 4 localities are protected under the "Nature" legislation, 5 are protected under the "Cultural" legislation, 14 are localities under the legislation concerning "Building and Planning", while 4 do not have any protection.
- **"Availability"**: the category considers if the locality could have been inaccessible due to problems related with "private property" (2) where the landowner did not make any specific agreement with the Geopark, or for "safety" reasons (2).
- **"Threatened":** there are 10 localities at risk of threat. while the ones which are not considered to be under threat are 20; there is one locality which is partly at risk and partly not.

The final 46 selected sites are mainly classified into three categories: "geological (blue colour) sites – these account for 16, cultural (purple colour) sites – these are 8 in total, while 20 have mixed values (Fig 10, in violet).

Furthermore, the 46 geopark localities have been classified considering the connection to some general information that can be useful for tourists following these categories:

- Prior arrangement: the location can be visited after an appointment (8)
- Availability of accommodation: presence of accommodation nearby. (8)
- Availability of rooms to let presence of rooms for renting nearby. (4)
- Availability of served meals: possibility to serve meals nearby. (3)
- Availability of simple meals: possibility to serve simple meals nearby. (4)
- Presence of shops. (3)
- Presence of exhibition. (6)
- Tours or activities by arrangement, guided tours are organized within the locality. (41)
- Marked path: the locality includes marked trails. (38)
- Accessible for disabled. (6)
- Disabled toilets. (6)

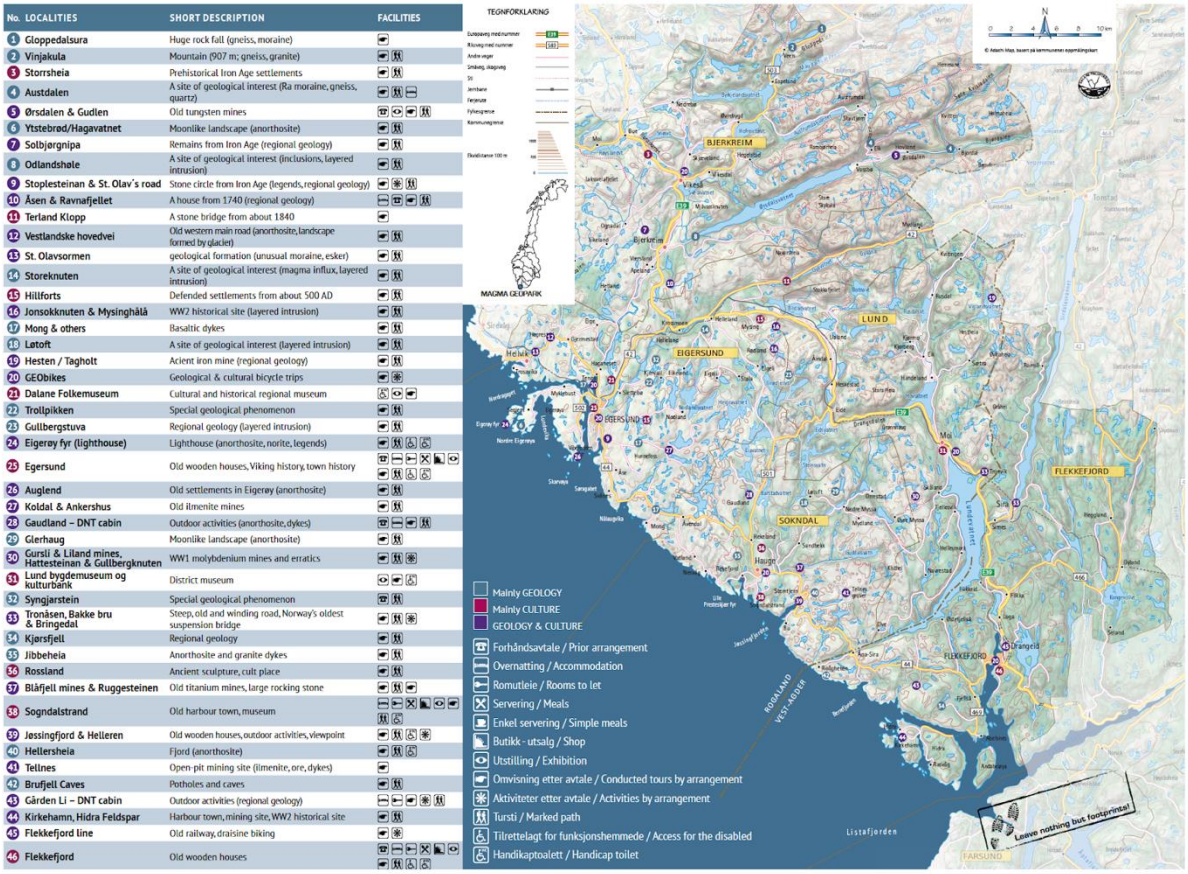

Figure 10 The 46 Geopark localities in MGp.

Since the establishment of the Magma Geopark Company in 2006, specific cultural and geological interpretations have been considered for each location selected, while the masterplan includes the accurate geosite valorisation plan. Cultural and geological aspects of the sites reflect the holistic approach requested to be a UNESCO Global Geopark.

From 2010 to 2020, the company performed interventions to increase the visibility of the selected geopark localities, providing them with interpretation panels and improving their accessibility with parking spots and toilet services. At present (November 2021), 24 localities have been properly equipped with parking, information panels and toilets.

Chapter 4 – Methods, Applications and Results

4.1. The research framework

The research framework is divided into three main phases:

1. The research baseline: desk research, literature review- field surveying, selection of time and spatial scales.
2. The analysis and selection of two geosite´s classification methodology in Italy and in Norway and the development of a new classification method.
3. The abiotic ecosystem services compared with the existing biotic ecosystem assessment: the selection of variables and the development of indicators and innovative assessment methodology for abiotic ecosystem services, within selected space and time.
4. The definition of abiotic indicator schema and assessment, as the main research outcome.

The first phase of the research has collected desk research and field data from two UNESCO Global Geoparks (SVGGp and MGp) and selecting 8 geosites, as case study: 4 from SVGGp (Varallo Sesia, Prato Sesia, Crevola, Balmuccia) and four in MGp (Jøssingfjord, Storeknuten, Eigerøy Lighthouse, Sogndalstrand). Geosite spatial distribution (Fuertes-Gutierrez & Fernandez-Martinez, 2010).

The selection of these geosite is reflecting the characteristic of each of those, explained in Chapter 4.2.1

The second phase included the analysis of state of the art regarding existing geosite classifications, with specific focus on the one in use at the University of Turin, within the Geosite and Geoheritage course led by Prof. Giardino and the ones developed by the Geological Survey of Norway for the development of the GIS database. (https://geo.ngu.no/kart/geologiskarv_mobil/)

The analysis of the 8 geosites preliminary characteristics through the classification set up within the Geosite and Geoheritage course led by Prof. Giardino is also included in the second phase.

The compared analysis of the two geosite classifications resulted in a new preliminary common database for geosite assessment which applied to the 8 geosites selected. (Orange, Outcome 1)

The Third phase includes the analysis of existing ecosystem classifications for biotic and abiotic services, the analysis of the development of methodologies related with biotic indicators applied and compared to the case study and to the abiotic nature, followed by testing results into the main research product: the abiotic service indicators assessment methodology. (Orange, Outcome 2)

The fourth phase is developing the abiotic indicator schema and final assessment methodology, as the main research outcome.

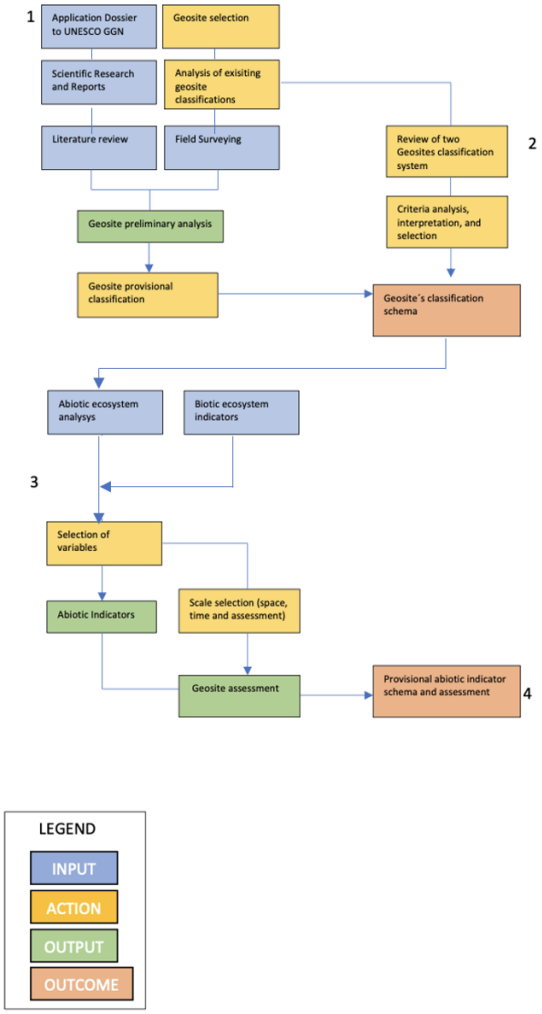

Figure 11- The PhD´s Research framework: Inputs (violet), Actions (yellow), Output (green) and Outcome (orange).

4.1.1 The research baseline, First Phase (1).

This phase is characterised by 4 main inputs (Blue, Inputs):

1. Analysis of the Application Dossier from the two selected UGGp to UNESCO
2. Analysis of scientific research and report from the two areas
3. Literature review
4. Definition of geosite spatial distribution and timescale
5. Field Survey in the selected UGGp.

Within the Phase1, the geosite spatial distribution and timescale have been defined as research time and spatial framework with specific analysis focusing on the two selected UGGp. The selection and assessment of 8 geosites took place within the two UGGp and four geosites were selected in SVGGp (Varallo Sesia, Prato Sesia, Crevola, Balmuccia) and four geosites in MGp (Jøssingfjord, Storeknuten, Eigerøy Lighthouse, Sogndalstrand)(Green-Outputs) ; while the preliminary surveys of existing analysis of geosite´s classification methodologies were also conducted (Yellow- Actions). (Chapter 4.2.1)

4.1.2 The analysis and selection of two geosite´s classification methodology and the development of a new classification method, Second Phase (2).

From the preliminary surveys of existing geosite´s classification methodologies, (Chapter 4.2.1) two specific methods have been analysed and compared: the one´s developed by Prof. Giardino at the University of Turin, and the other one developed by the Geological Survey of Norway for the implementation of the database. (Yellow-Actions)

During this phase, field data from eight geosites were adapted to the existing geosite's classification schema developed within the "Geosite and Geoheritage" Master's Course held by Professor. M.Giardino at the University of Turin, in the Department of Earth Science, Chapter 4.3.1.

A detailed comparison of the criteria in use in the two-classification schema has also been carried on: the result of the comparison and discussion led to the first research product, a new database where different criteria from the two initial systems merged (Orange-Outcome), Chapter 4.3.4.

The phase 2 and the phase 3 are connected: desk research on international classification and internationally accepted definitions regarding biodiversity, geodiversity and their role into ecosystem services have been analysed and compared while the selection of the criteria for the final database took place.

4.1.3 The Abiotic ecosystem services compared with the existing biotic ecosystem assessment: the development of indicators and innovative assessment methodology for abiotic ecosystem services,**Third Phase (3).**

This phase started from two main inputs: the preliminary analysis of the abiotic ecosystem services within the two selected UGGp and the investigation of existing assessment for biotic nature (Blue, Inputs).

During this phase a preliminary analysis of the existing abiotic ecosystem services has been carried on, starting with the Geodiversity definition by Gray (2013) in comparison with the selected geosite. assessment has been developed further,

The data from four geosites from each of the two UNESCO Global Geoparks has been analysed and compared to the geosystem services framework, starting from already-existing biodiversity indicators which act as a general framework.

Time and space parameters have been set together with a common evaluation scale. (Yellow, Actions).

Through a deep investigation and comparative research, specific factors (indicators) have been identified and explored, taking into consideration how they act within each single service, providing to the geosite´s assessment

4.1.4 This phase is taking into account the indicators selected within the previous phase: the developed evaluation scale allows to set up the final schema where the comparison between each abiotic service in each different geosites, which represents the main research outcome.(Orange, Outcome).

4.2. The research baseline, Phase one.

This phase is characterised by 5 main Inputs (Blue, Inputs):

As a preliminary step the research detected the criteria for geosite´s spatial distribution to be applied, and the timescale for the research development.

Analysis of the Application Dossier from the two selected UGGp to UNESCO: specific and comparative study of the areas, the methodology for the selection of the geosites, the management structure and the state of the art. Results of scientific research that have run in the Geopark have been considered in the overall literature review. Field surveys have been conducted along the first year, however due to Covid-19 restrictions the last two years investigations run only in MGp as part of the secondment.

4.2.1 Selection of criteria for geosite spatial distribution and timescale

Since Geodiversity deals with a variety of natural phenomena related to a wide range of spatial and temporal scales, the related abiotic ecosystem services can be controlled by global, continental, regional and local conditioning factors (Gray, 2013); moreover, they can be delivered either by slow, long-term Earth processes or by fast, contemporary and impulsive phenomena. Therefore, in the selection of the space and time framework for either the assessment of Geodiversity or the evaluation of each single ecosystem service (Zwolinski et al., 2018; Gray, 2018), it is worthwhile to consider the human perspective of the observer analysing the geosite.

This PhD research took into consideration a "human" framework of geodiversity and related ecosystem services by considering the evolutionary stages of the geological processes and their spatial and temporal dimensions with respect to human history (Giardino, 2019). In this perspective, two possible related ecosystem services have been considered (Annex 6 -Phase 3):

- "static" conditioning factors, with none or slight changes within the geosite during human life.
- "dynamic" processes, with on-going changes during time and space dimensions relevant for the human perspective of the observer analysing the geosite.

The "Anthropocene" (Hamilton C., 2019) definition has been adopted as the time frame of the PhD research, within the definition of the Sub commission on Quaternary Stratigraphy- Working Group in 2016: "*the '**Anthropocene'** is a term widely used since its coining by Paul Crutzen and Eugene Stoermer in 2000 to denote the present geological time interval, in which many conditions and processes on Earth are profoundly altered by human impact. This impact has intensified significantly since the onset of industrialization, taking us out of the Earth System state typical of the Holocene Epoch that post-dates the last glaciation*" (Zhisheng A. et al., 2021).

Even though Anthropocene is not accepted as an official interval in the IUGS Geological Time Scale, the existence of an informal term defining the Earth time interval "*which humans have a decisive influence on the state, dynamics and future of the Earth System* and *i*It is widely agreed that the Earth is currently in such a state.

In 2016, the Anthropocene Working Group agreed that the Anthropocene is different from the Holocene and began in the year 1950 when the Great Acceleration, a dramatic increase in human activity affecting the planet, took off.

The Anthropocene definition adopted in the present research is the same one proposed by the Working Group mentioned above, which defines the Anthropocene as the most recent geological time interval starting with *"the artificial radionuclides spread worldwide by thermonuclear bomb tests from the early 1950s*"(National Geographic 2019).

The adoption in the research of the concept of the Anthropocene is very important to understanding and underlining the recent change in the natural environment caused by human unsustainable development and to improve the better understanding of how the relationship between abiotic nature and the benefits for a sustainable modern society should be.

<u>The space frames</u>

An important preliminary task is related with the analysis and description of the geosites and the study of the spatial distribution and dimensions of the different geological and/or geomorphological features of which they are composed. The Fuertes-Gutiérrez & Fernandez-Martinez (2010) definitions adopted in the "Geosites inventory in the Leon Province" was applied to the present study with particular attention to "points" and "complex areas" as "*large zone with high geodiversity and a type of geosite that results from the grouping of several geosites from different categories*

Within the local scale of geosite assessment, the analysis focusing on two research "space frames":
- the geosite area as the" minimum bounding box" and
- the" geosite buffer zone".

According to its geometrical definition, the minimum bounding box (O'Rourke, 1985) is the smallest rectangular shape you can draw including one or a set of objects; we applied this concept to the geosites, including their main

points of interest. We applied a geographical version of this concept: i.e., the "axis-aligned minimal bounding box" to get an approximate location of the geosites within a map.

Thereafter, according to a functional approach to geosites (Giardino & Mortara, 1999; Ferrero *et al.*, 2012), the research defined the geosite buffer zone as: "*the area including all the elements needed for the accessibility of the geosite, its fruition and its effective management*".

The type and size of the space frame to be used has been agreed with the research team based on the physical characteristics of 4 geosites and the specific needs of the assessment.

4.2.2 Selection of eight geosites within the two UNESCO Global Geoparks

Within the Phase 1, the selection and assessment of 8 geosites took place within the two UGGp,, four geosites were selected in SVGGp (Varallo Sesia, Prato Sesia, Crevola, Balmuccia) and four geosites in MGp (Jøssingfjord, Storeknuten, Eigerøy Lighthouse, Sogndalstrand) (Green-Outputs) (Figure14).

Varallo Sesia, Sacro Monte: the geosite has been selected as a Geopark site, due to its cultural and geological value: in fact it is located in a paleo glacial valley and the hill is hosting one of the Italian´s Sacred Mountain World Heritage Sites. The importance of the site is worldwide recognized, however the application Dossier does not provide a specific detailed description of the cultural and geological aspects within the holistic approach required for being a geosite in an UNESCO Global Geopark. It is protected by National Law, and it is under the jurisdiction of the Ministry for Cultural Heritage which is not integrated in the Geopark´s structure and management.
Varallo in the Application Dossier is also described as including a "Museum" and is classified as a site "requesting holistic valorization": the present research aims at contributing to a further development of the site and to the integration between the two UNESCO management bodies and designations, required to be an UNESCO Global Geopark having double designation (Annex 2).

Prato Sesia , is one of the most representative geosite for the exploitation of the supervulcano, is characterized by megabreccia outcrops and riolite blocks, formed during the collapse of the caldera in which they are found.It is classified as a "geosite" in the application to UGGp having geological interest, with no connection explained to the holistic approach required for being a geosite in an UNESCO Global Geopark. It has international geological importance, and it has great accessibility and educational value, the inclusion in the research analysis is due to its benchmark value for other sites within several abiotic ecosystem services (Annex 2).

Crevola, is one of the most representative geosite for the exploitation of the supervulcano,is located along the Sesia river and is one of the best exposures of the contact between the Mafic Complex and the Kinzigite Formation, including amphibolite-facies migmatite. It is classified as a "geosite" in the application to UGGp having geological interest, with no connection explained to the holistic approach required for being a geosite in an UNESCO Global Geopark. The further assessment within the present research could lead into a better understanding of the overall anthropogenic impact in the area and lead to the application to protection measures and innovative solutions (Annex 2).

Balmuccia, is one of the most representative geosite for the exploitation of the supervulcano: the outcrop of Balmuccia peridotites which is in an excellent state of conservation. It includes a massive, inhomogeneous body, of about 4 kmq of surface. It is classified as a "geosite" in the application to UGGp with no connection explained to the holistic approach required for being a geosite in an UNESCO Global Geopark. The further assessment within the present research could lead into a better understanding of the overall anthropogenic impact and innovative solutions.

Sogndalstrand, is one of the most historical representative sites in MGp, it is a traditional example of coastal harbour Norwegian wooden village, mostly protected by Law. It is included in the Application to UGGp as a "Cultural site" having "National" relevance. The site also includes a local museum, which has been valorized by local communities before the Geopark was established. The interpretation of the geological and cultural aspects of the site is well developed both in place and online. (www.magmageopark.com) The inclusion in the research is due to the need to better understand how to increase cooperation with the local community. (Annex 3)

Jøssingfjord and Helleren, it is classified in the Application to UGGp as geosite having International geological relevance, where historical aspects are also very well integrated in the site interpretation both in place and online.

The geosite is a typical fjord, developed during the last ice ages, and the Helleren houses are wooden houses dating back from the 1800s, however large parts of the buildings might be considerably older. Most probably, there have been settlements under Helleren from the 1500. Dalane Folkemuseum, MGp ´s owner is today the owner and responsible caretaker of the houses.The Jøssingfjord This fjord is especially known for the historical Altmark episode that took place here on 16 February 1940. The Altmark affair was the event where the German military tanker 'Altmark' was boarded by British marine vessels, and British marines were released from German captivity. The Altmark event was used as an argument by the Germans to attack and occupy Norway, as they then felt that Norway's neutrality was then compromised after this event.
The fjord is also the place where the Titania facility was founded in 1902 and has continuously produced ilmenite since 1916 with a production volume of 24.5 mt/y ilmenite concentrate in 1917.
The site is also rich in outdoor activities, and it is now the site for the new Science Museum which will also host the Geopark´s exhibition and office with an investment of local stakeholders of about 10 million Euro (DalaneFolkemuseum 2021)

Storeknuten is an ongoing developing site in MGp, it has "regional" ranking, it is easily accessible and classified as "Geopark location" however no interpretation has been developed yet from the Geopark. The site is included in a private property, an agreement should be made. The present research aims at supporting the Geopark management to its implementation, it is considered as having potential for education, science and geotourism.

Eigerøy Lighthouse is protected by Law, and it is classified as having cultural and geological importance. The site is well used for education, thanks to the educational path developed by the Geopark with related information regarding the very well exposed anorthosite and glacial landscape. The site has recently also received good interpretation of the natural environment: migrators used to settle in the natural lakes along the path: the ornithologist Group and the Geopark developed a specific quiz game for visitors and schools to play in the site focused on birds. The site is one of the most visited places in the Geopark, due to its accessibility and beauty. The inclusion in the research aims at supporting the development of strategies which consider several natural aspects occurring in the site.

The geosite selection is also following the common characteristics of each couple of geosite from the two UGGps selected, which can be explain as following:

Since the preliminary examination took place, similar characteristics were easily detectable between the 8 selected geosites, resumed as following;

The idea of comparing Varallo Sesia and Sogndalstrand geosite comes from the fact that both have interesting cultural heritage and are relevant from the tourism prospective, Prato Sesia and Jøssingfjord are important as geosite of international relevance while Crevola and Storeknuten are still not developed, so they can be compared as having unexpressed potential. Balmuccia and Eigerøy lighthouse are easily accessible and very relevant from the geological point of view.

Varallo Sesia (96) and Sogndalstrand (38). These sites have historical and cultural values and the link between the geological contents and cultural landscape is very clear. Both these geosites are very well-known by locals and visitors; they include a museum and are considered as important sites from both an educational and touristic perspective. Both geosites are protected by Cultural Legislation.
If we take into consideration the specific matter of geotourism, the Sogndalstrand geosite was already well-developed at the time of the MGp Application (panels, parking spots, public toilets), while, according to SVGGp, the Varallo Sesia is a "site under development".

Prato Sesia (24) - Jøssingfjord(39). These sites are both characterised by having "International" scientific ranking values, and both are considered having "educational" and "naturalistic" values. However, Joøssingfjord is protected by the Law, while Prato Sesia is not. They are both included as "already developed" geosites in both Geopark Applications.

Crevola (21) - Storeknuten (14). Both sites have geological importance: Regional (Storeknuten) and International (Crevola). Crevola is considered a Geosite which is already developed within the SVGGp Application, but it is not accessible by the public. Storeknuten is accessible but information about the geosite is missing in MGp. Both sites have high potential to become relevant for the development of geotourism activities but they both need substantial improvements.

Balmuccia (16) -Eigerøy Lighthouse (24). Both the sites are classified as "Geopark" geosites within the Applications. They are both important from a geological point of view but also for scientific educational purposes. Both sites have easy access, parking spots and information for the public.

The eight geosites have been analysed for establishing a common geosite assessment framework, while for establishing the preliminary abiotic ecosystem indicator framework, the research focused on four selected geosites: Jøssingfjord and Eigerøy(Fig. 14, red frame), Prato Sesia and Crevola (Fig. 14, red frame).

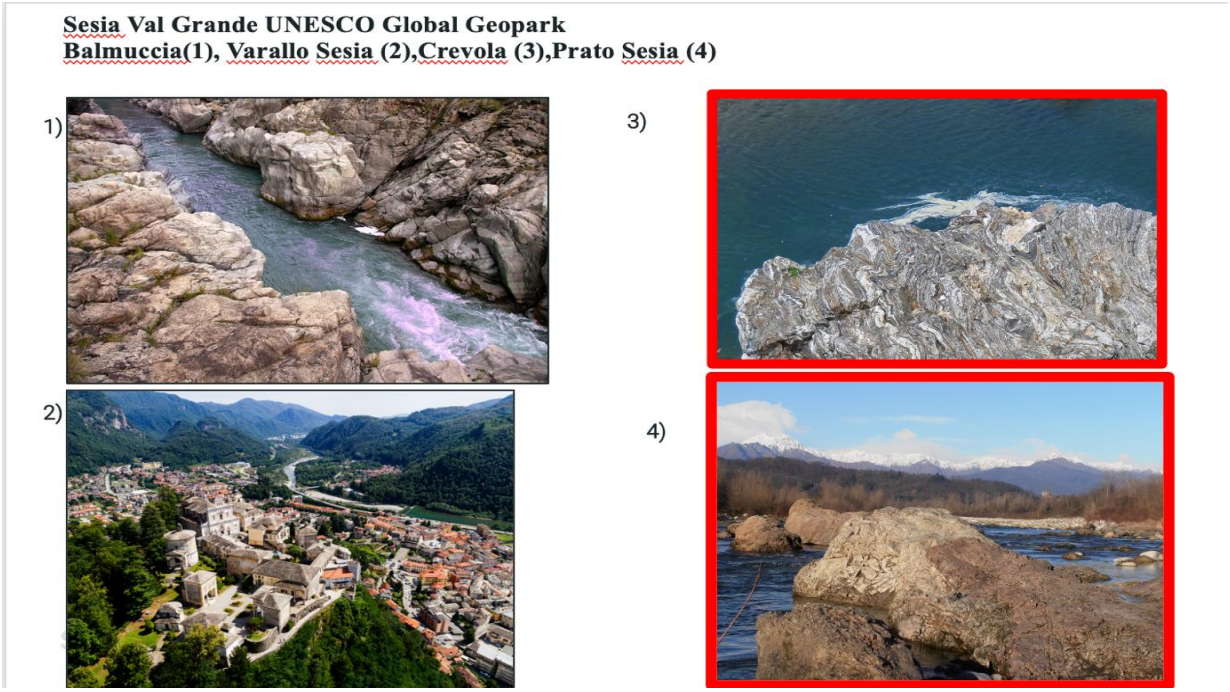

Figure 14, Balmuccia (1), Varallo Sesia (2) Crevola (3), Prato Sesia (4): Geosites selected in Sesia Val Grande

Figure 14, Jossingfjørd (1), Storeknuten (2), Eigeroy Lighthouse (3),
(Sogndalstrand (4), Geosites selected in Magma Geopark.

4.3 The analysis and selection of two geosite´s classification methodology and the development of a new classification method, Second Phase (2).

4.3.1 The geosite classification schema adopted by the University of Turin, Geosite and Geoheritage − Master Course Programme

Genesis

The first research phase included the analysis of previous procedures developed in Switzerland (Berger, Grandgirard V., 1995), which includes categories such as the geosite's scientific interest, potential threats and further suggestions for the management body in charge of the geosite's valorisation and conservation.

The starting point for the development of the present methodology was the procedure delivered by the German Federation in 1996 when, for the first time, the geosites' recording and evaluation phases were identified as two separate steps.

Another important contribution to the development of the first research product was given by the procedure for recording geosites in the Alpine context and applied in the Natural Park of Gran Paradiso by the CNR-IRPI from Turin, which pays specific attention to the connections between environmental values and human activities. (Giardino & Mortara, 1999).

The methodology adopted by the University of Turin aquired elements from the one established in 2005 by Modena University, which entails applying seven main parameters: scientific values (based on the number of scientific publications), educational values (representativeness), extension, rarity, integrity, visibility, and additional values (ecological and other geological values) (Bissing, 2008; Coratza, Giusti, 2005; Coratza, Regolini-Bissing, 2009; Coratza *et al.*, 2018).

Pereira, in evaluating Montesinho Natural Park, has increased the number of parameters and variables, adding innovative concepts such as cultural value, accessibility to the site and level of protection, which have also been adopted by the classification schema in use (Pereira et *al.*, 2007).

The evaluation schema used in the present research takes also into consideration elements from the Reynard methodology (Reynard *et al*., 2012) which focus on "Integrity", "Representativeness", and "Rareness and Palaeographical" values; these are applied to describe the geosite's "scientific" value in detail (Ghiraldi, Coratza, Biaggi, Giardino, Marchetti &Perrotti, 2009; Ghiraldi *et al*., 2009; Ghiraldi, Coratza, Marchetti, 2010; Regolini, Bissing, 2010).

Description of the categories from the database.

Three main working phases are included in the database: "**Registration**", "**Evaluation**" and "**Provisional abiotic ecosystem assessment**"; each of these are then divided into subcategories.

The **Registration** includes the following subcategories:

Information inventory:

- Compiler: name of the person in charge of the compilation.
- Authority compiler: In case an institution is in charge of the compilation.
- Cataloguer: in case the file is included in a catalogue.
- Authority cataloguer: the authority in charge of the catalogue.
- Date of compilation.
- Data acquisition: Survey/Bibliography.
- Disclosable: Yes/No/Partially

Information geosite

- Geosite code within the UGGps (Number in the current Geopark classification, See Annexes 2,3)
- Name of the geosite: name given by the Geopark.

- Description: brief description.

Geosite dimension

- Area (m^2)
- Length (m)
- Height (m)
- Thickness (m)

Scientific information (Most relevant scientific interest).

Primary scientific interest: the most important interests represented by the geosite.
This includes several categories: Geological, Geo-mining, Hydrogeological, Paleontological, Pedological, Petrographical, Mineralogical, Stratigraphical, Cultural, and Geological.

Level of scientific interest/notes about the interest: Scale and brief description of the selected interests.

Contextual information (other relevant information concerning the geosite)
Contextual interest: Cultural, Sports, Educational, Landscape, Geohazard, Climate change, Historical, Speleological Naturalistic.

Characteristic elements:

- Lithology: type(s) of rock and/or superficial deposits and name of the related geological unit.
- Chronostratigraphy: name of the chronostratigraphic unit according to the International Commission on Stratigraphy
- Age of the process: geological time interval represented by the contents of the geosite.
- Land use: Wood, Cultivated Terraced, Savage Meadow, Urbanized Infrastructure, Rock Debris.
- Shape typology: Single, Multiple, Complex, System.
- Shape: Point, Line, Areal, Mixed.
- Exposure: Natural, Artificial, Property, Public, Private, Mixed.
- Property: Public, Private, Mixed.

Existing legal bonds:

- Legislation level: local, regional, national, international.
- Inclusion and typology of the protected area: National-Regional Park, SIC, ZPS, Wetland, Cultural site.
- Category of legislation regulating the area: Landscape and Planning, Geological, Urban planning, Cultural, Nature.

Information about the location of the site:

- District
- Municipality
- Locality
- Details
- Coordinates (East)
- Coordinates (North)
- Reference: WGS84, UTMED50, Gauss-Boaga Geographical
- Type of map including the geosite
- Scale: 1:10.000;1:25.000; 1:50.000; 1:100.000; 1:250.000; 1:500.000

Cartographic information

- Author of the map
- Data of publication
- Title or caption
- Reference

- Typology: Topographical, Geological, Geomorphological, Other.

Bibliographic information

- Authors: compiler of the information
- Year of publication
- Title
- Magazine or book
- Publisher
- Pages

Iconographic information

- Authors: compiler of the information
- Data of publication
- Title or caption
- Reference
- Typology: Printing, Digital, Slide, Other
- Accessibility information
- Information on hazards-natural impacts
- Information on natural vulnerability-human impact
- Mitigation suggestions
- Valorisation suggestions

The Evaluation

The Evaluation sheet considers and includes preliminary scores given from the field analysis ranging from:
0: Min score, lower interest, or value;
1: Max score-highest interest or value.

Scores are attributed with selected intervals: 0, 0.33, 0.67, 1.

Scientific evaluation:

- Integrity: state of conservation of the site. Bad conservation may be due to natural or human factors.
- Rareness: this concerns the rarity of the site with respect to a reference space. The criterion serves to identify exceptional landforms in an area.
- Representativeness: this concerns site exemplarity, used with respect to a reference space
- Other geologic interests: ones which are different from the previous one already described
- Palaeogeographical value: if any
- Existing scientific publications related to the site
- Notes

Educational evaluation

Educational value: educational tools developed in connection with the geosite.
Publications: publications with an educational purpose.

Aesthetic evaluation

It concerns the "scenography" of the geosite, in terms of contrast with surrounding landscapes, number of viewpoints and development and structuring of the form. It includes:

- Visibility: evaluating the visibility of the site
- Contrast: evaluating the chromatic contrast of the geosite with the environment
- Point of view: evaluating the number and the distance of the point of view
- Landscape relevance: evaluating if the landscape around the geosite could be relevant for running interpretation activities or preservation measures

- Obstacles: evaluating if there is an impact created by obstacles, old useless structures at the geosite.

Ecological evaluation

- Ecological value: this concerns the ecological importance of the site and if the site is protected by national or regional laws.
- Protected area: the geosite is included in a protected area.

Historical and cultural evaluation

- History: historical evaluation of the geosite
- Religion: religious aspect within the geosite
- Art and literature: the geosite have been a source of inspiration for art and/or literature.

Accessibility evaluation

- Access: evaluating accessibility to the geosite by car
- Distance on foot: evaluating the distance on foot if the geosite is not directly accessible by car
- Difficulty of access: evaluating the difficulty considering Alpine Italian Club standards
- Disabled access: evaluating if it is accessible for disabled people
- Food services and overnight stays: evaluating the possibility for services related with food and accommodation.

Hazards, Vulnerability, Human Impact

- Hazards: the active and/or potential natural processes which could affect the geosite. This includes geological, geomorphological and meteo-hydrological processes
- Natural vulnerability: evaluating at what scale the geosite is vulnerable to natural hazard phenomena
- Human impacts: evaluating the anthropic actions impacting the geosite.

4.3.2- Geosite provisional classification, Phase 1-Action 1.

The above-mentioned description and evaluation form have been applied to selected geosites in the Sesia and Magma Geoparks. This chapter describes the application of said database from the University of Turin, to the Eigerøy geosite in the Magma Geopark (Annex 4).

I have applied this provisional classification to all geosite but I have decided to describe here only the application to one geosite, however all the other classifications are visible in the Annex 4.

The Scientific information of this geosite reveals three main fields of interest in order of importance: geological, petrographic, and mineralogical.
The geosite is a "mixed" geosite in an area of approximately 5 km in length and 3 km wide (Rectangular of Inclusion, Fig. 15), which includes eight stops detected by the geopark as the most representative spots, as described in the Magma Geopark Application (Wilson, 2006).

The Eigerøy geosite is in an area characterised by prevailing magmatic rocks of anorthosite composition: the rock is an anorthosite with orthopyroxene mega crystals, associated with brecciated anorthosite, which is representative of the Geopark's main geological features.

Figure 15, Map of Eigerøy geosite

The geosite is easily accessible by car or by bike but the overall geosite can only be visited on foot and is not accessible to the disabled people; the National Norwegian Outdoor Organization scale considers the geosite easily accessible for tourists.

The Integrity, Rarity, and Uniqueness of the geosite are deemed excellent. In terms of Integrity, the geosite features magmatic breccia, diorite and anorthosite, which has high value of representativeness for the Geopark. In fact, the magmatic breccia is the result of intrusion of noritic magma breaking up recently solidified anorthosite.

The site is also interesting from a cultural, ecological, and natural point of view (it is a protected area) and it includes elements of paleogeographic value.

Educational material such as the Geopark App, educational sheets and a webpage are provided (https://magmageopark.no/en/discover-experience/locations/eigeroy-fyr/).

Visibility is excellent in the geosite: there are no artificial or natural obstacles at the geosite. In addition, the site is not vulnerable to external natural phenomena, anthropic or natural.

4.3.3 The geosite classification of the Geological Survey of Norway

Genesis

During the last five years, the Geological Survey of Norway (NGU) has been developing an online database, where each detected geosite is classified following chosen categories (NGU, 2017).

The overall work is based on solid analysis background based on previous and current geosite classification approaches which included several aspects further than the "geological" ones, like: the cultural, the natural and other scientific additional values which can be related with a geosite (Erikstad 1997; Directorate for Cultural

Heritage 2000; Reynard, Fontana, Kozlik, Scapozza 2007; Erikstad 2008; Fernández, Timón & Marín 2014; Brilha 2016; Gatley & Parkes 2018).

The database is an on-going project; however, due to the recent New Norwegian Legislation concerning the Nature Management: the new legislation is called the "Nature Diversity Act, and replaces the "Nature Conservation Act" from 1972: *a dominant part of the documentation concentrates on biodiversity, habitats and species, it also consists of some important improvements for geoconservation* (Erikstad, 2010).

Following the recommendation given, the current priority for NGU is to align their geosite classification and webGIS within the general National classification given for natural management developed by the Norwegian Biodiversity Information Centre (NBIC). The new classification system is divided into a set of classifications on different scales, and it reflects a higher degree of integration of geological and ecological features. (NBIC,2010).

NGU is now working on aligning the database classification in use to the ones defined for natural heritage, rather than adapting to an international "geologically-oriented" system for the comparison of geosites between different Countries (Erikstad 2014).

NGU has recently divided the entries in the database between "geotope": "a *delimited area with a given geological composition can be characterized as a geotope. This may belong to a common or rare type. Some are valuable by virtue of being unusual in Norwegian nature and / or vulnerable and threatened. Such sites can be valued according to a general methodology. (geotope value)*", These areas where specific protection management should be prioritised due to its rarity and risk of extinction red listed species are included in the habitat): their geological values are also relevant for the protection of biodiversity.

On the other hand, the "geological heritage" includes objects of special, qualitative value, for science, teaching, and experiences. A limited area that represents part of our geological heritage can be characterised as a geosite: such sites can be valued according to an expert-oriented methodology (geosite value). The geosites are also assessed for their importance for science, education and tourism, with several parameters assigned for each value. (Angvik, Dahal, *et alia*, 2020)

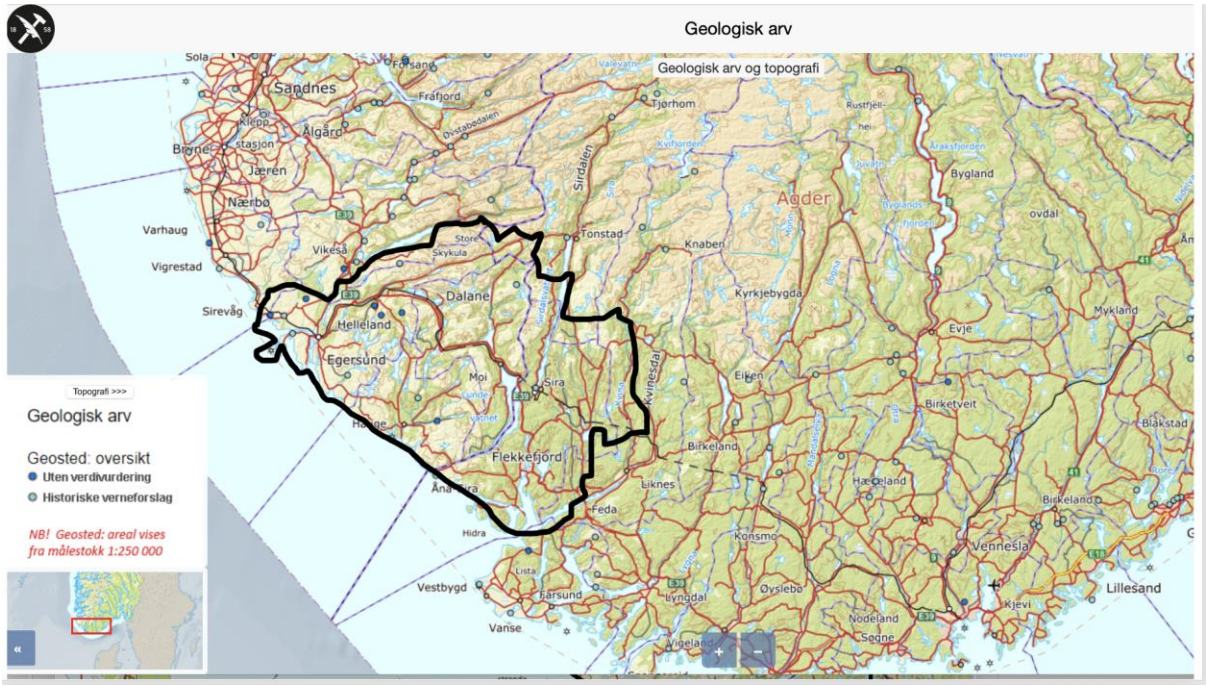

Figure 12: MGp in the NGU database, [online]. Available at (https://geo.ngu.no/kart/geologiskarv_mobil/).

Description of the categories in the database

Starting from the analysis of the classification adopted in the database, some considerations are possible concerning the categories in use which are listed below.

Information inventory- included into the metadata.
Compiler: name of the person in charge of the compilation.
Authority compiler: In case an institution is in charge of the compilation.
Date of compilation.
Shape typology
Data acquisition: Survey/Bibliography.

Included into the metadata:
The Geosite or geotop name: Topographical name of the site
Municipality: Municipality where the site is located
County: Region where the site is located
Coordinates: The coordinates of the site
Comments: Any further notes regarding the site
Pictures.

Geosite-Geotop main geological category:
Bedrock
Pre quaternary landscape
Quaternary

Different subcategories:
Stratigraphy
Geomorphology
Sedimentology
Palaeontology
Mineralogy
Paleoenvironment
Hidrogeologi
Tectonic
Magmatic
Metamorphosize
Geobiosphere
Geochronological
Submarine
Geohazard
Georesource
Culture
History of Earth

Geological time: Era and Period

Conservation and Visibility, NGU defines good condition if the landform (geosite and geotope) has not been affected by, for example, from road construction that breaks the shape of the whole. It is not necessarily the case that artificial intervention automatically reduces the condition: in fact it may be that quarrying in an area may have revealed qualities in the rock that have given very important information for defining a geosite in the first place, since things that were previously invisible have become visible. "Condition" is also linked to an observation point, where the condition of further interventions can be changed in comparison with how intact the geostate was before any interventions were made.

Other values: site suitable for education, science or tourism.

Quality: NGU database is differentiating between geotope values, (value of geological sites important for biodiversity which are following the natural value) and the so called “geosite values” (value of geological sites

with an inherent geological value). The latter is assessed for their importance for science, education, and tourism, with several parameters assigned for each value. (NGU 2020)

Supporting data field, includes:
Other values than geological (natural, cultural, infrastructure)
Natural treat
Human treat
Level of treat
Need for management
Type of management
Protection status
Need for protection
Accessibility

In general the **Protection status description,** are developed following the data provided by the database of the Norwegian Environmental Agency (Miljødirektorate, 2019), whether the site in question is under some kind of legal protection (e.g. national park, protected sites etc.), and whether conservation, management measures are taken or mentioned in the protection documents.

Natural Treat, Human Treat, Need for management and type of management requested are categories which are linked with the classification and definitions of geotope and geosite. Geotop are classified following their conservation status and threats and management needs are consequently assessed.

Accessibility (by walk) is divided into the following categories
Easy
Accessible with challenges
Difficult
Not considered

The **Description field** includes**:**

References: main references from scientific literature.

PDF generert: 2021-11-19

NORGES GEOLOGISKE UNDERSØKELSE

GEOHERITAGE

Geosite: Eigerøy
Last updated: 12.01.2016

LOCATION

Municipality	:Eigersund (1101)
County	:Rogaland
East (UTM 33N)	:-28520
North (UTM 33N)	:6515849

COMMENTS
The area is continuous and does not consist of several parts. The position is within the area, but it is not necessarily the most representative.

PHOTOS
Not registered

PROTECTION AND USE

Protection status	:Not protected
Protection status description	:
Dicipline	:
Potential use	:
Typology	:

DESCRIPTIONS

GEOLOGICAL DESCRIPTION (only Norwegian)
På den nordlige del av Eigerøy er det to drumliner, en ved Skadberg, og en ved Myklebust. Drumlinen ved Myklebust er den største. Den er 1,1 km lang og 300 m bred, og den rager høgt over det omgivende terreng. Drumlinen ved Skadberg er 550 m lang og 150 m bred, og den rager også høgt over det omgivende terreng. Begge har en lengdeakse i SV-NØ - lig retning.

Drumlinene på Eigerøy er, sammen med drumlinene på Karmøy, de mest markerte i fylket. Det knytter seg i tillegg store nasjonale og internasjonale vitenskapelige interesser til Eigerøy-drumlinene, idet det her ble funnet at de ikke utelukkende består av morenemateriale.

I et snitt i Skadberg-drumlinen (grustaket) ble det funnet 3 forskjellige morenelag, det ene over det andre. Under disse ble det funnet lagdelte sedimenter som er tolket å være havavsetninger og strandavsetninger.

Pollenkorn i de to underste (eldste) morenene viser at de må være eldre enn siste istids maksimum. Den underste morenen er avsatt av en bre som beveget seg i samme retning som lengdeaksen på drumlinen, mot SV. Men morenen over er avsatt av en bre som beveget seg mot SØ, dvs. kom fra Nordsjøen! Den øverste morenen er igjen avsatt av en bre som beveget seg mot SV.

Sedimentene under morenene viser at havnivå forut for siste istids maksimum var omtrent som idag, dvs. ingen isostatisk nedpresning av jordskorpen. Noe lignende er funnet på Karmøy.

Det vil være uhyre viktig for norsk kvartærgeologi at drumlinene på Eigerøy blir oppbevart for ettertiden. Det står enda en del igjen før en helt kan tolke det en har funnet der. F.eks.:
1) hvorfra kom isen som beveget seg mot SØ?
2) når var havnivå så lavt som idag?
3) hvordan er dynamikken i en is som former ut forskjellige typer sedimenter en ryggform?
Riksveg 502 krysser Myklebust-drumlinen, og går delvis oppå og langs den. Begge drumlinene er bebygd og oppdyrket. Der er et lite grustak i SV-enden av Skadberg-drumlinen. Sommeren 1985 så del ut til a være nedlagt.

REFERENCES

ARCHIVE REFERENCE

ARCHIVE	ARCHIVE KEY
Regional proposals for protected areas of quartenary deposits	E2

REFERENCE ARCHIVE NGU
Anundsen, Karl Sollie ; Holst, Ivar 1987. Forslag til vern av kvartærgeologiske områder og forekomster i Rogaland.
Miljøverndepartementet. Rapport. Rapport (T-678). 129
Abstract:
Innhold: 1.Innledning 2. Utvalg og prioritering av vern 3. Kvartærgeologisk historie i Rogaland 4. Geomorfologien i Rogaland 5. Omtale av jordarter og formelementer 6. Beskrivelse av verneforslag

OTHER REFERENCES
Garnes, K., 1976. Stratigrafi og morfogenese av drumliner på Eigerøya, Rogaland. Arkeologisk Museum Stavanger. Skrifter No 1.

URL:http://geo.ngu.no/api/faktaark/geologiskarv/visGeologiskArvOmr.php?more=false&p_objid=21038&lang=eng

Figure 13 Ex. from the NGU database, Eigerøy geosite description in Magma Geopark,, [online]. Available at (https://geo.ngu.no/kart/geologiskarv_mobil/)

4.4. Review of the two Geosites classification system Phase 2, Actions.

Starting from the above-described classification methodologies, the research group has compared the criteria for geosite classification adopted by the University of Turin (UniTo) (Chapter 4.3.1) to the one in use in the Norwegian database for geosite classification (Chapter 4.3.3). A detailed comparison of the criteria in use in the two-classification schema has been carried on: the result of the comparison and discussion led to the first research product, a new database where different criteria from the two initial systems merged (Orange-Outcome-Phase2).

4.4.1 Criteria analysis, interpretation, and final selection. (Annex 1, Sheet 1-2-3).

The methodology adopted started from the analysis, interpretation of the selected category in each of the two methodologies. The categories were detected, each one was analysed and then merged. (Annex 1, sheet 1)

The first eight categories detected and merged from the two databases are (Fig.3):

1. Information inventory
2. Metadata, including pictures, literature, and map
3. Shape typology, the geosite type: punctual, linear, areal, viewpoint or landscape

4. Type of geosite, categorizes the geosite following its main geological characteristics, based on the international scientific level of interest.
5. Scientific interest aims to describe the most relevant geological characteristics of the geosite.
6. Geological environment, t sub-category includes a list of lithological units adopted by IUGS,
7. Geological Era
8. Geological Period

Information inventory	Metadata	Shape typology	Type of geosite	Scientific interest	Geological environment	Era	Period
	Picture	Point	Bedrock	Stratigraphic	Glacial	Precambrian	Quarternary
	Paper	Line	Pre quarternary landscape development	Geomorphological	Fluvial	Paleozoic	Tertiary
	Map	Area	Quarternary	Sedimentological	Coastal	Mesozoic	Cretaceous
		Viewpoint		Paleontological	Marine	Cenozoic	Jurassic
		Landscape		Paleoenvironmental	Chemical dissolution		Triassic
				Tectonical	Subsurface magmatic		Permian
				Magmatic	Slope movement		Carboniferous/Pennsylvanian
				Metamorphical	Other		Carboniferous/Missiddippian
				Geobiosphere			Devonian
				Geocronological			Silurian
				Submarine			Ordovician
				Geohazard			Cambrian
				Georesource			Precambrian
				Geocultural			
				History of science			
				Pedological (soil science)			
				Climate change			
				Petrographical			
				Mineralogical			

Table 3 Seven categories from the two databases analysed, Gentilini S. (2022), White: common categories, Light yellow: categories not included in the UniTo database, dark yellow: categories not included in the NGU database.

Seven other categories detected and merged from the two databases are (Table 4):

9. Value-ratio: visibility of the geological main process.
10. Existing Dissemination is related to the dissemination materials available.
11. Conservation, site conservation.
12. Visual Value, visibility of the geological process.
13. Other values, than geological values

Value- ratio	Existing Dissemination	Conservation S	Visual Value	Other values	Natural treats	Human treats	Level of treat
Limited	Leaflets	Limited	Not visible	Historical	Erosion and weathering	Infrastructures	Low
Good	APP	Good	Obstructed	Nature and biology	Overvegetation	Urban infrastructure	Middle
Very good	Virtual Reality contents	Very Good	Good	Urban area and infrasti	Water and flood	Quarring	High
Not valued	App and leaflets	Not valued	Excellent	Sport and ricreational	Landslide	Deposit	Not valued
	Leaflets and VR			Speleological	Icefall	Pollution	
	App,leaflets and VR			Intangible heritage	Other	Scientific sampling	
	Signboard			Other values	None	None	
	Signboard and leaflets					Infrastructure-pipelines	
	Signboard and APP					Urban area	
	Signboard and VR						
	Signboard, APP, leaflets and VR						
	Signboard, App, VR						
	Signboard, APP, leaflets						

Table 4, Five categories from the two databases analysed, Gentilini S. (2022), White: common categories, Light yellow: categories not included in the UniTo database, dark yellow: categories not included in the NGU database.

In between the following categories, three are specifically related with the geosites treats in relation with natural phenomena, human pressure, and the treat intensity.

14. Natural treats
15. Human treats
16. Level of treat

Consequently, if the geosite needs protection, the databases introduce other categories which are linked with the necessity of specific management related with the landscape connected with the geosite and specifically to the type of measures needed for the geosite management.

17. Need for landscape management

18. Site manager measure

The status of protection indicates if there are any specific laws concerning the geosite and its preservation, and the category 19 indicates if there is a need for protection.

19. Protection status
20. Need for protection

Level of treat	Need for landscape management	Site manager measures	Protection status	Need for protection
Low	No need	Vegetation	Local protection	yes
Middle	Middle need	Sheilding	Regional protection	no
High	Big need	Cleaning	National	More info required
Not valued	Noone	Protection measures	International	
		Site manager measures	Noone	
		None		

Table 5, Seven categories from the two databases analysed, Gentilini S. (2022), White: common categories, Dark yellow: categories not included in the UniTo database, light yellow: categories not included in the NGU database.

The Table 6 shows four categories more related with the protection measures and management status of the geosite. The need of landscape management is directly connected with the type of measures undertaken by the site managers. The level of protection with the need for protection.

Need for landscape management	Site manager measures	Protection status	Need for protection
No need	Vegetation	Local protection	yes
Middle need	Sheilding	Regional protection	no
Big need	Cleaning	National	More info required
Noone	Protection measures	International	
	Site manager measures	Noone	
	None		

Table 6, the 4 categories from the two databases analysed, Gentilini S. (2022), Dark yellow: categories not included in the UniTo database

The Table 7 shows in white the last 8 databases categories:

21. The level of Accessibility to the geosite on foot.
22. Number of international scientific publications.
23. Most diffuse land uses.
24. Exposure: include either the natural or artificial exposure of geoheritage.
25. Property where the geosite is located.
26. Category of protection, which kind of protection the geosite belongs to.
27. Improvement suggestions for increasing the attractiveness and educational value of the geosite.
28. Lithology.

Accessibility	International scientific publications	Land use	Exposure	Property	Category of protection	Improvement suggestions	Lithology
Easy	None	Wood	Natural	Public	Landscape planning	Info center	acidic igneous material
with some challenges	Between 1 and 5	Cultivated	Artificial	Private	Geological	Leaflets	acidic igneous rock
difficult	More than 5	Terraced	Collection	Mixed	Urban planning	Signboards	alkali olivine basalt
not valued	Stratotipe	Savage			Cultural heritage	App	alkali feldspar granite
		Urbanized			Other	Signpost	alkali feldspar rhyolite
		Rocks			None	Information board	alkali feldspar syenite
		Debris				Virtual Contents	alkali feldspar syenitic rock
		Corine					alkali feldspar trachyte
		Reference					alkali feldspar trachytic rock
		Landcover					amphibolite
		Pasture					andesite
							anorthosite

Table 7, Seven categories from the two databases analysed, Gentilini S. (2022), White: common categories, Light yellow: categories not included in the UniTo database.

From the preliminary analysis, and from the tables below, it is possible to detect the following common parameters between the two databases (Annex1 sheet 2), Table 7.

1. Shape typology
2. Scientific interest
3. Era
4. Period
5. Value-ratio
6. Conservation
7. Visual Value
8. Other values
9. Natural threats
10. Human threats
11. Level of threat
12. Need for landscape management
13. Site manager measures
14. Protection status
15. Need for protection
16. Accessibility
17. Land use

Information inventory	Shape typology	Scientific interest	Era	Period	Value- ratio	Conservatior	Visual Value	Other values	Natural treats	Human treats	Level of treat	Need for landscape management	Site manager measures	Protection status	Need for protection	Accessibility	Land use
	Point	Sedimentological	Precambrian	Quarternary	Limited	Limited	Not visible	Historical	Erosion and weathering	Infrastructures	Low	No need	Vegetation	Local protection	yes	Easy	Pasture
	Line	Paleoenvironmental	Paleozoic	Tertiary	Good	Good	Obstructed	Nature and bio	Overvegetation	Urban infrastructure	Middle	Middle need	Sheilding	Noone	no	with some challenges	
	Area	Tectonical	Mesozoic	Cretaceous	Very good	Very Good	Good	Urban area an	Water and flood	Quarring	High	Big need	Cleaning		More info required	difficult	
	Landscape	Magmatic	Cenozoic	Jurassic	Not valued	Not valued	Excellent	Intangible heri	Other	Deposit	Not valued	Noone	Protection measures			not valued	
		Metamorphical		Triassic				Other values	None	Scientific sampling			Site manager measures				
		Geobiosphere		Permian						None			None				
		Geocronological		Carboniferous/Pennsylvanian						Infrastructure-pipelines							
		Submarine		Carboniferous/Missiddippian						Urban area							
		Geohazard		Devonian													
		History of science		Silurian													
		Petrographical		Ordovician													
		Mineralogical		Cambrian													
				Precambrian													

Table 8, Common categories from the two databases analysed, Gentilini S. (2022).

There are 7 categories from the NGU database which are not included into the UniTo database (Annex 1, Sheet 3) and Table 9:

1. The “viewpoint” subcategory within the geosite´s shape typology
2. The type of geosite: its classification based on the level of interest in the international scale.
3. Level of threats
4. Need for landscape management
5. Site manager measures
6. Protection status

7. Need for protection

Missing UNITO							
	Shape typology	Type of geosite	Level of treat	Need for landscape management	Site manager measures	Protection status	Need for protection
	Viewpoint	Bedrock	Low	No need	Vegetation	Local protection	yes
		Pre quarternary landscape development	Middle	Middle need	Sheilding	Regional protection	no
		Quarternary	High	Big need	Cleaning	National	More info required
			Not valued	Noone	Protection measures	International	
					Site manager measures	Noone	
					None		

Table 9, Categories from NGU database not included into the UniTo database, Gentilini S. (2022)

11 detected categories within the UniTo database, are not considered by the NGU (Annex9, sheet 4) and Table 10:

1. Metadata
2. Scientific interest (Pedological and climate Change)
3. Geological environment categories.
4. Other values: sport and speleological
5. Natural threats: landslide and icefall
6. Human threats: pollution
7. Land use
8. Exposure
9. Category of protection

Scientific interest	Geological environment	Other values	Natural treats	Human treats	Protection status	Land use	Exposure	Category of protection
Pedological (soil science)	Glacial	Sport and ricreational	Landslide	Pollution	National	Wood	Natural	Landscape planning
Climate change	Fluvial	Speleological	Icefall		International	Cultivated	Artificial	Geological
	Coastal					Terraced	Collection	Urban planning
	Marine					Savage		Cultural heritage
	Chemical dissolution					Urbanized		Other
	Subsurface magmatic					Rocks		None
	Slope movement					Debris		
	Other					Corine		
						Reference		
						Landcover		

Table 10, Categories from UniTO database not included into the NGU database, Gentilini S. (2022)

4.4.2 Results: the geosite´s classification schema, Outcome1, Phase 2 (Annex1, Sheet 6)

After a detailed review of each category detected in the two databases, the final common geosite´s classification scheme and provisional database for geosite´s assessment have been developed, including eleven main redefined categories.

1. Geographic information
2. Type of geosite
3. Geological Time
4. Representativeness
5. Quality
6. Enhancement potential
7. Supporting data
8. Landscape
9. Lithology
10. Description
11. Reference

Each chosen category can be explained as follows:

"**Geographic information**" describes the name of the locality and the coordinates.

The first database category is "**Geographic Information**". It includes: the Name of the geosite, the Coordinates (West and North), the UTM zone, and the "shape typology" related to the typology of the geosite.

The "shape typology" has been divided into these subcategories:

- Point, Line, Area, Landscape, Viewpoint, and "Complex area", depending on the type of geosite.
  The "Complex area" defines an aerial geosite which is composed of several points of interest.
  The "Viewpoint" aims at describing if the geosite could also be considered as a "viewpoint", while the "complex area" describes if the geosite includes both areal and punctual points of interest.

"**Type of Geosite**" categorizes the geosite following its main geological characteristics, based on the international scientific level of interest. It allows classification of the main contents of the geosites, the related scientific interests and the dominant geological environment. It includes information concerning the following subcategories:

"Main type" of rocks in the geosite, which indicates the prevailing type of rocks characterizing the geosite. The related subcategories are the following:

- Bedrock
- Pre-Quaternary landscape development
- Quaternary

"Scientific interest" aims to describe the most relevant geological characteristics of the geosite. It includes three possible options. In order of importance, these characteristics are:

- Stratigraphic
- Geomorphological
- Sedimentological
- Palaeontological
- Mineralogical
- Paleoenvironmental
- Hydrogeological
- Tectonic
- Magmatic
- Geobiosphere-related
- Geochronological
- Submarine
- Geohazard-related
- Georesource-related
- Geocultural
- History of science-related
- Pedological

Compared to the previous classification, the list of "Scientific interest" categories has been updated with two new categories: Pedology (Soil Science) and Climate Change (geosites with specific contents on climate studies).

The Geological environment sub-category includes a list of lithological units adopted by IUGS, as follows:

- Glacial
- Fluvial
- Marine
- Eolian
- Chemical dissolution-related
- Subsurface metamorphic
- Subsurface magmatic
- Slope movement-related
- Other

"**Geological time**": includes Eon, Period, and the Geological Unit.

"**Representativeness**" includes visibility at regional and national level and concerns "*the appropriateness of the geosite to illustrate a geological process or feature that brings a meaningful contribution to the understanding of the geological topic, process, feature, or geological framework*" (Brilha, 2016).

It includes the geosite representativeness at regional and national levels, and a scale for the visibility of the geological processes within the geosite.

The category describes both the importance and favourable conditions of a geosite in providing a good representation of a type of feature or system.

The subcategories "National" and "Regional" can be explained as follows:

"National representativeness" refers to features which are considered important for understanding the whole geological and geomorphological setting and/or history of a Country.
"Regional representativeness is a characteristic of geosites featuring landforms or rock types of outstanding significance in the context of what occurs in broad areas typical of a Region (Sharples, 1993).

The "visibility" sub-category, deriving from the UniTo classification, measures how visible the main geological processes are and how easy it is to understand them. It is divided into the following attributes, which define in detail how good the "visibility of the process" in the field is.

As stated above, the "visibility" attribute, measures how favourable the conditions of a geosite are in visualizing the main geological processes and understanding them. Visibility is "limited" when there are no visual traces which can explain the main geological processes; "good visibility" is when the geosite offers a certain level of understanding for specialists, while the "very good" grade is given when an explanation is provided to everyone, also to non-geologists.

"**Quality"** is a combination of several factors (Evidence-Perception, Rarity-Uniqueness, Conservation Status, Visual value) which contribute to the overall scientific relevance of the geosite.

- Evidence- Perception: , measuring how visible the geological process is;
  Among the "quality" factors of a geosite, both "evidence" and "perception" are related to landscape attributes. Evidence informs about the visibility of the geosite, "perception" expresses the higher possibility to individualize the geosite through geomorphological evidence and/or color contrasts within the landscape (Reynard *et al.*,2007).

- Rarity-Uniqueness:, aimed at assessing how rare it is: it is the number of geosites in the study area presenting similar geological features (Brilha, 2016). The criterion serves to identify exceptional landforms in an area (Coratza *et al.,* 2018).

- Conservation Status: related to the current conservation status of the geosite, considering both natural processes and human actions (Brilha,2016). It defines the integrity and grade of preservation of the geosite. The scale includes "Poor": the geosite is not preserving any original characteristics due to natural degradation or human activities; "Average": the geosites characteristics are visible to geologists or trainees; "Good": the geosite has very good quality and can easily be recognized by everyone.

- Visual Value. relates to the quality of the geosite; it shows how easy it is to see the geosite in the surrounding landscape. The "Visual value" scale is divided into: "Not Visible", "Obstructed", "Good" and "Excellent". The "Not Visible" choice occurs when the geosite is not visible in the landscape to a non-expert audience; "Obstructed" describes a geosite which could eventually become visible if the obstacle were removed; "Good" visual value is when the geosite can be seen by a geologist or trainees; "Excellent" visual value is when a geosite can be seen in the landscape by everyone.

Enhancement potential expresses the potential for development of each geosite in terms of Education, Tourism, Research, and adding some improvement suggestions for better expressing the potentialities in connection with the geosites destination of use.

The category includes subcategories “Tourism”, “Research” and “Education” with the aim to evaluate the “potential” best use for the geosite. The ranking values are: “Limited”, “Good”, “Very Good”. The enhancement category also includes subcategories “Existing dissemination” and “Improvement Suggestion”.

In Education and Tourism, the “Limited” value corresponds to the limited potential of the geosite when it is not accessible and/ or when the visual value is very low; the “Good” scale relates to the possibility of using the geosite in connection with extra explanations, the “Very Good” category is for a self-explaining geosite, both in education and tourism.
Research potential: “Limited” values correspond to a geosite which is not interesting for the scientific interpretation of the area; “Good” is for a geosite which has the potential to support existing research; “Very Good” has the potential for opening to new research or upgrading existing, ongoing research which can lead to scientific papers.
“Existing dissemination” as a new category is related to the dissemination materials available to the public (visitors, students, inhabitants, researchers, etc).

The “Improvement suggestion” field has been added to give space to potential improvements of the geosite. Suggestions for geosite improvements include a new Geopark info-centre, leaflets, a signboard, an App, virtual reality, an information board, and “other”.

Supporting data includes values other than the geological value of the geosite and it includes several topics related to the management of the geosites:

- Other values: the “Other values” subcategory describes geosite values other than the geological heritage, such as those related to: Natural Sciences, Biology, Archaeology, Urban areas and Infrastructure, Speleology, History, Intangible Heritage, Education, and Sport.

- Natural threats: express threats of nature to the geosite, such as vegetation or erosion. “Natural Threats” to the geosites of both geoparks include “Erosion and weathering”, “Over-vegetation”, “Water and flood”, and five more types of threats: “Landslide”, “Wildfire”, “Icefall”, “Rockfall”, and “Other”. The category “Wildfire” was especially relevant for both geoparks, taking into consideration recent effects related to climate change both in the European Alps and in Norway.

- Human threats: express the anthropic pressure on the geosite, such as urbanization or pollution.Within “Human Threats”, subcategories included are “Infrastructure”; “Urban area”, “Overloading”, “Quarrying”, “Landfill”, “Pollution” and “Change of Land Use”.

- Level of threats: express at what level the geosite is in danger, if some special management measures are needed, and what type. For a qualitative assessment of both the “Natural” and the “Human” threats to geosites, “Low”, “Medium”,” High” or “not valued” attributes are possible within this category.

- Need for management: shows if the geosite requires specific management measures.

- Type of management: indicates which actions are required for a geosites use and valorisation.

Because of their recognition and preliminary assessment, suggestions for possible interventions to limit “threats” to geosites are indicated within the “need for management” and “type of management” categories. These have been adopted from the NGU classification to use the level of threats (natural or human) for linking the “protection status” with the “need for protection”. As an example, based on different levels of threats within an area characterized by over vegetation, different “preliminary management measures” are possible, such as: “Cleaning from vegetation”, “Physical protection”, “Safety measures”. The database thus provides quick and easy preliminary classification, useful for reporting information to the management of the site.

- Protection status: indicates if there are any active protection measures on the geosite, and what type of measures they are. This also includes the need for protection, in case the geosite is not protected but its rarity and level of pressure are relevant.

- Geosite accessibility: The category has been adopted taking into consideration the possible options of direct access to the geosite on foot: “Universal” access (including disabled), “Easy” access (for kids and elderly people), access with “some challenges” and “Difficult” access (experts)”.

- Number of scientific publications: a new category which is the number of peer-reviewed scientific publications is the criteria for being assessed by the International Union of Geological Science (IUGN) as a geosite having international value.

Landscape analyses the overall landscape around the geosite and is divided into the following subcategories:

Land use: the main type of use of the land where the geosite is located.
Exposure: defines the natural or artificial type of landscape. It indicated to include either the natural or artificial exposure of geoheritage. Therefore, the "collection" choices address all the cases where geological heritage is part of a museum or exhibition which needed to be distinguished rather clearly from natural exposures, caves or artificial quarries.
Property: is about the geosite property, private or public.

The category has been added in order to better locate the geosite within a territorial framework and to follow an eventual need for landscape planning, by means of the "Land use", "Exposure" and "Property" subcategories. All three categories have been taken from the Italian classification and adapted to the NGU standards.

The "**Lithology**" category was added as new ones, adopted following the classification provided by the International Union of Geological Science. (IUGS).

To conclude, five main new categories have been added to the final database (Annex 1, Sheet 5), Table 11:

1. Existing dissemination
2. Improvement suggestions
3. Property
4. International Publication
5. Lithology

The "existing dissemination" is referring to the present status of the dissemination tools, the existence of leaflets, App, Virtual reality tool and signboard have been considered. The database also includes the possible combination of the 4-dissemination material´s categories.

The "Improvement suggestions" category has been considered very relevant for the general interpretation of the geosites, especially considering the values and role of UGGp. The same categories for "existing dissemination" have been included.

Property: private or public ownership of the geosite influences its development and the overall development strategy of UGGp.

International Publication: The International Scientific Publications have been considered in the assessment, due to their importance for becoming and UGG: publications is the criteria for being assessed by the International Union of Geological Science (IUGN) as a geosite having international value.

The "Lithology" category was adopted following the classification provided by the International Union of Geological Science. (IUGS). Under the auspices of the Commission for the Application and Management of Geoscience Information (CGI), the IUGS Geoscience Terminology Working Group (https://cgi-iugs.org/project/geosciceterminology/) developed internationally accepted geoscience vocabularies for developing geoscience concepts (Richard 2006) being used in geoscience information systems, such as GeoSciML, an XML–based data transfer standard for the exchange of digital geoscientific information. Concerning lithology, GeoSciML includes 265 lithological rock names, hierarchically organised around up to six levels e.g. tholeiitic basalt, basalt, basic igneous rock, basic igneous material, igneous material, compound material (http://resource.geosciml.org/vocabulary/cgi/201211/simplelithology.rdf.) which have been used for developing ontology-driven representation of geological knowledge (Mantovani *et al.*, 2020) (https://inspire.ec.europa.eu/codelist/LithologyValue).

Existing Dissemination	International scientific publications	Improvement suggestions	Property	Lithology
Leaflets	None	Info center	Public	
APP	Between 1 and 5	Leaflets	Private	
Virtual Reality contents	More than 5	Signboards	Mixed	
App and leaflets	Stratotipe	App		
Leaflets and VR		Signpost		
App,leaflets and VR		Information board		
Signboard		Virtual Contents		
Signboard and leaflets				
Signboard and APP				
Signboard and VR				
Signboard, APP, leaflets and VR				
Signboard, App, VR				
Signboard, APP, leaflets				

Table 11, The database new categories in the final database, Gentilini S. (2022)

4.5 Conclusions

Detailed multiscale analyses of text, data, maps, and supplementary materials of two Applications from Geoparks in two different countries allowed to analyse the global, regional, and local dimensions of their geodiversity and highlighted differences and similarities of geological and geomorphological phenomena within their long-term history.

MGp application to UNESCO Global Geoparks is characterised by a pragmatic approach, which underlines the connection between the geological and cultural heritage since the beginning in the Geopark's action plan, which has been developed successfully from 2008 till nowadays.

Since the establishment of the Geopark company in 2006, the development of the geopark localities has been planned to follow a precise schema, a homogeneous heritage interpretation and a valorisation plan, which includes the establishment of two informative panels per location: one with general information about the UNESCO Global Geopark initiative and network and one describing the peculiarities of the specific locations, all in two languages: English and Norwegian.

MGp, in fact, is steadily developing localities taking into consideration the cultural tangible (ex. n.5 Ørsdalen & Gudlen mines and N.30 Gursli & Liland mines & Hattesteinan mines or Titania educational project) and intangible heritage (Amphidromic point, local food trail, Klokkestaina, etc.). Regular meetings with the stakeholders allowed the Geopark to prioritize or to substitute a couple of localities chosen in 2008 with others that have been considered more appropriate for education, tourism, or dissemination purposes.

MGp selected its geosite based on geological international scientific values and mainly considered "Geopark localities", i.e., those geosites "being of interest to the public, not only to a geologist". The operation included geosite classification as by their regional, national, or international interests, use (geotourism, education and science), protection status, availability (restrictions), threats and other information. The staff registered and listed 89 geosites within the Geopark; 58 of these are regarded as "Geopark localities" (Wilson R., 2008).
In Magma Geopark, the plan for geodiversity interpretation is developed and updated every year, and the action plan is continuously updated following most recent achievements and the overall sustainable strategy in place. The Geopark has secured economic support for next four years, as requested by the UNESCO Global Geoparks membership.

Every 4 years, Magma Geopark boards update the Action Plan, and the budget is secured for the following four years, signing bounded agreements with regional and local public stakeholders. Geodiversity is valued through many activities linked with specific projects which follow the company's strategy.

Taking into consideration the management structure, Magma Geopark AS is a private share company that was established before applying as UNESCO Global Geopark as responsible for the management and development of the overall area. Magma Geopark is financed directly by the owners, who are both private and public entities: municipalities, counties and, for 2019 and 2020 by the National Government.

In fact, one of the most important achievements of the last few years was the establishment of the Norwegian Geoparks and Geoheritage Committee for the dissemination of the UNESCO Global Geopark values in Norway. The Committee supports new initiatives of aspiring Geoparks and evaluates new applications before they are sent to the Norwegian UNESCO Commission. (Thjømøe *et al.*, 2014)

In addition, the Committee, with a combined actions involving all policy makers from the three UNESCO Global Geoparks, successfully lobbied for Geoparks to be included in the Governmental budget for the first time in 2019.

The SVGGp application to the UNESCO Global Geopark mostly focuses on the geosites' petrographic description, while the overall cultural and natural aspects of the area are not described in detail.

The SVGGp dossier is divided into several sections where the explanations of the geosite having cultural interest are not integrated with the geosites having scientific value. The "cultural" geosites are presented in a separate table without any connection to the overview of the geological heritage, and with no inclusion of geosites having cultural value in the plan for further development. It seems that, since the beginning, the Geopark staff considered the geological heritage separately from all the other aspects which characterised a UNESCO Global Geopark with no need for integration.

As of November 2021, SVGGp still lacks a valorisation plan for the overall Geopark's area. Only few information panels have been installed in the Sesia valley, while the Val Grande National Park has been working in valorising specific Geopark's related initiatives with no homogenous development plan for the overall Geopark area. Even if the geosites' review has been ongoing since 2018 thanks to the scientific advisory board of the Geopark and preliminary analysis of the geotouristic contents of the SVGGp has been performed (Perotti et al., 2020), a comprehensive action for homogeneous geosites is still lacking. To achieve a clear and unique Geopark visual identity in the Val Grande National Park, new information and road panels have been printed for the 2021 UNESCO revalidation visit. For enhanced geodiversity interpretation, new additional material has been provided by QR codes in the already-mounted panels; said content is accessible in different languages (Italian and English as a minimum; in some cases, also in French and German).

However, the last re-validation mission undertaken in 2021 gave a "yellow" card to the Geopark, underlining the needs for a stronger management structure and related five-year budget.

In SVGGp, the management responsibility is shared by three different institutions: two Regional Parks, one local Association, and one National Park which, now, is the main management body according to internal agreements. Since its establishment in 2011, the Geopark has not built up a management structure: in fact, each Institution involved manages its area of jurisdiction without interacting or the possibility of a common Geopark budget or management body. This leads to a lack of visibility and to a non-homogenous Geopark infrastructure development: under the jurisdiction of the National Park some Geopark actions are undertaken, but they are limited in space and in time, not following any development plan within a five-year framework, as requested to be a UNESCO Global Geopark.

The finance for the UNESCO Global Geoparks comes from different sources and there are no specific funds allocated for its functioning and operational costs. Furthermore, there are no direct employees working for the Geopark, but employees of the parks work a certain number of hours for the Geopark without sharing a clear common working strategy.

At a local level, it is possible to conclude that the existence and use of a specific database for geosite classification supports the development of the Geopark's geosite action plan, which is a mandatory tool for UNESCO Global Geoparks and the effective development of infrastructure. The adoption of the presented database adopted by the managers of the two analysed UGGp will facilitate the development of geosites, their monitoring procedure, the establishment of protection strategies and better interpretation plans.

It is also relevant to underline how the adoption of a common framework for Geosite classification within UNESCO Global Geoparks, would not only facilitate the preparation of the application dossier for membership to the UGGp Network but at the same time it would also support the evaluation and re-validation procedures in charge of the Advisory Committee.

The database for geosite classification, developed as a first research product, is then required to allow an equal evaluation and comparison between geoparks situated in different countries, and to better implement effective action plans which take into consideration geodiversity as a driver for sustainable development.

Chapter 5: Analysis and comparison of existing ecosystem classifications (Phase 3).

The Chapter is describing the third Research Phase: inputs (violet) are given from the abiotic Gray´s broad "abiotic services" definition and their application to the geosites and from the existing biotic ecosystem assessment methodologies and indicators.
Through the inputs, 4 geosites have been selected for further analysis and variables have been detected and described within a specific space and time frame (yellow). First output of the Phase 3 are the abiotic indicators, the application of which, results into the geosite assessment and second research output: the abiotic ecosystem indicator schema and assessment (orange), see Fig. n.1.

The Ecosystem services have been defined as: "*the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life*." (Bawa K. S & Kaufman, 1997; Chan *et al.*, 2006).

During the last decade of scientific research, the crucial role of ecosystem services in maintaining biodiversity and the related productions of goods have been deeply analysed, including the services life support functions both tangible (cleansing, recycling, renewal) and intangible (aesthetic and cultural).

Valuing these services allows managers to implement policies that could lead to maximum benefits for local communities, providing tools for evaluation and eventual risks. (Cooter *et al.*, 2013).

During the last decade, several systems and measurement methods have been developed considering the variable services provided by nature to the human population. This research briefly analyses the main characteristics of the following methodologies: the *Environmental-Economic Accounting (SEEA),* the *Millennium Ecosystem Assessment* and the *Common International Classification of Ecosystem Services (CICES).*

5.1. The System of Environmental-Economic Accounting (SEEA)

In March 2021, the new System of Environmental Economic Accounting (SEEA EA) statistical framework was adopted, allowing countries to measure their natural capital and understand the immense contributions of nature to our prosperity and the importance of protecting it. The SEEA EA takes a spatial approach to accounting, as the benefits a society receives from ecosystems depend on where those assets are in the landscape in relation to the beneficiaries. The system aims at setting up a comprehensive statistical framework for organising data about habitats and landscape, measuring the ecosystem services and their value, linking them with human activities. The United Nation in 2021 defined the system as: "*providing a structured approach to assessing the dependence and impacts of economic and human activity on the environment*" (United Nations, 2021).

However, within the EEA Ecosystem Accounting, nature's abiotic elements are not included in the classification; neither are services related to water filtration and quality. Here, "biomass" is indicated as the main conditioning factor, without mentioning the important roles of soil for drainage and filtration, or the role of bedrock for the water mineral composition which benefits people's health (Fig. 16). However, the EEA does not provide communities, stakeholders, and scientists with an omni-comprehensive system including both bio and geo services.

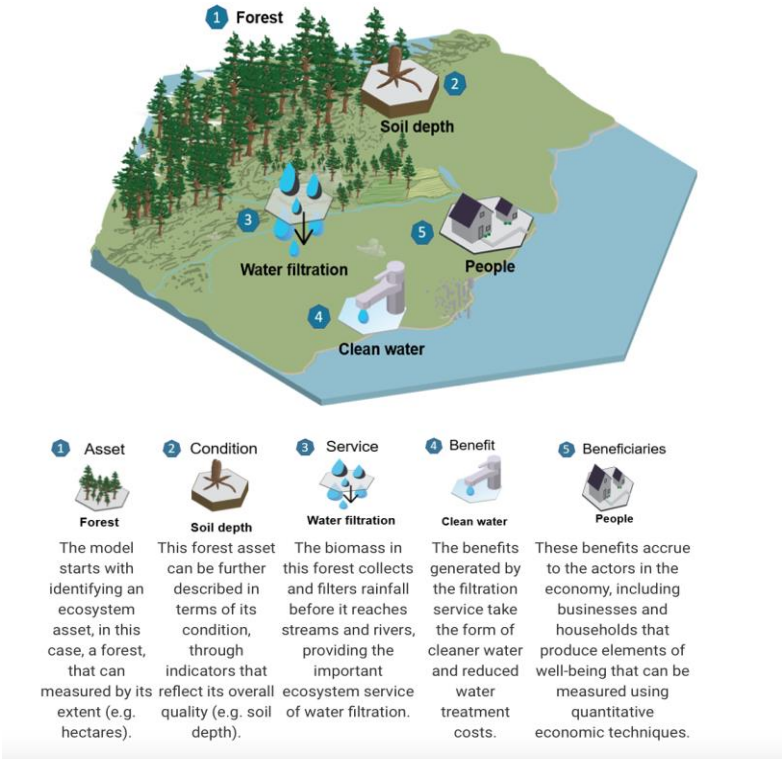

Figure 16, How ecosystem assets generate ecosystem services for beneficiaries in a spatial relationship (United Nations, 2021).

5.2 The Millennium Ecosystem Assessment

In the year 2000, United Nations Secretary-General Kofi Annan called for the Millennium Ecosystem Assessment (MEA) through a report to the UN General Assembly entitled *"We the Peoples: The Role of the United Nations in the 21st Century".*

In 1999, the MEA was initiated and conducted under the auspices of the United Nations, being governed by a multistate-holder board including representatives of international institutions, governments, business, NGOs, and indigenous peoples (MEA, 2005).

The MEA defines and classifies ecosystem services into several categories including provisioning services such as food, water, timber, and fibre; regulating services that affect the climate such as foods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling (Joseph & Alia, 2003).

However, as figure 17 depicts, the categories of ecosystem services and components of human well-being that are commonly encountered are very much linked together. In addition to the influence of ecosystem services on human well-being, other components − including environmental, economic, social, technological, and cultural factors − influence human well-being; ecosystems in turn are affected by changes in human well-being.

The main objective of the MEA (MEA, 2017) was to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being (Fig. 17) (Reid *et al*., 2005).

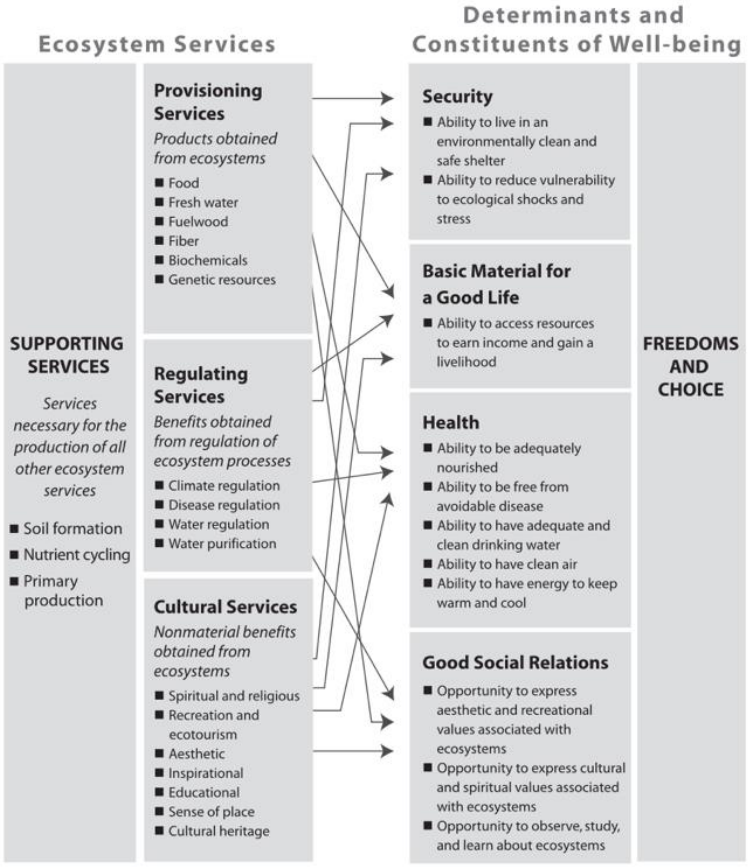

Figure 17 - Ecosystem Services and their Links to Human Well-Being (MEA, 2017)

The MEA classification − later also adopted by the United Kingdom to set up the National Ecosystem Assessment – does not adequately consider the services deriving from geodiversity (Gray,2004). It listed the so-called provisioning services as:
- Food (plants, animals);
- Fibre (wood, wool, cotton, etc.);
- Fuel (wood, etc.);
- Genetic resources;
- Biochemicals & pharmaceuticals;
- Ornamental resources (shells, flowers);
- Freshwater.

Apart from freshwater, all these are in fact biological services but there is no mention of the abiotic elements which guarantee, for instance, the production of different kind of soils (and related food), or the geological processes which are at the base of the hydrocarbon deposits (Fuel) (Schrodt F. et al., 2019) (Reid W.V. et al., 2005). Therefore, the current framework of the MEA cannot be considered a comprehensive strategy which includes both biotic and abiotic nature.

5.3 The Common International Classification of Ecosystem Services (CICES)

The Common International Classification of Ecosystem Services (CICES) has been developed from the environmental research undertaken by the European Environment Agency (EEA), with first edition in 2013, then revised in 2017.

The classification does not take into consideration the so-called “supporting services” as part of the ecosystem services. In fact, within the CICES, the “supporting services” are considered the underpinning elements which

ultimately determine "*the capacity of the ecosystem to deliver particular services that can be represented by concepts other than that of a service, say in terms of measures of ecosystem condition*" (Roy & Potschin, 2018).

The latest version of CICES (v 5.1) includes an annex which lists 35 abiotic services, described as an "extension" of the previous version; however, the document still does not express a clear vision concerning abiotic services assessment in the overall natural system in relation to biotic services (Van der Meulen *et al*., 2016) .

Considering the lack of a comprehensive and balanced classification of biotic and abiotic components of ecosystem services, Brilha proposed an innovative approach where geodiversity and biodiversity are equally important (Brilha *et al.*, 2018). A visual representation of the current relationship between geodiversity and biodiversity within the natural capital and ecosystem services approaches (Fig 18) shows the overlapping area (in yellow) where components of the two "natures" interact (such as water, soils, palaeoenvironments, landscapes, …) or, for instance, the so-called related "provision services" interact. These are examples of the overlap between ecosystem services and geosystem services since construction materials, industrial minerals and ornamental products are mainly derived from the physical Earth without the intervention of any significant role for wildlife.

This comprehensive approach also includes so-called "Geo-knowledge services" deriving from the history of the Earth, the history of geological research − including the results and interpretations of geological, palaeontological, geomorphological, geochemical, geophysical analysis − other methods, and the development of dating techniques (Gray 2011, 2012).

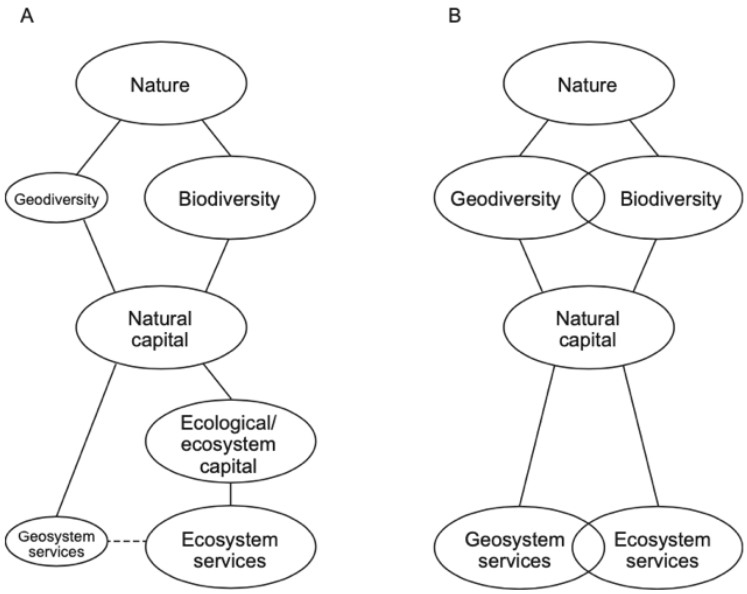

Figure 18 - A) It is showing the Nature and its diversion into Geodiversity and Biodiversity merging into the so called "Natural Capital " made of both Ecological ecosystem capital (from biodiversity) and geosytem capital (from abiotic nature) which are considered as distinctive part of nature, with no interaction between each other.

B) Proposed schema by Gray 2018, where Nature is composed of both Geodiversity and Biodiversity interacting and communicating into each other, the result of that interaction is also reflecting the ecosystem services and geosystem services, this underlines the necessity of specific synergy between abiotic and biotic nature, due to their equal importance for the assessment of natural world and related services.

Several quantitative studies confirm that geodiversity generates profit in terms of direct income and indirect benefit for communities, including those from the appraisal of Geoheritage and Geotourism. More in detail, a regional study estimated Geodiversity as able to attract annual visitor expenditures of £11 million to the Isle of Wight's economy, generating between £2.6 million and £4.9 million in local income and supporting between 324 and 441 full time equivalent local jobs. (Webber *et al.*, 2006).

It is also important to reiterate that the scientific-cultural values of geodiversity cannot be assessed only focusing on the economy, but they should also be addressed to other categories of service. For instance, the services linked

with spiritual or cultural needs are difficult to measure because they are not concretely visible or tangible; however, they have the same value. (Foo *et al*., 2011).

As a matter of fact, geodiversity provides the ecosystem with both extrinsic and intrinsic goods and services to the community; consequently, it becomes crucial to implement a geodiversity assessment within a methodology planning strategy that considers natural resource management.

5.4. The Geosystem services or abiotic ecosystem services

The definition and description of "geosystem" or "abiotic ecosystem services" introduced by Gray 2004,2008,2012,2013; Brilha *et al.*, 2018) underlines the multiple relevant services provided by abiotic nature to the society. His view considers 25 major geosystem services, which result from the fact that the Earth is a geo-diverse complex system (Fig. 19). Following the definitions given, they are divided into five categories:

- Regulating;
- Supporting;
- Provisioning;
- Cultural;
- Knowledge-related;

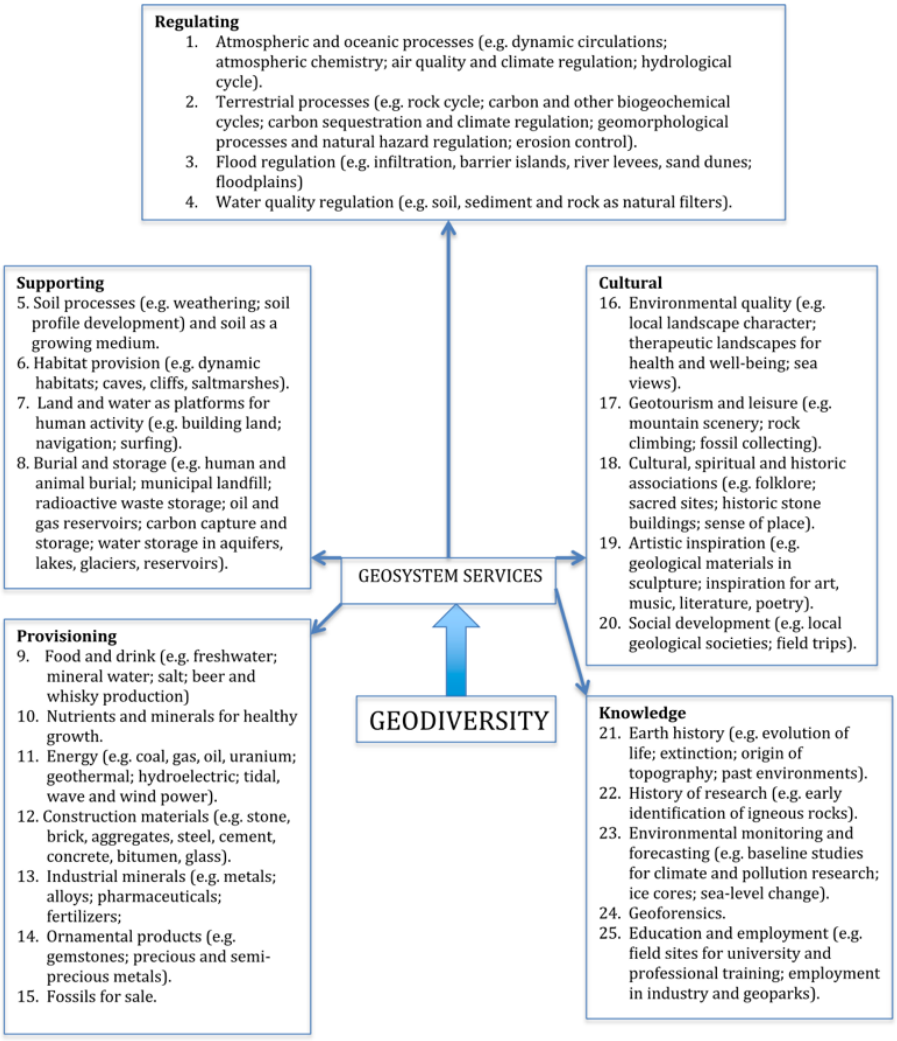

Figure 19 – Five categories of 25 major Geosystem Services offered by Geodiversity (Gray M.,2018)

5.4.1 Regulating Services

Regulating services are those which control the working of the physical environment and thus benefit society by cycling, distributing, or balancing environmental phenomena or materials. Physical processes are important as they create geomorphological landscapes and geological materials and play many other roles that benefit society. For example, the atmosphere and oceans play crucial roles in regulating the temperatures on the planet. Their global circulations redistribute heat away from the tropics and towards the poles; furthermore, the vital role of water cycle and protection from sun radiation is also well known.

This category includes all services related with the atmosphere, oceans currents and hydrological cycle. Gray M. defines them as: "*The combination of oceanic and atmospheric circulation drives global climate by redistributing the heat*".

Terrestrial Processes

Terrestrial processes include: the carbon cycle, the cycle of erosion, transportation, deposition, and the uplift processes that constantly renew the Earth with fresh rocks. Geomorphological processes are also included in this category; however, they have their own regulating functions linked with the mitigation of climate change.

Flood Control

Flood control services, from an abiotic point of view, are ones provided by geomorphological landforms such as beach ridges, river levees or sand dunes. Within these services, physical and ecological processes often act together.

Water quality

Soils and sediments act as "filters", improving water quality and adding minerals and important nutrients; furthermore, in the case of thick layer of not permeable soil, the sediments reduce the possibility of water pollution.

5.4.2 Supporting Services

The geosystem's "supporting services" contribute to human development thanks to the provision of platforms for human activities, rock cycles and soil formation, which are vital processes for agricultural and fishing activities. The geomorphological features are essential in the planning of cities, airports, and dams, while the rock characteristics allow people to better choose sites for storing materials, radioactive waste, or carbon sequestration (Gray M., 2004). Water categories as supporting service includes aquifer, wetlands, rivers, lakes, and soil water.

Soil services

The role of the soil, which is "the biologically active, porous medium that has developed in the uppermost layer of Earth's crust", supports not only plant growth but it also acts as a medium for food, timber and energy crops; it stores and regulates water, supports habitats and energy crops. (Sposito G., 2020)

Habitat provision

This includes some of the most important factors controlling the supporting service in the physical environment: topographic features, lithology and geochemistry influence the temperature and, consequently, the diversity of the bio-habitats.

Platforms

Land surface as a platform for human activities: to each human activity corresponds to a specific land "platform"; said platform takes a different form according to the selected different activities, for example surface for agriculture or platform for industrial building.

Burial and storage

Throughout human history, diverse rock types have been used for burial purposes or as gravestones; some communities also used them for storage.

5.4.3 Provisioning Services

Provisioning services derived directly from the geological resources, like industrial rocks and minerals, metallic minerals, energy materials, gemstones, which are, by definition, not renewable. Water and inorganic nutrients are also related to geological processes, and they have been included both in provisioning and supporting services. Water, within the provisioning service, includes domestic use, agricultural, industrial and energy use.

Food and Drink

Abiotic nature offers drinking water through aquifers, lakes, glaciers, ice sheets, but also food like calcium carbonate and salt.

Nutrients and minerals for healthy growth

Abiotic nature provides all the elements which are essential for plant and animal life; all minerals are obtained from food being derived from soil.

Mineral fuels

Coal, peat and oil deposits come from biotic and abiotic conditions, pressures and certain temperatures.

Construction minerals

Rocks and minerals are more diffused construction materials than timber frames, thatched roofs, and wooden cladding.

5.4.4 Cultural Services and Knowledge Services

Cultural services are defined by Gray M., as the "*value placed by society on some aspect of the physical environment by reason of its social or community significance*".

This category is directly linked with the so-called: "intrinsic values" or "social values" which are not the "economical" values linked with spiritual and cultural values which are very often difficult to quantify. In fact, cultural services relate to people's perception of the world, linked with aesthetic value of a landscape, and the historical or even sentimental value of a place, which is rather subjective and not directly linked with any economic benefits.

These values can be declined in three main types: "intrinsic values", which O'Neill defines as "*the sense of value that exists independently of human valuations"*; "instrumental values", which describe how an ecosystem, in our case a "geosystem" and its services, directly contribute to the beneficiary's wellbeing (Gray M. 2013); and

"relational values", how people relate with nature, in our case "abiotic nature", e.g. shepherds caring for their pastures. These three typologies of "cultural values" are the ones that shape people's perception of the abiotic world and that inform their choice of how to manage it. (Gray M., 2019; Small et al., 2017)

Environmental quality

This first subcategory refers to the visual appeal provided by the diversity of the physical environment, which is characterized by landforms, landscapes such beaches, glaciers, mountains, fjords, cliffs, glaciers, and waterfalls. The simple pleasure deriving from the beauty of natural variety is a service provided to human communities by geodiversity.

Geotourism and leisure activities

So-called "geotourism" is a new form of tourism based on the geological environment; it is quite a new form of tourism, which has been defined as promoting geo-sites and the conservation of geodiversity through visits to geological features, the use of geo-trails and viewpoints, guided tours, geo-activities, and the patronage of geosite visitor centres (Dowling 2014) (Gray2004; 2012).

After the Arouca Declaration (EGN, 2011), "geological tourism" is mostly viewed as one of the multiple elements of geotourism. UNESCO Global Geoparks represents one of the most interesting geotourism initiatives which aims at boosting local economic development also through tourism activities linked with geoconservation and geodiversity, involving local communities within a bottom-up approach (Thiene & Tempesta 2000). The value of this service is in terms of economic, educational and leisure benefits.

Cultural, historical and spiritual meaning

Since the beginning of human development, our ancestors have had a very close relationship with local landforms, geomaterials, and physical processes. Rather early on, humankind started to identify natural phenomena as an expression of mythological powers or giving names to locations related with spiritual and or religious values.

Artistic Inspiration

Geoheritage features, landscapes, and landforms have always been sources of inspiration for artists, writers, musicians, and poets. An example is provided by Harmon when he describes Thomas Moran and the photographer William Henry Jackson in bringing the scenic wonders of Yellowstone to the attention of the U.S. Congress and the public. (Harmon, 2004)

Social development

Activities related with geotourism, educational or geological community events are contributing to increasing people's awareness about the importance of geodiversity in society.

Earth History and History of Research

The study related to geological heritage and geodiversity contributes to increasing knowledge about the Earth history phenomena, understanding the changes along the history of the Earth, and facing new future challenges. One of the reasons for the importance of geological sites is that they contribute to the progress of scientific research.

Environmental Monitoring

Geological formations and geological sediments recording the environmental changes which occurred along the Earth's history. The analysis of the environmental records could help to understand the past but it also supports the understanding of present events and setting up effective strategies for the future.

Geoforensics

The abiotic nature could support geoforensics, which is the discipline connecting sediments, rocks and traces to suspected murder scenes.

As stated in the Chapter 5.3, the descriptions provided by Gray are aiming at underlining the needs of including abiotic nature as an active part of the overall assessment regarding landscape and services related to human development.
The Gray´s proposed approach opens debates and new important initiatives regarding the effective role of geodiversity and its importance for human development, needs of protection and its valorization.

The present research, starting from the application of Gray approaches and its assessment in the 8 selected geosites, described in the next paragraph, aiming to expand further the analysis, detecting innovative indicators to be applied at abiotic nature.

5.5 Preliminary analysis of the ecosystem services.

Each of the 25 abiotic ecosystem services has been analysed both through desk research and collecting data from the field. The data collected came from interviews with the MGp General Manager and interviews with members of the scientific board of SVUGGp.

The research is combining field data collection and data research, through the application of the Gray description and it is providing a preliminary assessment of abiotic ecosystem services in each of the 8 geosites selected (Complete assessment of Eigerøy is visible in Annex 4).

As the table n. 3 regarding Eigerøy shows it is possible to detect some conclusions about the services provided by the geosite to the communities.

The Supporting services

Habitat Provision: Birds and other wildlife also find the perfect habitat in the geosite, so the geosite is also providing a habitat platform.

Land and water as a platform for human activities: services are provided by the geosite to the communities thanks to the land provision for the development of human activities in relation with the building of the lighthouse and other coastal buildings related with the fishing industry.

Provisioning Services: The geosite also provides the communities with clay for making the local traditional pottery which has been produced for centuries.

The Knowledge-Cultural services are relevant both for the lighthouse and for the intangible heritage linked with the glacier grooves and striae on the bedrock surface, which are visible along the trail and provide important support to educational activities and storytelling.

From the Geotouristic point of view, the geosite is one of the most accessible walks in the Geopark and is used by hundreds of visitors all year round.

The geosite is important for the Earth history processes related with the Egersund-Ogna anorthosite: it represents the products of magma that slowly cooled in a huge chamber 20 km below the surface about 930 million years ago.

The geosite also provides important service related with the "History of Research".
Geologist Harrison Schmitt was born in the United States on July 3, 1935. He went to Oslo University to study geology in the late 50s and visited Eigersund in connection with field studies of the Moon rock Anorthosite. Schmitt is the only Earth scientist who has been on the Moon, aboard Apollo 17 Mission. During three days in December 1972, he gathered 110 kg of moonstone, including anorthosite from Eigerøy. The Geopark's interpretation panel is visible on site with information in English and Norwegian.

Environmental and Forecasting: In Eigerøy, there is a weather-temperature and wind power station inside the lighthouse, so it is relevant as a broadcasting weather station. The site is well used for educational purposes, is part of the Magma Geopark educational offer and is included in the APP and virtual reality.

Abiotic Ecosystem system services		
Regulating	1	Atmospheric and oceanic processes
	2	Earth processes
	3	Flood regulation
	4	Water quality regulation
Supporting	5	Soil processes
	6	**Habitat provision**
	7	**Land and water as platform for human activities**
	8	Burial and storage
Provisioning	9	Food and drink
	10	Nutrients and minerals
	11	Fuel
	12	Construction materials
	13	Industrial minerals
	14	**Ornamental products**
	15	Fossils
Cultural	16	Environmental
	17	**Geotourism and leisure**
	18	**Cultural spiritual and historic**
	19	Artistic inspiration
	20	Social development
Knowledge	21	**Earth history**
	22	**History of research**
	23	**Environmental monitoring and forecasting**
	24	Geoforensics
	25	**Education and employment**

Table 3, Abiotic Ecosystem Services detected in Eigerøy lighthouse, Gentilini. 2019, ref. to Gray 2013

Following the assessment results, is possible to conclude that, to run a specific evaluation of the ecosystem services in geosites, a tailored detailed framework for better understanding the connection between the services and the geosites would have been necessary; in fact, without the application of specific methodology for measuring the detailed impact of each single factor involved in the service, only superficial qualitative analysis could be carried out. These results underline the needs for further studies regarding the development of indicators for abiotic nature which are undertaken in the Chapter 5.5 as main outcome of the present research.

5.5.1 Analysis of existing indicators for biotic services and its adaptation

The focus of this research is the development of a targeted methodology for assessing both geodiversity and geoheritage to enhance management strategies and sustainability solutions within UNESCO Global Geoparks.
An essential starting point for the research is the detection of a possible framework of indicators for assessing the abiotic ecosystem services. Before applying this framework to the detailed analyses of four selected geosites within two UNESCO Global Geoparks, some conceptual issues of the methodology must be dealt with.

There are several parameters and rules to define new indicators, and several specific frameworks have been developed within biotic nature. The PhD research adopted the definition of the word indicator as *"a measure based on verifiable data that conveys information about more than just itself"* (Brown C. *et al*., 2014).

Since indicators must be addressed to a specific purpose and to a targeted audience, the PhD research applied the above-mentioned definition to the Geodiversity context. To develop specific indicators for the abiotic ecosystem services (abiotic nature by Gray, 2012), some important preliminary considerations for the establishment of the indicator's framework can be derived from the Biodiversity Indicators Partnership (BIP) (BIP 2011):

1. Spatial scale: the definition of a spatial scale depends on the end users' needs and its relevance to decision-making, from the context and the data availability.
2. Temporary scale: this depends on the outcome of the indicator.
3. Baseline: this will be important for making comparisons over time and this should reflect a relevant time.
4. Operationally: the data and methodology should be selected so the process can be reproduced in the future and by others.
5. Validation: important consideration when calculating indicators as it will explain outliers and identify inaccuracies.
6. Multiple data layers: Given the complexity of ecosystem services, it is usually a requirement that several indicators be adopted to represent a service more completely.
7. Measurement units: units need to be chosen and compared.
8. Raw/derived data: data required for indicators often needs to be derived from other datasets to be useful.

Special recommendations for the development and use of ecosystem services indicators within biotic nature have been developed by the United Nations Environment Programme World Conservation Monitoring Centre in 2011 (Walpole *et al*.; 2011), which can be resumed as following:

1. Ensure that the objectives are clear: specific questions need to be addressed.
2. Start with a small set of specific indicators.
3. Where possible, try to create indicators for all types of ecosystem services.
4. Develop indicators as an iterative process within existing data.
5. Benefits for societies need to be considered.
6. Include biodiversity, geodiversity and ecosystem services which are not interchangeable.
7. Deciding the scale of indicators is important for a decision-making contest.
8. Assess trends and consider synergies and trade off.
9. Engage stakeholders at an early stage of the research and choose specific target groups.
10. Strong communication for increasing public and private engagement.

The framework created by the Biodiversity Indicators Partnership has been chosen from this research as a base framework for developing provisional abiotic indicators (Biodiversity Indicators Partnership, 2011).
Within the related workflow (Fig. 20), the main component's colours (red, purple, green) correspond to main functions (Purpose, Production and Permanence) for the framework development:

- Purpose (red steps) – functions needed for selecting successful indicators that respond to the users' needs
- Production (purple steps) – essential actions to generate indicators.
- Permanence (green steps) – mechanisms for ensuring the indicator's continuity and sustainability of the services.

The framework underlines that while it is not mandatory to cover all the steps, "*the more of the steps that are covered in the process the more indicators will be successful".*

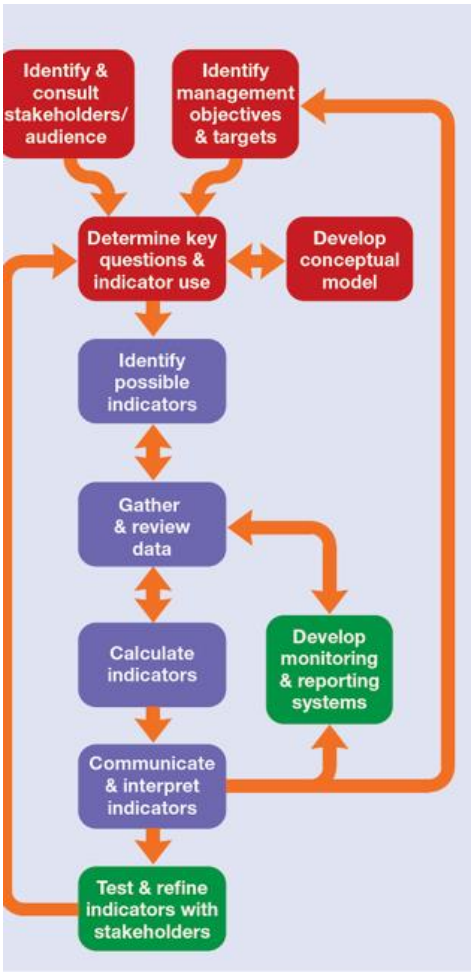

Figure 20 - Biodiversity Indicators Development Framework, from Biodiversity Indicators Partnership: (https://www.bipindicators.net/national-indicator-development)

5.5.2 Application of the framework made by the Biodiversity Indicators Partnership

a) Identify and consult stakeholders / audience

Stakeholders need to be identified together with the target audience for the use of the indicators. The accuracy of this step guarantees the fulfilment of real needs.

The following stakeholder categories have been involved in the current research:

- ⇒ Geopark managers
- ⇒ Norwegian Geological Survey members
- ⇒ Members of the roster of evaluators UNESCO Global Geoparks.
- ⇒ Scientists

Specifically, consultations took place with the Magma Geopark Director, Chief of the Norwegian Geopark's Committee and UNESCO external appointed evaluator, the Chief of the Sesia Val Grande scientific committee and UNESCO IGCP advisor, and the Manager for new Geoparks and geotourism at the Norwegian Geological Survey.

The main target group addressed in the development of the framework are UNESCO Global Geoparks, UNESCO Global Geoparks managers, and local policy makers.

The research lacks the policy makers involvement during the development of the methodology due to Covid-19 pandemic restrictions.

b) Identify management objectives and targets

The purpose of the identification of indicators for abiotic ecosystem services is to support decision making and managers to develop specific strategies for Geopark management and landscape planning. All aspiring and recognized UNESCO Global Geoparks already agreed on objectives and targets defined in the International Geoscience and Geoparks Programme (IGGP) Operational Guidelines. (UNESCO, 2015)

The management objectives can relate to the overall research objectives:

- ⇒ To detect the weak points of the territories in terms of assessment of geodiversity and biodiversity.
- ⇒ To define which abiotic services are acting in the two pilot Geoparks and at what scale.
- ⇒ To establish provisional values which support the managers in developing tailored strategies for landscape planning also in case of geopark application to the IGGP Programme.
- ⇒ To provide managers and institutions with a tool able to register the geosite's characteristics "on site" and to develop guidance for best environmental practices.

c) Determine key questions and indicator use

Key questions are crucial for defining the purpose of the indicators; questions may require several data sets or indicators. Questions for each single indicator have been set up to detect the most influential geological phenomena influencing the services. The research adopted an iterative process for the definition of questions, starting from preliminary general questions, leading to more detailed enquiries listed on the Annex 6, described in detail in the following chapters (Chapters 5.4).

d) Develop a conceptual model

A conceptual model related with the research has been developed in comparison with the one presented above by the Biodiversity Indicators Development Framework (Fig. 20; Chapter 5.2.1). Several progressing phases are included in the workflow, from preliminary general classification of the type of ecosystem services to more precise definitions of indicators by means of targeted tables and indexes. Questions detected by each service give answers and support to detect specific indicators.

e) Identify possible indicators

The identification of the final preliminary abiotic services indicators has its route within the already approved indicators developed for biotic nature assessment, in combination with scientific rigour and creative thinking. (Chapters 4.4.3 and 4.4.4). The identification of possible indicators proceeded step by step in parallel with the iterative process applied for the question's development: starting from qualitative broad indicators (Annex 6, Phase 1) linked with generic definitions, it ends with detailed specific quantitative scientific-based indicators (Annex 6, Phase 3).

f) Calculate indicators

The calculation of the indicators, explained in detail in the following Chapter 5.4 and 5.5, has been developed adopting a homogenous scaling system within each service; however, one common scale could not be applied to all the services due to the peculiar characteristics involved.

g) Communicate indicators

The developed provisional indicators have not been communicated yet in any story or narrative. Presentation, interpretation, and discussion of the indicators are welcome within scientific and technical meetings of the Geoparks' community

h) Test and refine indicators

Due to the COVID-19 restrictions during the PhD research time, appropriate testing and refining of the detected provisional indicators have not taken place yet; therefore, further testing of indicators in other UNESCO Global Geoparks territories is recommended.

i) Monitoring and reporting system

The monitoring and reporting system should be developed after further data testing and strengthening of the suggested methodology. It is recommended for monitoring results after a certain period.

5.6 The development of the provisional abiotic indicators, detailed analysis of the second research product (Annex 6)

The second research output is the final tool for developing the abiotic indicators, (Annex 6). Here the four main phases of the abiotic ecosystem indicator's development are resumed on a single worksheet ("Sheet 1; "Sheet 2"; "Sheet 3"; "Sheet 4").

An iterative process, starting from "Sheet 1" (preliminary qualitative analysis of abiotic ecosystem services), continuing throughout "Sheet 2" (comparison to biotic conditioning factors) and "Sheet 3" (comparison to abiotic conditioning factors) leads to "Sheet 4", i.e., the final calculation of quantitative indicators for each of the four detected geosites.

The final output (Annex 6) is presented as a tool for supporting the Geopark manager in selecting, describing, and assessing geosites within UNESCO Global Geoparks.

5.6.1 Preliminary qualitative analysis of the existing definition of abiotic services (Annex 6, Sheet 1)

The analysis aimed at the detection of indicators for abiotic nature, after analysing the overall Grey theory, focused on the comparison between the examples given by Gray (2013) for each service and preliminary questions raised though the field analysis run in both UGGp. (Annex 4, Sheet 1, Columns A-B).

Preliminary questions (Annex 4, -Sheet1, Column "D) focusing on detecting if the single geosite influences the service and "at what scale", which is the geosite role, its impact and eventual contribution.

From the preliminary broad questions (column D) has been possible to detect preliminary broad qualitative indicators (column E) which have been defined following examples of abiotic services (column C) from the existing literature.

5.6.2 Selection and brief analysis of provisional biotic factors influencing each abiotic service (Annex 6, Sheet 2)

Starting from the 25 abiotic ecosystem services main categories, the present research developed a comparison with biotic services detected by the UNEP-WCMC (2011).

In the Sheet n.2, Column A. are listed the main abiotic services (Gray 2013):

Regulating: N1) Atmospheric and oceanic processes, N2) Terrestrial processes, N3) Flood control and N4) Water quality regulation.

Supporting: N5) Soil processes, N6) Habitat provision, N7) Land as a platform for human activities and N8) Burial and storage.

Provisioning: N9) Food and drink, N10) Nutrients and minerals, N11) Fuel, N12) Construction materials, N13) Industrial materials N14) Ornamental products and N15) Fossils.

Cultural-Knowledge: N16) Environmental quality, N17) Geotourism and leisure, N18) Cultural spiritual and historic, N19) Artistic inspiration, N20) Social development N21) Earth history, N22) History of research, N23) Environmental monitoring and forecasting, N24) Geoforensics and N25) Education and employment.

The Sheet 2, column C includes the biotic services detected by UNEP-WCMC:

Regulating: N7) Air quality regulation, N8) Climate regulation, N9) Natural hazard mitigation, N10) Water regulation, N11) Waste treatment, N12) Erosion protection, N13) Soil Formation, N14) Pollination, N15) Biological Regulation.

Supporting: N16) Nursery habitat, N17) Gene pool protection.

Provisioning: N1) Food, N2) Water, N3) Fibre and Fuel, N4) Genetic materials, N5) Biochemical products, N6) Ornamental species.

Cultural-Knowledge: N18) Aesthetic appreciation, N19) Recreational opportunities, N20) Inspiration for culture and design, N21) Cultural heritage, N22) Spiritual and religious inspiration and N23) Education and science for formal education.

After listing the biotic ecosystem services, the related indicators (UNEP-WCMC -Walpole M. et al.,2011; Brown C. et al. 2014) are summarised in column D; however, the overall explanation par each of the indicators is visible in the following Table 4.

Services comments and examples	Ecological process component providing the service (or influencing its availability) = functions	State indicator (how much of the service is present)	Performance indicator (how much can be used/provided in sustainable way)
Provisioning			
1. Food	Presence of edible plants and animals	Total or average stock in kg/ha	Net Productivity (in kcal/ ha/year or other units)
2. Water	Presence of water reservoirs	Total amount of water (m^3/ha)	Max sustainable water extraction (m^3/ha/Year)
3. Fibre and fuel and other raw material	Presence of species or abiotic components with potential use for timber, fuel or raw material	Total biomass (kg/ha)	Net productivity (kg/ha/y)
4. Genetic materials: genes for resistance to plant pathogens	Presence of species with (potentially) useful genetic material	Total 'gene bank' value (e.g. number of species and subspecies)	Maximum sustainable harvest
5. Biochemical products and medicinal resources	Presence of species or abiotic components with potentially useful chemicals and/or medicinal use	Total amount of useful substances that can be extracted (kg/ha)	Maximum sustainable harvest (in unit mass/ area/time)
6. Ornamental species and/or resources	Presence of species or abiotic resources with ornamental use	Total biomass (kg/ha)	Maximum sustainable harvest
Regulating			
7. Air quality regulation: e.g. capturing dust particles	Capacity of ecosystems to extract aerosols and chemicals from the atmosphere	Leaf area index NOx-fixation	Number of aerosols or chemicals 'extracted'- effect on air quality

8. Climate regulation	Influence of ecosystems on local and global climate through land-cover and biologically-mediated processes	Greenhouse gas-balance (especially carbon sequestration);	Quantity of Greenhouse gases, fixed and/or emitted, effect on climate parameters
9. Natural hazard mitigation	Role of forests in dampening extreme events (e.g. protection against flood damage)	Land cover characteristics and similar	Reduction of flood-danger and prevented damage to infrastructure
10. Water regulation	Role of forests in water infiltration and gradual release of water	Water-storage (buffer) capacity in m^3	Quantity of water retention and influence of hydrological regime (e.g. irrigation)
11. Waste treatment	Role of biota and abiotic processes in removal or breakdown of organic matter, xenic nutrients and compounds	Water retention capacity in soils or at the surface	Max amount of chemicals that can be recycled or immobilized on a sustainable basis
12. Erosion protection	Role of vegetation and biota in soil retention	Denitrification (kg N/ha/y); Immobilization in plants and soil	Amount of soil retained or sediment captured
13. Soil formation and regeneration	Role of natural processes in soil formation and regeneration	Vegetation cover root-matrix e.g. bio-turbation	Amount of topsoil (re) generated per ha/y
14. Pollination	Abundance and effectiveness of pollinators	Number and impact of pollinating species	Dependence of crops on natural pollination
15. Biological regulation	Control of pest populations through trophic relations	Number and impact of pest-control species	Reduction of human diseases, live-stock pests
Habitat or Supporting			
16. Nursery habitat	Importance of ecosystems to provide breeding, feeding or resting habitat for transient species	Number of transient species and individuals (especially with commercial value)	Dependence of other ecosystems (or 'economies') on nursery service
17. Genepool protection	Maintenance of a given ecological balance and evolutionary processes	Natural biodiversity (especially endemic species); Habitat integrity (irt min. critical size)	Ecological value (i.e. difference between actual and potential biodiversity value)
Culture and amenity			
18. Aesthetic: appreciation of natural scenery (other than through deliberate recreational activities)	Aesthetic quality of the landscape, based on, for example, structural diversity, 'greenness', tranquillity	Number/area of landscape features with stated appreciation	Expressed aesthetic value, for example: number of houses bordering natural areas, number of users of 'scenic routes'
19. Recreational: opportunities for tourism and recreational activities	Landscape-features Attractive wildlife	Number/area of landscape and wildlife features with stated recreational value	Maximum sustainable number of people and facilities
20. Inspiration for culture, art and design	Landscape features or species with inspirational value to human arts	Number/area of landscape features or species with inspirational value	Actual use number of books, paintings. Using ecosystems as inspiration
21. Cultural heritage and identity: sense of place and belonging	Culturally important landscape features or species	Number/area of culturally important landscape features or species	Number of people 'using' forests for cultural heritage and identity
22. Spiritual and religious inspiration	Landscape features or species with spiritual and religious value	Presence of landscape features or species with spiritual value	Number of people who attach spiritual or religious significance to ecosystems
23. Education and science opportunities for formal and informal education and training	Features with special educational and scientific value/interest	Presence of features with special educational and scientific value/interest	Number of classes visiting. Number of scientific studies

Table 4. Indicators for determining use of ecosystem services (UNEP-WCMC 2011).

The above biotic services have been compared with the abiotic services and possible matches have been investigated; see table below. (Table 5)

A	**B**	**C**
Abiotic Services	**Connected Biotic services**	**Biodiversity Indicators**
Regulating		
N1) Atmospheric and oceanic processes	7) Air quality regulation	Leaf area index NOx-fixation
N2) Terrestrial processes	9) Natural hazard mitigation 10) Water regulation 12) Erosion protection 13) Soil formation and regeneration	Land cover characteristics and similar Water-storage (buffer) capacity in m3 Denitrification (kg N/ha/y); Immobilisation in plants and soil Vegetation cover root-matrix e.g. bio-turbation
N3) Flood control	9) Natural hazard mitigation 10) Water regulation 12) Erosion protection 13) Soil formation and regeneration	Land cover characteristics and similar Water-storage (buffer) capacity in m3 Denitrification (kg N/ha/y) Immobilization in plants and soil Vegetation cover root-matrix e.g. bio-turbation
N4) Water quality regulation	10) Water regulation 12) Erosion protection 13) Soil formation and regeneration	Water-storage (buffer) capacity in m3 Denitrification (kg N/ha/y) Immobilization in plants and soil Vegetation cover root-matrix e.g. bio-turbation
Supporting		
N5) Soil processes	13) Soil formation and regeneration	Vegetation cover root-matrix e.g. bio-turbation
N6) Habitat provision	17) Genepool protection	Natural biodiversity (especially endemic species); Habitat integrity (irt min. critical size)
N7) Land as a platform for human activities	11) Waste treatment 13) Soil formation and regeneration 16) Nursery habitat	Water retention capacity in soils or at the surface Vegetation cover root-matrix e.g. bio-turbation Number of transient species and individuals (especially with commercial value)
N8) Burial and storage	None	
Provisioning		
N9) Food and drink	1) Food 2) Water	Total or average stock in kg/ha Total amount of water (m3/ha)

N10) Nutrients and minerals	13) Soil formation and regeneration	Vegetation cover root-matrix e.g. bio-turbation
N11) Fuel	3) Fibre and Fuel	Total biomass (kg/ha)
N12) Construction materials	None	
N13) Industrial materials	None	
N14) Ornamental products	None	Total biomass (kg/ha)
N15) Fossils	None	
Cultural and knowledge		
N16) Environmental quality	8) Climate regulation	Greenhouse gas-balance (especially carbon sequestration)
N17) Geotourism and leisure	19) Recreational opportunities	Number/area of landscape and wildlife features with stated recreational value
N18) Cultural spiritual and historic	20) Inspiration for culture and design	Number/area of landscape features or species with inspirational value
N19) Artistic inspiration	20) Inspiration for culture and design	Number/area of landscape features or species with inspirational value
N20) Social development	23) Education and science for formal education	Presence of features with special educational and scientific value/interest
N21) Earth history	23) Education and science for formal education	Presence of features with special educational and scientific value/interest
N22) History of research	23) Education and science for formal education	Presence of features with special educational and scientific value/interest
N23) Environmental monitoring and forecasting	None	
N24) Geoforensics	None	
N25) Education and employment.	23) Education and science for formal education	Presence of features with special educational and scientific value/interest

Table 5. Proposed connections between abiotic ecosystem Services (Gray M. 2015) and biotic Ecosystem Services (UNEP-WCMC 2011). Gentilini S. 2021.

Table 5 shows significant overlapping between biotic and abiotic indicators, which both characterize the 25 abiotic ecosystem services (Gray M., 2018). Eighteen indicators detected for biotic services (Table 5, Column C) are directly connected with one or more abiotic services: the common indicators constitute the baseline for the following development of provisional abiotic nature indicators within the present research.

5.6.3 Selection of the space and time framework for the evaluation of each single ecosystem service (Annex 6, Sheet 3).

Since Geodiversity deals with a variety of natural phenomena related to a wide range of spatial and temporal scales, the related abiotic ecosystem services can be controlled by global, continental, regional and local conditioning factors (Gray, 2013); moreover, they can be delivered either by slow, long-term Earth processes or by fast, contemporary, and impulsive phenomena. Therefore, in the selection of the space and time framework for either the assessment of Geodiversity or the evaluation of each single ecosystem service (Zwolinski *et al*., 2018; Gray, 2018), it is worthwhile to consider the human perspective of the observer analysing the geosite.

This PhD research took into consideration a "human" framework of geodiversity and related ecosystem services by considering the evolutionary stages of the geological processes and their spatial and temporal dimensions with respect to human history (Giardino, 2019). In this perspective, two possible related ecosystem services have been considered:

- "static" conditioning factors, with none or slight changes within the geosite during human life.
- "dynamic" processes, with on-going changes during time and space dimensions relevant for the human perspective of the observer analysing the geosite.

Geological processes which influence the services (Sheet 3, Column C)

Phase 3 includes a detailed description of each service, starting from the two preliminary definitions: one from Gray M. (2013) and the one by the PhD research team, derived from the field work and desk research.

Two main questions were asked:

1)What are the main geological processes at the base of each service and what are their scientific definitions?
2) Which geological processes could increase or decrease the influence of the geosite in the specific service?

Abiotic factors influencing the process and, consequently, the service (Sheet 3, Column D)

Starting from the geological definition, the research proceeds with the detection of each single factor. Within the Phase 3 worksheet, Column D lists the abiotic factors which influence the development of the overall geological process and consequently, each ecosystem service. By detecting the abiotic factors, the so-called indicator "variables" have been individualised and are shown in the following columns (E to M).

The indicator variables are selected to allow measurements based on verifiable data. Scale and assessment are added in the following research development.

Here below, the application of the above-described framework to the Abiotic Service N2 "Terrestrial Processes":

By considering the abiotic factors influencing the development of N2 ecosystem service, a geosite is "active" when it is affected by active geological processes either of an endogenetic and exogenetic nature:

- tectonic uplift or volcanic processes, or
- other phenomena like rock weathering, erosion, transportation, deposition (here the role of rivers, sea waves, beaches, salt marshes and other geomorphological phenomena).

The variables relevant for individualising indicators are then related with:

- crustal mobility /uplift (characterized by various rates);
- erosion (influenced by sub factors, namely those controlling local energy of erosional processes and resistance to erosion),
- transportation (related to the presence of local geomorphic agent) and
- deposition.

Here below the related questions, supporting the development of qualitative indicators:

1) Are any rock weathering, erosion, transportation, deposition, uplift (role of rivers, sea waves, beaches, salt marshes) and/or geomorphological processes active within the geosite?
2) Are the geosites located in a river band, on a beach, or subject to erosion due to glacier, wind or current factors?

Columns E-F-G-H include the four detected variables (crustal mobility, erosion of the bedrock, transportation, and deposition) and the related sub-questions for detecting quantitative indicators.

Column N lists the "Benefits for society", one for each service, focusing on a local, regional, and national level. There are many abiotic benefits to society deriving from abiotic services: soil capacity, store carbon, soil productivity, land use, construction minerals, tourism activities, empowerment of citizens, etc. (Gray 2018,2019; Brilha).
Further explanation of each single variable and the quantitative evaluation of each abiotic ecosystem service are listed and presented within Annex 6, Phase 4, including rates and comments on results of the application to geosites.

5.7 Abiotic service indicators and assessment methodology, Output 2.

The research further analyses each variable assigning them a specific definition, values and scale.
Each single factor has been assessed within a scale ranging from 10 (minimum- equal to zero) to 100 points (maximum). The scale also includes four intermediate values: Low = 30 Medium = 50 High = 80
Max = 100.

5.7.1 Regulating services

1) <u>Atmospheric and oceanic processes (N1).</u>

A. *Question:* How high is the protection of the single geosite from the atmospheric and oceanic processes? To understand at what level-scale the geosite is regulating the climate, it is necessary to know to what extent the geosite is influenced by the climate phenomena. To assess at what scale the geosite's abiotic characteristics can effectively mitigate the effect of the atmospheric and oceanic process on the local climate, the following scale has been applied: the highest score corresponds to the highest level of protection exerted by the geosite.

B. *Geological processes which influence the services:*
The PhD team's definition of service: mitigation actions/effects/processes provided by the characteristics of the geosites to the community.
Gray.'s definition of service: "The combination of oceanic and atmospheric circulation driving global climate by redistributing heat".
Gray's definition of climate corresponds to the one found in dictionaries, that is: "*the general weather conditions usually found in a particular place*" (Cambridge Dictionary: "climate").
Climate is composed of six main interrelated factors (variables) which contribute to temperature mitigation or, on the other side, temperature dropping.

C. *Abiotic factors influencing the process. Scale and assessment*:
The climate is influenced by the following abiotic factors (variables):

a) Altitude
We have defined the scale from 0 m a.s.l. to above 1500 m a.s.l.

The higher the altitude, the lower the level of protection against the atmospheric and oceanic process in a geosite. The lower the altitude, the higher the protection.

We have set the following scale and values:
- Below 500 m a.s.l. = 100
- From 500 to 1000 m a.s.l. = 80
- From 1000 to 1500 m a.s.l. = 50
- From 1500 to 2500 m a.s.l.= 30
- From 2500 to 3500 m a.s.l. = 10

b) Climate zone
There are five main temperature zones according to the Köppen- Geiger Climate Classification: Temperate, Humid Tropical, Arid, Continental and Polar.
Each zone is divided according to seasonal precipitation and temperature patterns (Arnfield, 2020; Peel *et alia*, 2007).

<u>Temperate</u>: moderate rainfall spread across the year or a portion of the year with sporadic drought; mild to warm summers and cool to cold winters.

<u>Humid Tropical:</u> humid tropical climates, as the name implies, are warm and wet. The mean temperature for any month seldom falls below 64°F (18°C), so there is no winter but there is plenty of rainfall in these climates. They receive on average about 150 centimetres of rain per year, which may be concentrated over a few months or spread throughout the entire year. (Cunningham , n.d.)

Arid: an arid climate is one that receives less than 10 inches (25.4 centimetres) of rainfall in an entire year. Flash floods are frequently a danger in arid climates after thunderstorms, as the dry, compact soil cannot absorb water quickly enough to capture the rain. Streams swell with water for a few hours and then dry up again until the next cloudburst (Encyclopaedia of Water Science, n.d.).

Continental: a climate characterized by hot summers, cold winters, and little rainfall, typical of the interior of a continent (Collins English Dictionary, "Continental Climate").

Polar: the climatic type associated with regions inside the Arctic and Antarctic Circles. A gradation of climatic characteristics exists towards the poles, from tundra conditions to those of perpetual frost. (Dictionary of Ecology "Polar Climate").

Geosites located in temperate and arid climates are less exposed to weathering, so they are more protected; the polar climate has the biggest impact on the local climate and weathering, so it is linked to the lowest score.
The two Geoparks are both inside the Continental zone.
The scale and the score are the following:

- Arid = 100
- Temperate= 80
- Continental = 50
- Tropical = 30
- Polar = 10

c) Presence of mountain chains (1000 m a.s.l.)

We took into consideration only mountain chains above 1000 m elevation; the distance is calculated as the difference in altitude between the geosite and the summit of the mountain in the vicinity.
We considered the distance from the geosite as a parameter for determining the role of the mountain chain in the protection of the geosite from atmospheric processes. The mountain reliefs play a crucial role in climate mitigation, so geosites located in the proximity of significantly high mountains could offer a different climate to the communities living in it compared to geosites located in plains and flat areas.
The scale and values are the following:

- No mountain = 10
- mountain presence between 100 km to 70 km = 30
- mountain presence between 70 km to 50 km = 50
- mountain presence between 50 km to 30 km = 80
- mountain presence closer than 30 km = 100

d) Slope exposure (North/South)

The slope exposure influences the atmospheric-climate characteristics of the geosite both in the southern and northern hemispheres.

- In the Northern hemisphere, geosites exposed South get more light exposure, so they are linked to the maximum score = 100
- Flat area = 50
- W-E = 30, while geosites exposed North are linked with the minimum score N = 10.

In the Southern hemisphere, it is exactly the opposite.

e) Water proximity

We have extensively discussed this parameter, considering first the water source, then the amount of water needed to influence the microclimate at a geosite. We agreed that the sea is the only water reservoir able to impact the microclimate of a geosite for a prolonged period.
The scale and score selected is based on the vicinity of the sea to the geosite; the closer the sea is, the higher the score.

- less than 10 Km = 100
- From 10 km to 30 km = 80
- From 30 km to 50 km = 50
- From 50 km to 100 km = 30

- and above 100 km = 10

f) Wind exposure
The exposure to wind currents is also a relevant variable for assessing geosite protection. The geosite can be exposed to wind depending on the vegetation type and quantity; here are the chosen scales and scores:
- Geosite not covered by any high-medium size vegetation = 10
- Partly repaired by high-medium size vegetation = 20
- Well protected = 50
- Protected (presence of tick high forest) = 100

D. *Assessment* results (see calculation Annex 6 worksheet "Phase 4"; Column E)
From the application of the above parameters and scores (indicators), we can get the following results:
Eigerøy: 53%
Prato Sesia: 60%
Jøssingfjord: 68%
Crevola: 60%

Both the geosites in Sesia Val Grande Geopark offer the same level protection from the Atmospheric Ocean processes to the community. They are both located on the riverbed of the Sesia river, with Alpine mountains in the vicinity and both are quite protected from the wind. The level of protection is higher than both geosites in Magma UGG.

Eigerøy in Magma UGG is an exposed geosite, located in a flat area along the North Sea, without any vegetation which is less protected from the Atmospheric and Oceanic processes compare to ther **Jøssingfjord** geosite, which is the most protected of the four geosites. The geosite is located into a fjord valley, which contributes to mitigating the effects of the climate processes.

E. *Benefits for society*
The abiotic factors regulating the climate give obvious benefits to society, at local, regional, national and international (global) levels. At the international level, climate regulation influences the carbon cycle (sink on peat soils), hydrological cycle and climate conditions (precipitation and temperature). At the regional level, abiotic elements like the rising mountains (height and shape controlled by uplift rates and geologic materials) influence the patterns and rates of erosion (that are also dependent on the amount and type of precipitation- rainfall erosivity). Locally, the mountain chain or mountain reliefs directly affect the community's life which is directly dependent on the amount of precipitation (water reservoir, agriculture), and land erosion (landslides, number of soils for agriculture). The regulation of the climate due to abiotic factors can also influence the implementation of renewable energy (wind, solar, waves, hydropower), the exploitation of specific minerals (presence of specific minerals are influenced by the differentiation of soils), and the rate of the nutrient cycle.

2) Terrestrial processes

A preliminary consideration is needed regarding the "Point of view" of the observer; in this case, it is important to "look" at the geosite from "outside" to "inside" the geosite buffer zone selected.

A. *Questions:* to understand if the geosite is regulating the Earth phenomena for the renovation of Earth materials, it is necessary to know if there are any ongoing relevant active and sizable phenomena acting within it.

B. *Geological processes which influence services:*
The PhD team's definition: a) Presence at the geosite of active geological phenomena that renew the properties of Earth materials.
Gray M.'s definition: b) Carbon cycle, erosion, transportation, deposition, and uplift processes that constantly renew the Earth's surface with "fresh" rocks.

C. *Abiotic factors influencing the geological process and scale:*
The lithological cycle is defined as: "the presence at the geosite of active volcanic processes or other phenomena like rock weathering, erosion, transportation, deposition, uplift (role of rivers, sea waves, beaches, salt marshes) and geomorphological processes". From this definition we

have started to investigate each single factor which can impact the influence of the geosite in the terrestrial processes.

a. Crustal mobility

It occurs when the geosite has been part of active tectonic processes in the considered time and space frames.

The uplifting phenomena and the consequent crustal mobility contribute to the renovation of the Earth's geological material.

We refer to the "Global Earthquake Model (GEM) Global Seismic Hazard Map (version 2018.1), (Pagani M., et al. 2018)".

The Peak of Ground Acceleration shows the intensity of earthquakes in specific geographical areas, taking into consideration the European Map (Woessner et al., 2015). The Peak can be used in our research as a parameter to measure how active within plate tectonic a single area is.

We set up the following scale and score, from the Global Map (European section).

- Peak of Ground Acceleration High = over 0.90 = 100
- Between 0.90 to 0.20 = Medium = 50
- 0.05 – 0.20 Low = 30
- 0.02 – No mobility = 10

b. Erosion

We have looking for parameters to calculate the geosite's average tendency towards bedrock erosion (which we consider is always >0) and to produce the so-called "sediments" which refer to: "*the conglomerate of materials, organic and inorganic, that can be carried away by water, wind or ice*" (Fondriest Environmental Learning Centre, 2014).

We have been studying seven factors that we consider to be the base for assessing erosion. The higher the total values given by the sum of all the seven factors is, the higher the average level of bedrock weathering within the geosite.

1) The location of the geosite takes into consideration three geomorphological features: river bands, glaciers, and shores. Rivers, shores, and glaciers are the most impactful geomorphological features concerning the erodibility index.
   This is the scale and score we have set up based on the geosite location:
   - predominantly located on a shore, on a glacier or on a riverbed = 100
   - partially overlapping one of the features = 50
   - No, there are no similar features within the geosite =10

2) To measure at what scale a geosite contributes to bedrock erosion, we need to define what the most common types of rocks and mineral composition within the geosite are and what their average approximate erosion index is. Common interpretation of surface lithology within geosites (Figs 21-24) is based on the International Geological Map of Europe" (IGME).

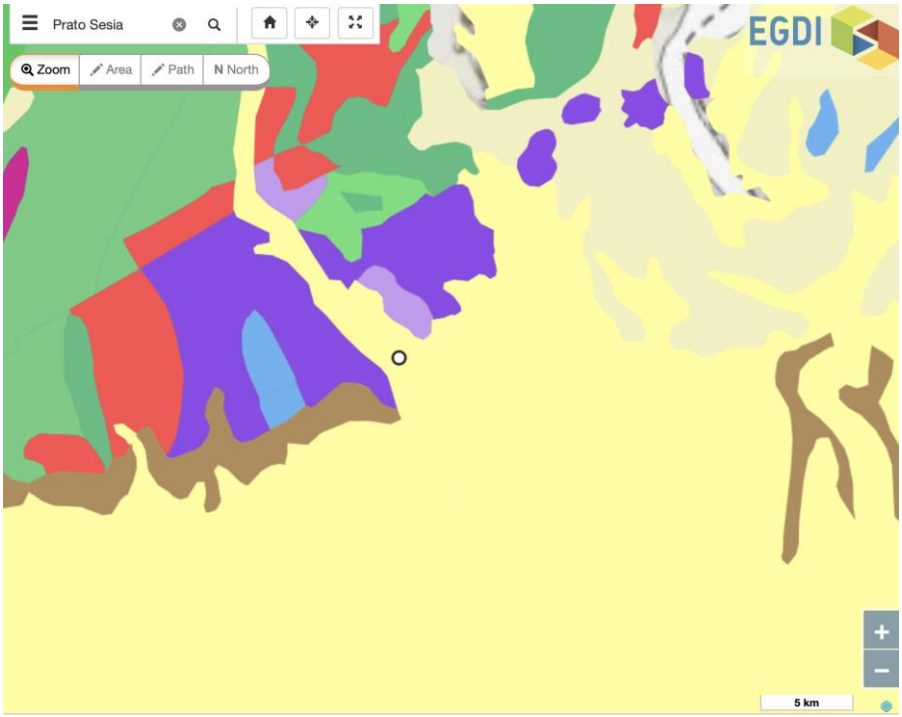

Figure 21 - Prato Sesia surface lithology-IGME,
Dark violet:boninite, Yellow:clastic sediments, Brown:claystone, Light green: gneiss, Dark Green: granulite, Red: monzogranite, Light sand: Diamicton, Pink: alkali feldspar syenite rock

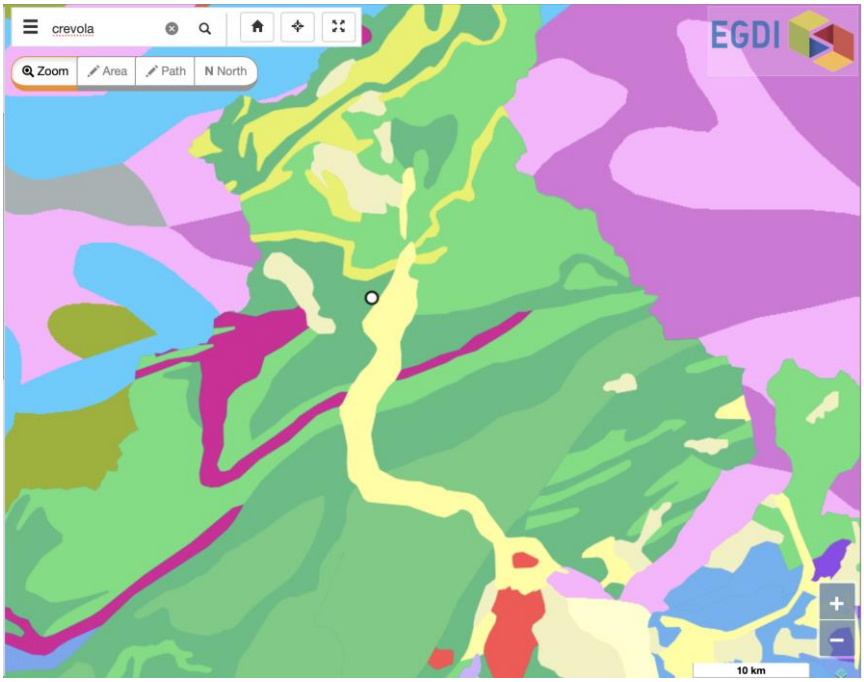

Figure 22 - Crevola surface lithology- IGME
Yellow: clastic sediments, Dark green: impact generated material, Olive green: iron rich sedimentary rock, Light green: gneiss, Dark Green: granulite, Red: monzogranite, light sand: Diamicton, Dark Pink: komatitic rock, Light blue:impure dolomite, Dark blue:impure limestone

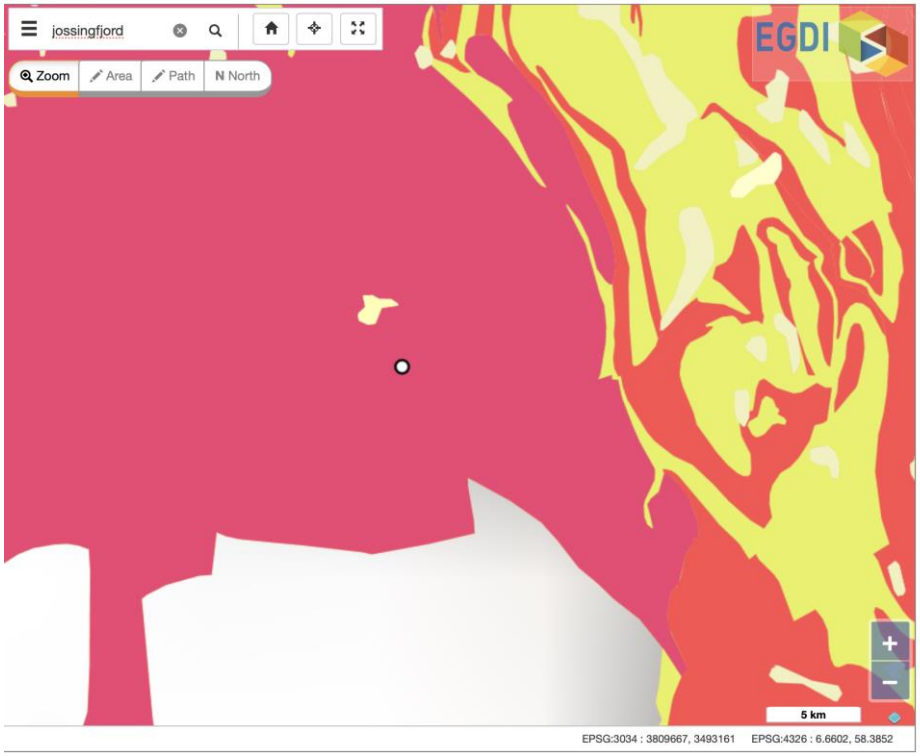

Figure 23 - Jossingfjørd lithological map-IGME
Pink: alkali feldspar syenite rock, Light red: tonalite, Yellow: Fault related material

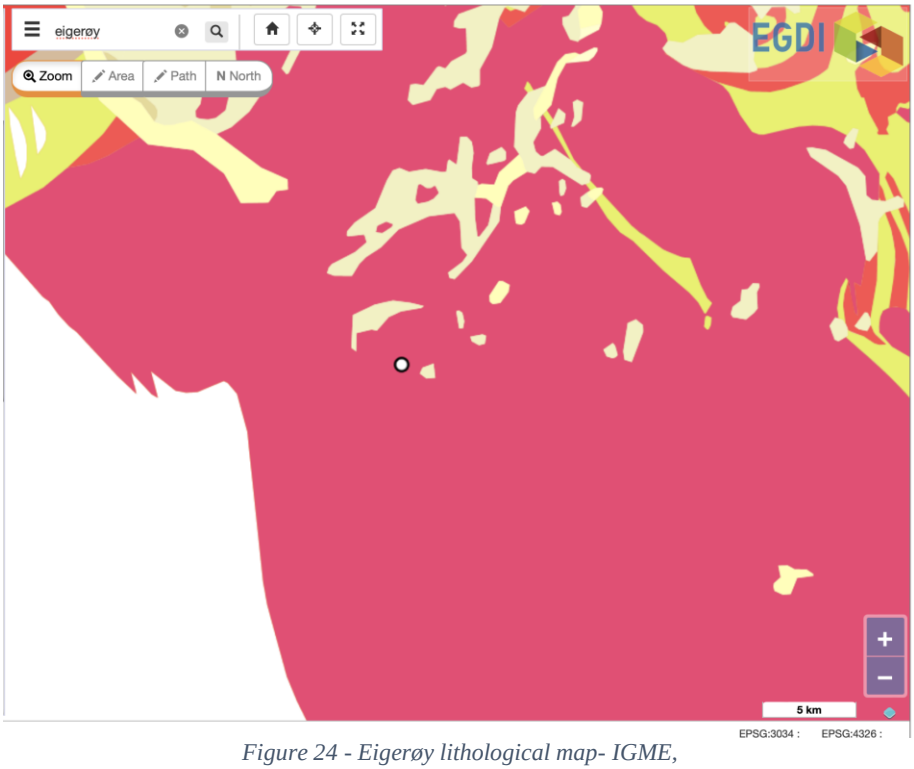

Figure 24 - Eigerøy lithological map- IGME,
Pink: alkali feldspar syenite rock, Light red: tonalite, Yellow: Fault related material

To higher index of erosion corresponds a higher score.
Scale and score chosen:

- Sedimentary rocks (sandstone, calcite) = 100

- Clay; (pyroxene, feldspar, clastic metamorphosed sediments) = 80
- Magmatic rocks (diorite, gabbro quartz) =10

3) The soil presence plays a crucial role within the bedrock erosion's factors, reducing weathering of the underlying rock layers. (Land Covering Map from the European Environmental Agency - EEA). In the maps (figs 25 and 26), the lack of soil is clearly visible in the Magma Geopark Regions while "arable land and permanent crops" prevail in the geosite selected within the Sesia Val Grande Geopark.

We agreed that the higher the presence of soil within the geosite is, the lower weathering would be. Here are the scales and scores:

- Geosite mainly covered by soil = 10
- Partly covered by soil = 50
- No soil: geosite is more exposed to weathering of the bedrocks = 100

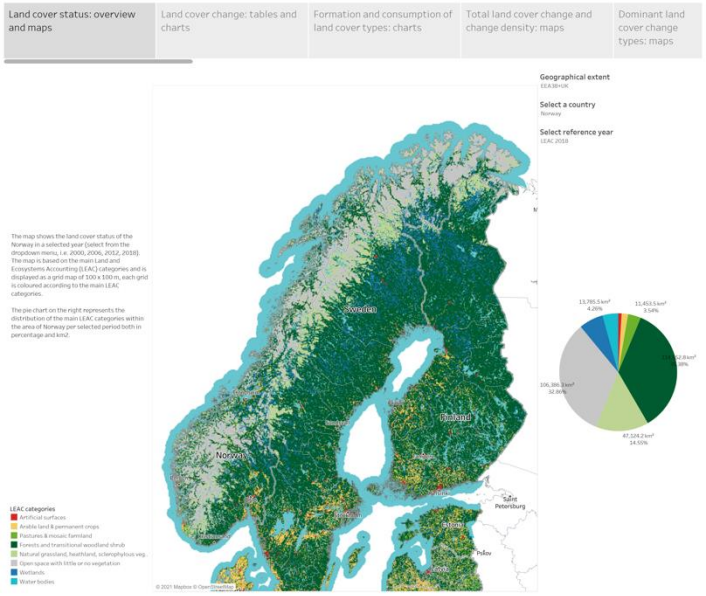

Figure 25 - Land cover status-Norway -European Environmental Agency 2019

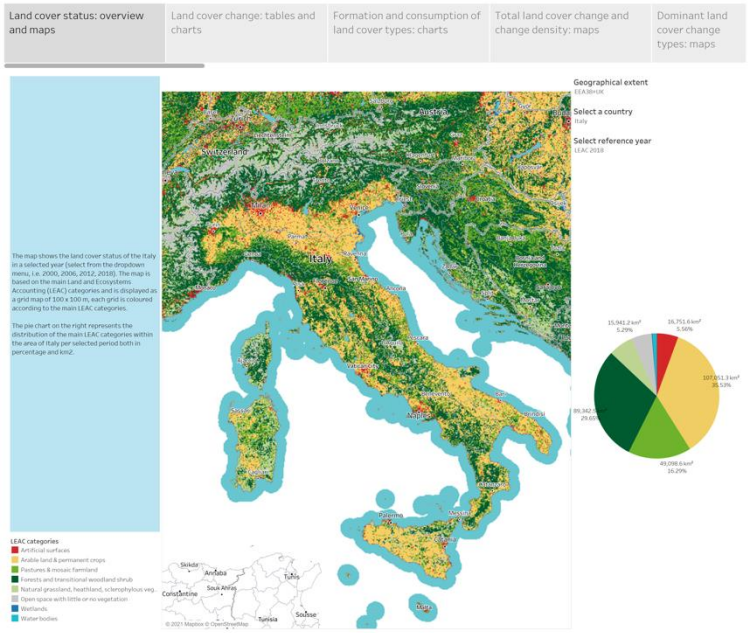

Figure 26 - Land cover status Italy- European Environmental Agency 2019

4) The geosite exposure to temperature drops affects the rate and type of weathering. At high elevations, cold night-time temperatures during much of the year can produce relentless freeze-thaw cycles (frost wedging) (Eastern Illinois University, 2012). The exposure to drops in temperature and the permeability of the rocks are two relevant factors for assessing the geosites' degree of erosion. The higher the exposure to a drop in temperature with the presence of permeable rocks is, the higher the bedrock's average erodibility is.

Here the scale and scores assigned:
- Yes, permeability with high exposure = 100
- Medium Exposure = 50
- No permeability or exposure =10

5) The wind exposure to erosion is also one relevant factor to be considered.
We specifically refer to the wind erosion susceptibility map from the European Union and generally refer to the "Global erodibility index" (even though the results of this study are a combination of many other factors than simply just wind exposure) (Borrelli et al., 2014). The European Map of wind exposure (Fig. 27) shows the minimum level of erosion in the Regions where the Magma Geopark is located, while they display a high rate of erosion in the Sesia Val Grande Geopark area.

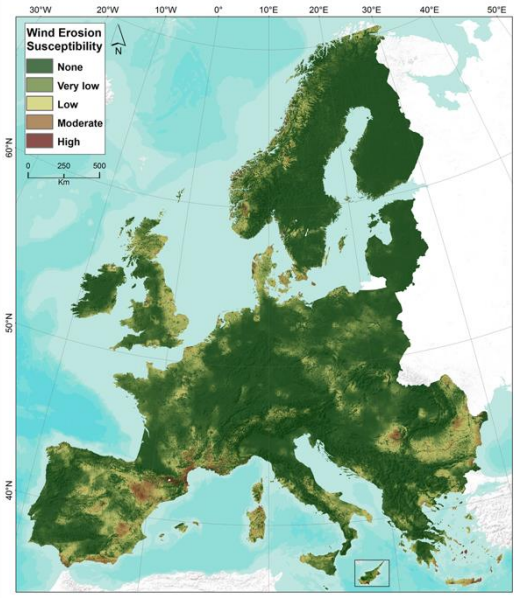

Figure 27 - Wind Erosion Susceptibility-ESDAC 2014

We connected high levels of wind exposure to higher scores. Here are the scale and scores selected:
- Yes, with high exposure = 100
- Medium exposure = 50
- No = 10

6) The slope gradient refers to the angle any part of the earth's surface makes with a horizontal datum. "*Slope gradient greatly affects the amount of surface water run-off and soil sediment loss. Soil erosion rates become acute when slope angle exceeds a critical value and then increases logarithmically*" (Kosmas C. 1995). We refer to the 37% slope gradient.
The lower is the slope gradient, the lower the possible soil erodibility.

Here the scale and score selected:
- Above 37% = 100
- Middle (average slope gradient) = 50
- Under 37% = 10

c. Transportation

The transportation phase is characterized by sediment transported by water, ice, gravity, or wind. To assess the transportation rate of the geosites selected we have referred to specific studies concerning the Sesia river (Arpa Piemonte, 1993); for Magma Geopark the presence of magmatic rocks, the absence of rivers or glaciers do not allow relevant gradient of sediment transportation. We have assessed the sediment transportation based on specific research and typology of rocks. However, the presence of soil in Jossigfjørd allows us to consider the level of transportation in the geosite "medium".

In our geosites, we have applied the following scale and scores:

- High rate of transportation = 100
- Medium rate = 50
- Low = 30
- No transportation = 10

For more accurate measurements in place, we refer to the most accepted scientific theories and methods (Hengelund & Hansen ,1967).

d. Deposition

Sediment deposition can be found anywhere in a drainage system, from high mountain streams, to rivers, lakes, deltas, and floodplains. It occurs when the agent of erosion (water, wind) lays down sediments. In the study data from sedimentation are available only from Sesia river, MGp geological characteristic do not include sedimentary rocks.

In our geosites we have applied sedimentation data from regional studies only related to the Sesia river; the absence of a river or glacier within MGp geosites and the prevailing presence of outcrops of magmatic rocks do not allow us to apply any sedimentation data. However, the presence of sediments and soil in Jossigfjørd, allowed us to consider the level of deposition in the geosite "medium". For a more accurate measurement, we refer to the most accepted scientific theories and methods (Hengelund F., Hansen E.; 1967; Ferring, 1986).

For a rough, short-term (last century) evaluation of depositional rates, we applied the following scale and scores:

- Yes, there is a high rate of deposition (> 1.0 cm/year) = 100
- Medium (0.1-1 cm/year) = 50
- Low (< 0.1cm/year) = 30
- No deposition = 10

D. Assessment results (see calculation within annex 6, Excel worksheet "Phase 4; Column E)

From the application of the above parameters and scores (indicators), we can deduce the following results:

Eigerøy 27%
Prato Sesia 61%
Jossngfjørd 34%
Crevola 42%

The **Eigerøy** geosite is not affected by relevant terrestrial processes due to the absence of soil and prevalence of magmatic rocks, so it offers the lowest contribution to abiotic ecosystem service N.2.

The **Prato Sesia** geosite is the most influenced by terrestrial processes, due to the overlapping of the geosite with local geomorphological features (channel curvature, fluvial bars, loose materials) of the Sesia river, which maximize the washout and the transportation-deposition phenomena. Pebble and gravel (clastic sediments) are the prevailing channel material, so can be more easily eroded compared to the magmatic rocks characterizing the other geosites.

Jossingfjørd has higher deposition and transportation level compared to Eigerøy because of the presence of soil.

Crevola got an intermediate score due to the presence of the dam which reduces the erosion, transportation, and deposition on site; the metamorphic prevailing bedrock also contributes to a lower score than Prato Sesia.

E. *Benefits for society*
The abiotic factors regulating terrestrial processes have a strong direct impact on ecosystem services on a global scale. The release of carbon dioxide is also activated by plate tectonics (vulcanism), while rock weathering contributes to its storage through limestone and carbonate soils. Enhanced carbon sequestration is a major regulating service that helps mitigate global warming and can increase soil productivity.

At a regional-local level, the abiotic terrestrial processes having a direct impact on ecosystem services are erosion, transportation, deposition, and uplift. The regulation services linked with erosion affect the local population in terms of reducing the number of exposed soils (shortage of sediment); the erosion index also depends on the minerals and the rocks' structural properties. Certain types of rocks play a crucial role in regulating erosion and can be used to create artificial barriers. The transportation of debris by the river regulates the distribution and energy from the land to the sea (sediment supply). The deposition could create barriers along the coasts that protect the ecosystem while sediment deposition influences the diffusion of seismic waves. Marine sediments are powerful containers for stocks, acting as regulators of climate change and greenhouse gases. The so-called: "transitional environments", in which water and sediments loaded by rivers are transported and deposited in the plains, make the soil quite rich in sediments. The community, through appropriate measurements, needs to become able to monitor and consequently control the regulating phenomena provided by the geomorphology of the geosite; this would make the community able to act for coastal defence, to set up appropriate hazard risk assessment, and a proper "land use" planning.

3) <u>Flood control</u>

Here, a preliminary consideration is needed regarding the "point of view" to evaluate ecosystem services within a geosite. To find out possible controlling factors of flood phenomena, we need to look "outside of the geosite". Then we must observe the geosite from outside to find out which possible abiotic factors are regulating the floods, by opposing them to their hazards and related risks.

A. *Question:* What factors contribute to flood regulation within the geosite? The scope is to assess how much the geosite characteristics are influencing the flood events.

B. *Geological processes which influence the services:*
The PhD team's preliminary definition of the service: a) Landforms and Geomorphological processes regulating geohazards; the abiotic and the biotic systems working together to control the flood (e.g. organic material and inorganic clay)
Gray.'s definition of the service: b) Soil- clay can reduce erosion, natural physical barriers (river levees, single beach ridges)

C. *Abiotic factors influencing the process. Scale and assessment*:
The presence of a geomorphic agent is the first preliminary condition that needs defining.
The abiotic indicators involved in the analysis are different when rivers, lakes, or seas are in proximity of the geosite. Total score evaluation: a higher score is equal to a higher geosite contribution to the flood control service.

a) <u>Presence of landforms</u>
The abiotic factors involved in the service are the ones linked with flood regulation and risk, such as the following geomorphological (erosional and depositional) features: hills, clay deposits, dunes, barrier islands, human made constructions, salt marshes, river levees, beach ridges, etc. This factor is valid for assessment both in the presence of rivers and lakes and in the case of presence of coastline in the proximity of the geosite.

We have counted the number of geomorphological features which are acting like barriers for the geosite; higher numbers of geomorphological features correspond to higher levels of protection. The higher the number of landforms, the lower the possibility of flooding; the higher the protection, the higher the geosite's flood control.

Here the scale and scores selected:
- More than 4 relevant features within the geosite = 100
- 3-4 = 50
- 1-2 = 20

- none =10

b) Amount of precipitation

The amount of precipitation is a factor that influences flood regulation in case of lake or river proximity. For the Magma Geopark, we adopted data from the Norwegian Meteorological Institute from Senorge: the average precipitation over the last 60 years. We applied statistics from the Italian Meteorological Institute for Sesia Val Grande Geopark from the Ministry of the Environment and Forest (MAEF) considering the average of the last 10 years in the province of Novara. (Figs. 27, 28)

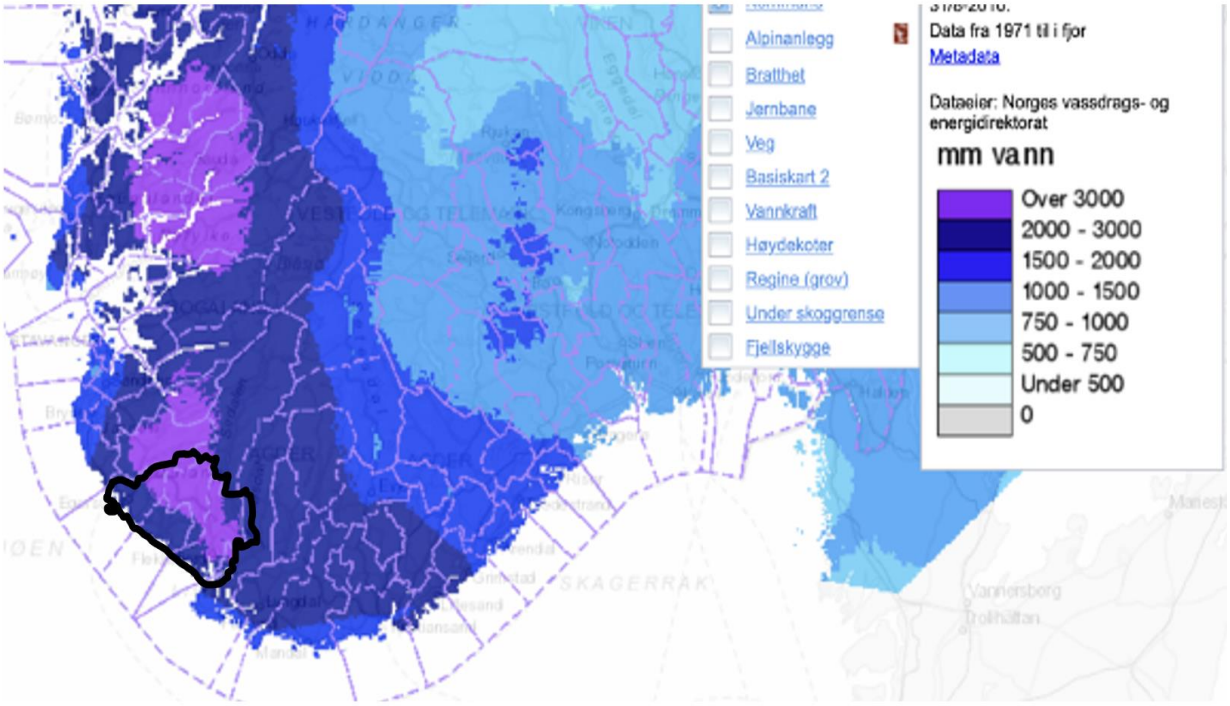

Figure 28 - Norwegian average precipitation with focus on MGp area-Senorge (ml/year)

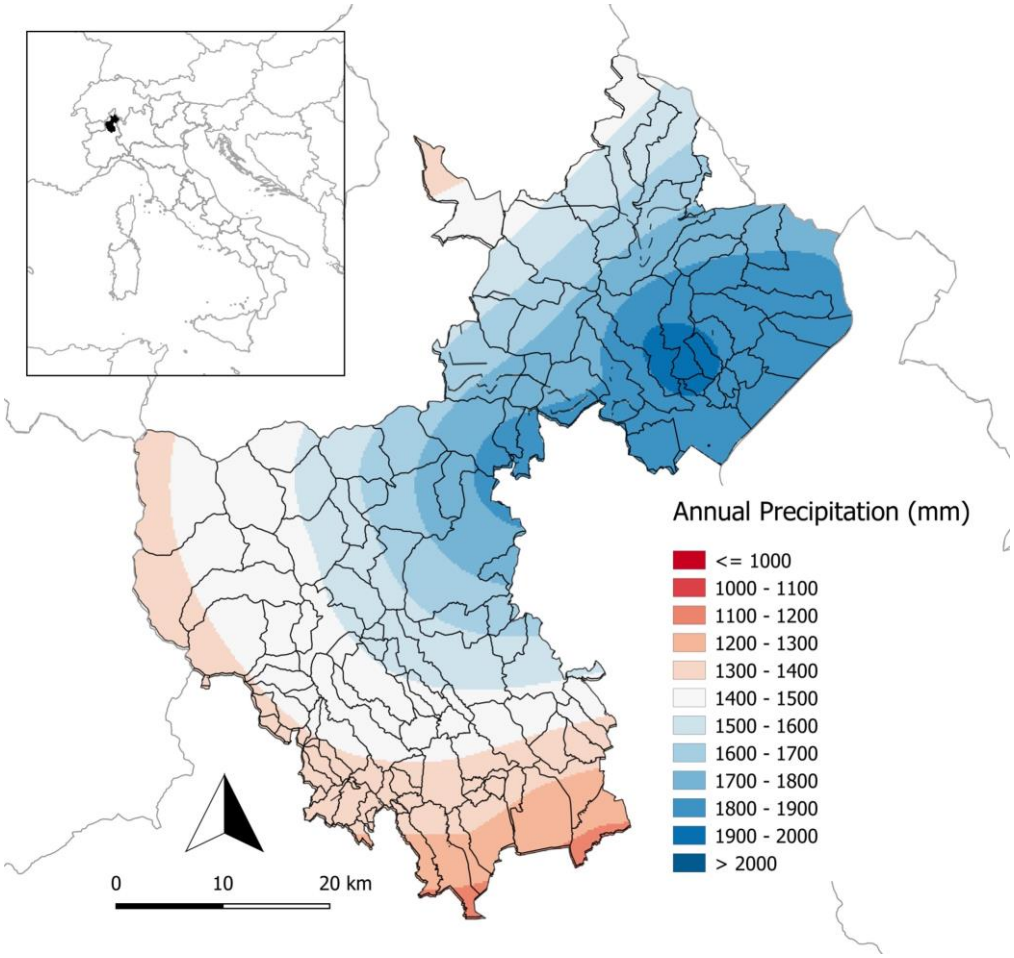

Figure 29 - Average Annual Precipitation-Novara Province-MAEF (ml/ year)

The higher the precipitation, the higher the risk of flooding (consequently, a higher score is given).

The scale selected and scores:

- 3 m/year = 100
- from 1-3 m/year = 50
- from 1 m/year to 0.5 Mt = 20
- less than 0.5 m or no river-lake = 10

c) Flood return period

The factor occurs both in case of river and lake presence.

We define the "flood return period" as "the probability that an event will be met or exceeded during an interval of n. years".To assess the value in the Sesia Val Grande Geopark, we adopted parameters defined by the Piano di Gestione del Rischio Alluvione (Boccia, 2020), while for Magma Geopark we adopted data from the Norwegian Environmental Service Atlas (O'Rourke, 1985).

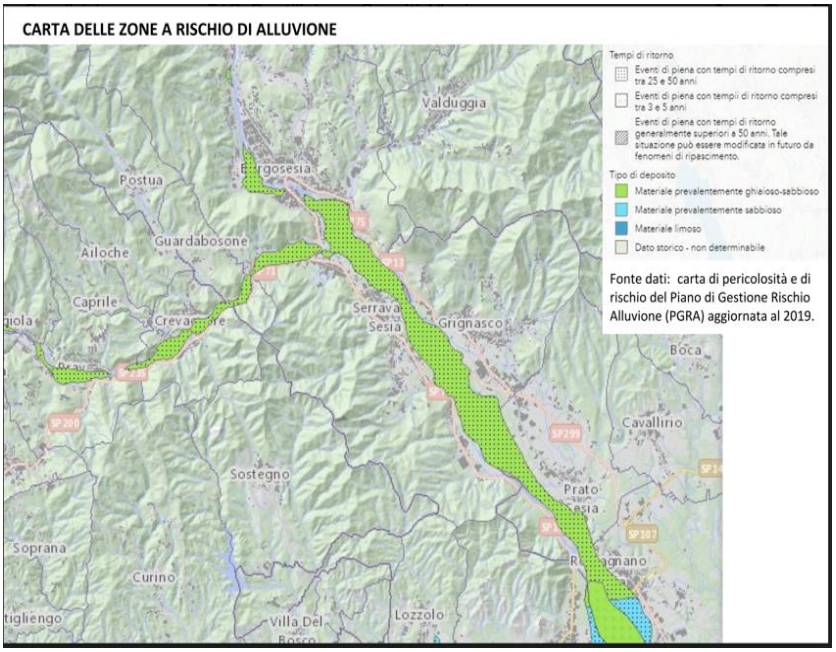

Figure 30 - Piano Gestione del Rischio Alluvione (Boccia I. et al. 2020)

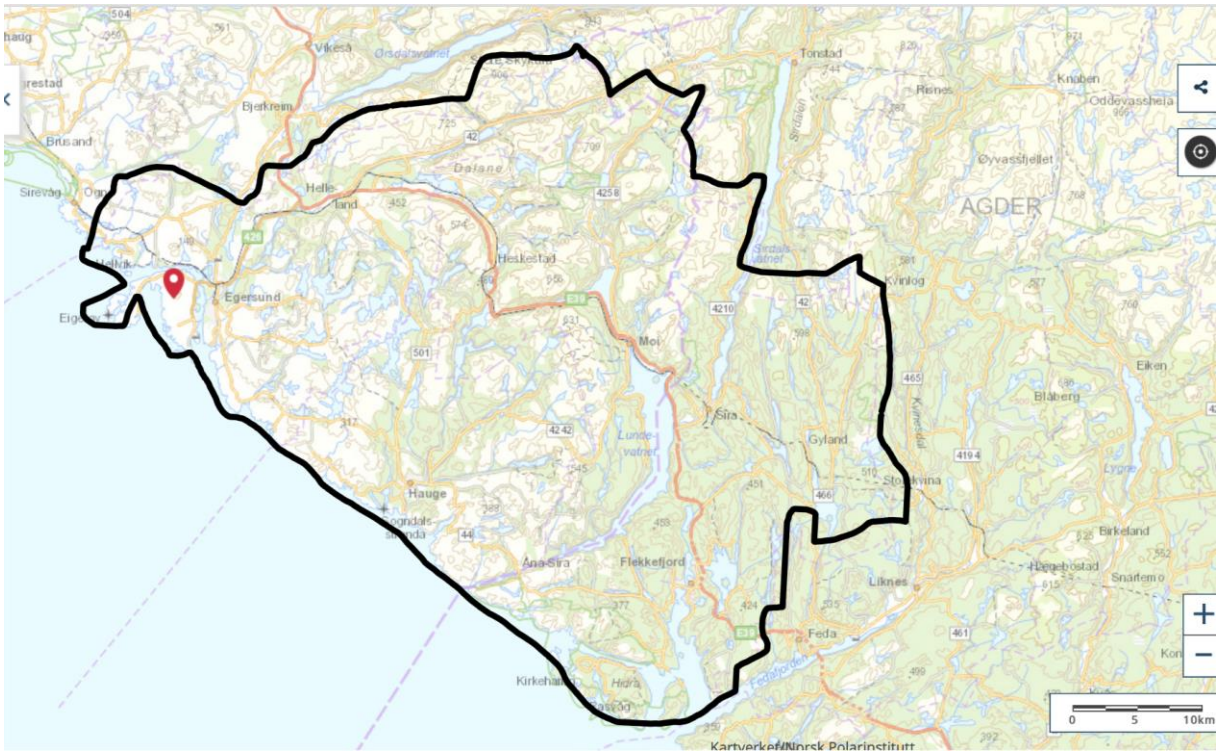

Figure 31- MGp- Flood risk (Green, from Environmental Atlas)

The longer the interval of time between two major events, the less the geosite is exposed to flood. So, we can conclude that the longer the time between two floods, the better the geosite (the whole ecosystem) is acting against floods (regulating service).

Here the scale selected and the connected score:

- No river or lakes = 100
- More than 50 years flood return period = 90
- From 25 to 50 years flood return period = 50
- From 3 to 5 years flood return period =10

d) Maximum water discharge

In case of river presence, the maximum water discharges the volume of water flowing through a river channel at any given point and is measured in cubic metres per second.
High water discharge rivers generally tend to flood more than low water discharge ones. We decided to attribute higher points to lower water discharge rivers which allows the geosite to better regulate the flood.
Water discharge for the Sesia river has been obtained by the Piemonte Regional Agency Environmental Protection. The stream crossing Jossingfjørd (Migaren) has no data available, but the water discharges are rather low all year around.

Here the scale and scores:

- No river =100 points
- Less than 10 m^3/sec/ average per month = 90 points
- From 10-50 m^3/sec/ average per month = 60
- From 50-500 m^3/sec/ average per month = 30
- Above 500 m^3/sec/ average per month = 10

e) Sea tide and average wind speed

In the case of geosites close to the coastline, the tide is a factor to be considered, as with high tides, there is a higher risk of floods. We have been consulting the online Tide Forecast for Eigerøy and Jossingfjørd in the Magma Geopark. The tide and the wind change every hour so this parameter must be calculated at the exact time and day. For this research we take into consideration 8th March 2021 at 11 am. The tide is approximately zero and wind is expected to be 9-10 m/s in both geosites.

High tide combined with high wind speed could easily lead to flood phenomena.

Here the scale and scores suggested:

- No sea = 100
- From 0 to 1 m and less than 10 m/s wind = 90
- From 1-3 m and above 10 m/s wind = 60
- From 3-8 m and above 15 m/s wind = 30
- Above 8 m and above 25 m/s wind = 10

D. *Assessment* results (see calculation Excel sheet n.4)

Total score evaluation: a high score corresponds to a high contribution of the geosite to flood control.
From the application of the above parameters and scores (indicators), we can deduce the following results:

- **Eigerøy**: 64%
- **Prato Sesia**: 46%
- **Jøssingfjord:** 64%
- **Crevola**: 48%

The **Eigerøy** and **Jøssingfjord** geosites offers a medium-height defence against flood events; this is due to the absence of rivers and to the presence of landforms like hills and fjords which eventually could act as a relative barrier against storms from the sea; however, we need to take into consideration that the wind and tide should be measured hours by hours.

Prato Sesia does not offer adequate protection against flood phenomena due to the absence of natural or artificial barriers, and due to the return time of the flood period, as demonstrated by the latest destructive episode in January 2021.
The **Crevola** geosite provides the same protection from floods, compared to Prato Sesia within the detected parameters.

E. *Benefits for society*
The regulation of flood has important consequences at an international-regional-local level. At all levels, controlling the flood allows Governments to increase vulnerability to floods and to set up proper planning schema for better land use. To monitor and build infrastructures, a proper analysis on landforms, geomorphological processes and index of erosion are needed.

4) <u>Water quality regulation</u>

A. *Question:* How much do the abiotic characteristics of the geosite regulate/ influence water quality?

B. *Geological processes which influence the services:*
The PhD's preliminary definition: a) Water quality regulation includes all the geomaterials which improve the quality of water.
Gray's definition: b) Soil, sediments and rock attenuate polluting substances and help the water quality both surface and groundwater.

An indispensable premise, before analysing this abiotic service, concerns the general principles of the "geology of the aquifers". The nature and distribution of aquifers and aquitards in a geological system are controlled by lithology, stratigraphy and structure of deposits and geological formations (De Wiest & Davis, 1966; WHO, 2017). In this research, we assume that the aquifer is in place; consequently, we do not analyse the pre-conditions for its existence. We analyse what the abiotic factors for mineral water are, not the ones linked to the presence of the aquifers.
There are several abiotic factors which influence water quality. For "water quality", we adopted the definition given by the World Health Organization (WHO, 2017) and we also took into consideration the "definition for mineral water quality" by the FAO (FAO; WHO, 2019).

C. *Abiotic factors influencing the process. Scale and assessment*:
To be defined as "mineral", water needs to contain: sodium, potassium, calcium, magnesium, chloride, sulphate, hydrogen carbonate. "Mineral" waters originated from underground reservoirs. Each mineral water has peculiar characteristics due to the layers of bedrock that the water flowed through in its source region, which determine the amount and composition of natural ingredients in it.
Following the definition of "mineral" water, in order to define at what scale one geosite influences the quality of the groundwater, we need to analyse following factors: a) Mineralogic Properties of the rocks on surface-bedrock b) Permeability and porosity of the soil (the higher the porosity, the higher the permeability).

a) <u>Mineralogic properties of the rock</u>
We started our analysis by connecting each basic mineral (the ones essential to defining water as "mineral": sodium, potassium, calcium, magnesium, chloride, sulphate, hydrogen carbonate) with the bedrock type they originated from.

- Sodium and potassium could potentially dissolve from all kinds of bedrocks.
- Calcium and magnesium dissolved from limestone, dolomite, and gypsum.
- Chloride, all types of rocks.
- Sulphate dissolved from rocks containing gypsum, iron sulphides, and other sulphur compounds.
- Hydrogen carbonate is generated by the action of carbon dioxide in water on carbonate rocks such as limestone and dolomite.
- Magmatic rocks do not influence the mineralogic properties of the aquifers.

The conclusion is that bedrock made of limestone, dolomite, gypsum, iron sulphides, and sulphur compounds could potentially generate aquifers made of mineral water, while other kinds of bedrock cannot.
Here are the selected scale and scores:

The geosite is mainly characterized by limestone, dolomite or gypsum:
- Yes =100
- No = 10

The geosite is mainly characterized by gypsum, iron sulphate:
- Yes =100
- No =10

Magmatic rocks do (or are not) influence the mineralogic properties of the aquifers (the geosite is characterized by magmatic rocks),
- Yes =10
- No = 100

b) Permeability of the soil

Permeability is a property of the porous medium that measures the capacity and ability of the formation to transmit fluids (Darcy Law). The least permeable rocks are not-fractured intrusive igneous and metamorphic rocks, followed by not-fractured mudstone, sandstone, and limestone. The permeability of sandstone can vary widely depending on the degree of sorting and the amount of cement that is present. Clay textured soils have small pore spaces that cause water to drain slowly through the soil; they have low permeability, which results in low infiltration rates and poor drainage.
The presence of mineral water depends on bedrock type at the geosite but also on the permeability of the soil.

Here are the selected scale and scores:
The geosite is mostly characterized by gravel (the rock highly influences the water quality because its material leaves a lot of empty space within the particles).
To what extent?
- Completely covered by gravel = 100
- Half covered by gravel = 50
- Not covered by gravel = 10

The geosite is mostly characterized by sand.
To what extent?
- Completely covered by sand = 100
- Half covered by sand = 50
- Not covered by sand = 10

The geosite is mostly characterized by clay.
To what extent?
- Completely covered by clay = 100
- Half covered by clay = 50
- Not covered by clay = 10

D. *Assessment* results (see calculation Excel sheet n.4)

Total score evaluation: high scores correspond to a high contribution of the geosite to flood control.
From the application of the above parameters and scores (indicators), we can deduce the following results:

- **Eigerøy: 10%**
- **Prato Sesia: 23%**
- **Jøssingfjord: 10%**
- **Crevola: 23%**

Due to the magmatic bedrock and total absence of permeable soil, **Eigerøy** and **Jøssingfjord** do not contribute to the regulation of mineral water aquifers which are almost absent in the overall Geopark.

The **Prato Sesia** and **Crevola** also contribute slightly due to the presence of magmatic bedrocks characterized by iron sulphate and iron.

E. *Benefits for society*
The regulation of the quality of the water has a relevant impact on a regional and local scale. The analysis of the geological surface, permeability, and porosity of the soil are important factors to be taken into consideration. The possibility to calculate the specific water regulation quality service gives authorities the chance to be aware of the presence of mineral water, its quantity and, consequently, how to use it for the community's supply.

5.7.2 Regulating services, Supporting Services

For these kinds of ecosystem services, we need to focus on abiotic processes contributing to the development of **soils** (5) and **habitats** (6) for enhanced biodiversity and related resources, of **platforms** (7) for human activities, and of **burial and storage** (8) sites. The consequences of their activity will be analysed in both a geomorphological landscape and a geological environment.

5) <u>Soil processes</u>

A. *Questions:* What are the abiotic factors influencing the soil development and its quantity and quality? What are the most relevant supporting services that the soil provides to the community?

B. *Geological processes which influence the services:*

The PhD's team preliminary definition: Quantity of soil offering weathering material.
Gray M.'s definition and examples of services: soil processes provide these services to the community, agriculture, forestry, fuel, and genetic resources.

C. *Abiotic factors influencing the process. Scale and assessment*:
What are the abiotic processes influencing soil development?
Apart from climactic and lithological factors controlling soil fertility and related agricultural activities (see below), the Earth's main surface processes are erosion, transportation, and deposition. By analysing erosion, transportation, and deposition indicators within a specific geosite, we can evaluate its tendency to support main abiotic services linked with soil processes, such as agriculture, forestry, fuel and genetics. In fact, erosion, transportation, and deposition processes control the predisposition of soil for fertility and, consequently, provide higher chances to support agriculture and forest activities.

Since this research is not aimed at calculating each single factor influencing soil fertility which would require specific analyses from a soil scientist, we simply used indicators related to the spatial and temporal distribution of agricultural activities and forests within geosites. Indicators for "fuel and genetics" will be considered within the provisioning services. The overall calculation gives us an approximate idea about the overall tendency of the geosite in supporting soil processes and, consequently, agricultural and forestry activities.

a) <u>Erosion, deposition and transportation</u>

The three factors have been calculated following the parameters already in use for the "terrestrial processes" (see above).

b) <u>Agricultural activities</u>

Soil health has been defined as "the continued capacity of the soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health" (FAO). To support the services linked with agricultural activities, the soil needs to be fertile.

What are the factors which influence the fertility of the soil?

There are majorly 12 factors which influence soil fertility; for a deeper and more precise research, a pedologist would be required in the team. Here are the factors to be taken into consideration:

1) Infiltration of water.
2) Soil structure.
3) Active Soil life.
4) Content of organic matter.
5) Minerals present in the soil.
6) Acidity or Soil ph.
7) Water Retention capacity of soil.
8) Water draining ability of the soil.
9) Nutrient release capability.

For evaluating geosites in Norway, we have been using the data from the Norwegian Environmental Atlas (fig. 34), while for those in Italy we used data from the Instituto Superiore Ricerca Ambientale (ISPRA) database (fig 33).

Figure 33 -, Prato Sesia- Grassland (Green, geosite in blue)

Figure 34 -, Jøssingfjord- Agricultural use of the soil (yellow orange, Geosite in red)

Scale and score detected:
Are within the geosite active agricultural activities (crop cultivation, vineyard, orchard)

- Yes = 100
- in the past = 50
- No = 10

c) Forestry activities

The presence of forest activities depends on many abiotic factors, which are linked with soil quality. The team decided to evaluate the presence of forests at the present time as a scale.
Is the geosite hosting an unmanaged forest?
If so, at what grade is the forest covering the geosite?

For Norway, we have used the data from the Environmental Atlas (Figs 35, 36), while for Italy we have analysed data from the Sistema Informativo Regionale Regione Piemonte (http://www.sistemapiemonte.it) (Figs 37, 38).
Here below the scale and score detected:

1. Fully covered by a forest = 100
2. Partially covered by forest = 50
3. No forest = 10

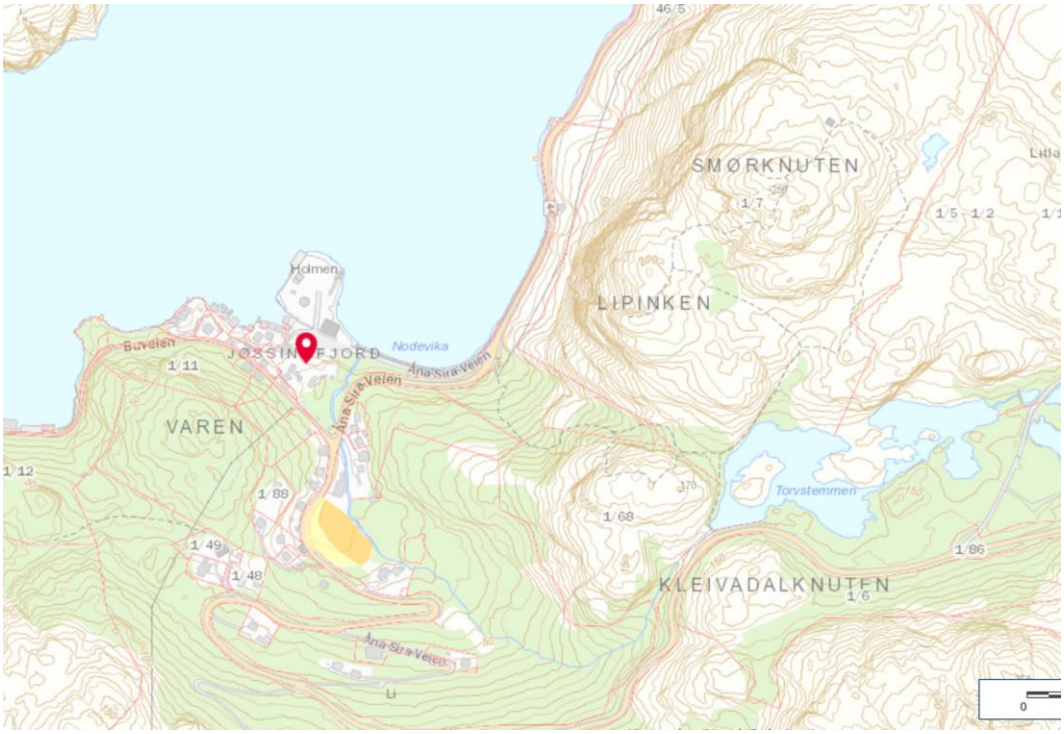

Figure 35 -, Jøssingfjord Land use Map, Forest (Green, geosite in red)

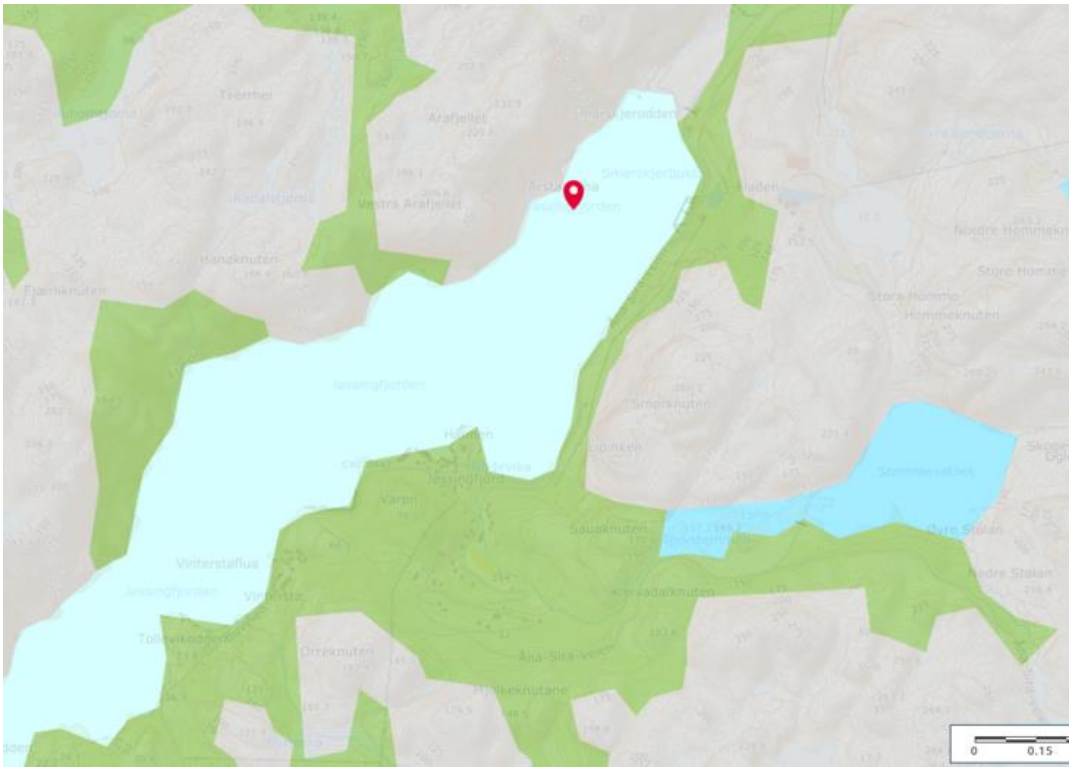

Figure 36 - Jøssingfjord Forest coverage. (Green, geosite in blue)

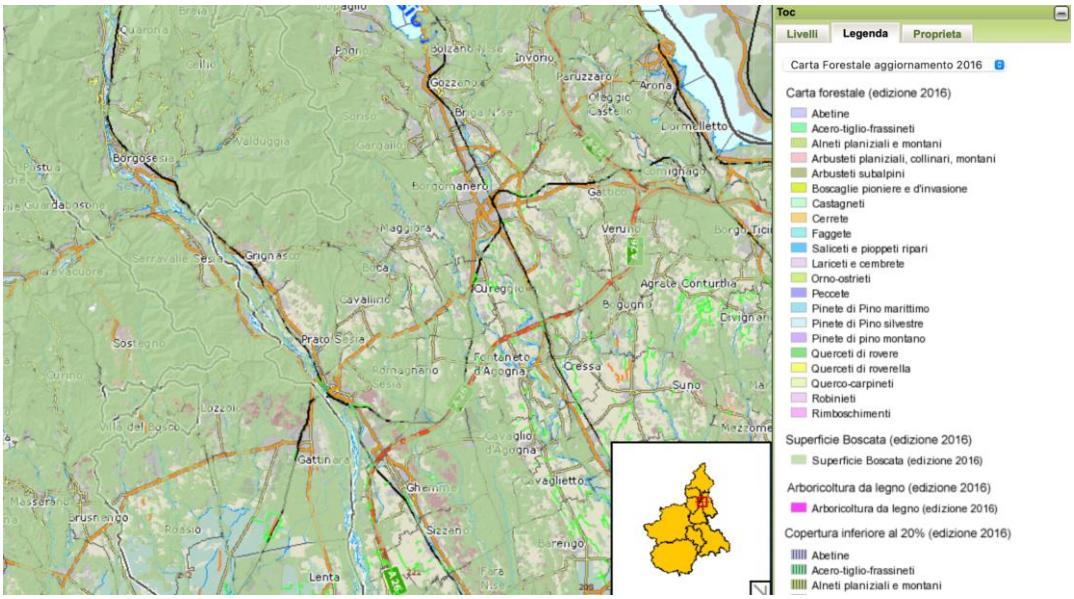

Figure 37 -Prato Sesia- Forest Coverage- (Green, geosite in blue).

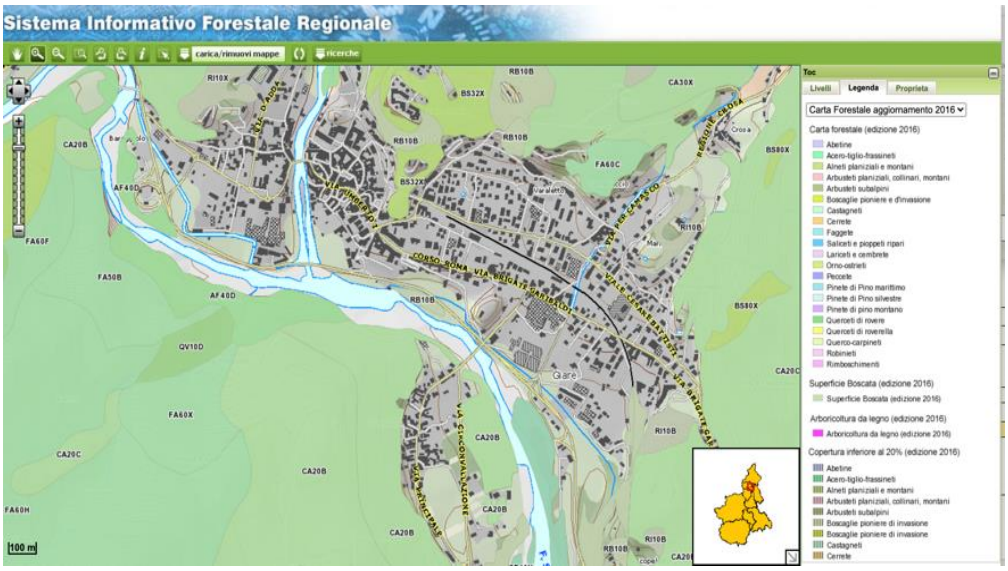

Figure 38 - Crevola- Forest Coverage (Green, geosite in blue)

d) Fuel and genetics

Fuel and genetic resources are considered "provisioning" services. They will be analysed in the "provisioning" section.

D. *Assessment* results

Total score evaluation: high score corresponds to high geosite contribution to soil processes and related main services to the community: agriculture and forestry.

From the application of the above parameters and scores (indicators), we can deduce the following results:

Eigerøy: 25.45%
Prato Sesia: 60%
Jøssingfjord: 35.45%
Crevola: 40%

The **Eigerøy** geosite is generally poor in soil, due to geological characteristics and consequently poorly supports agricultural activities and forestry.
At **Jøssingfjord,** the higher presence of soil, due to moraine deposits, make possible for the geosite to support agriculture and forestry, at a higher scale compared to Eigerøy.
Crevola has a slightly higher score than Jøssingfjord due to higher erosion, transportation and deposition thanks to the river presence.
Prato Sesia has a higher score due to the presence of forest and river activities which guarantees high amounts of debris transportation and deposition.

E. *Benefits for society*
Soil processes play an important role within national, regional and local communities. Soil processes offer both abiotic and biotic services. Agriculture, forestry, fuel, and genetic resources are crucial for human development. Agriculture plays a key role in providing a wide range of ecosystem services, such as food, feed, fibre, and biofuel, thus taking part in the economic development of countries. Forestry is defined as "*the science or skill of growing and taking care of trees in forests, especially in order to obtain wood "* (Collins Dictionary Definition). Forestry, along with farming, remains crucial for land use and the management of natural resources in the EU's rural areas, and as a basis for economic diversification in rural communities, especially for mitigation to climate change.
The assessments of threats to soil functions leads to a need to formally identify the functions that the soil performs. The proposed Soil Framework Directive (CEC, 2006) of the European Union recognizes seven soil functions that are vulnerable to soil threats:
1. biomass production, including agriculture and forestry;
2. storing, filtering, and transforming nutrients, substances, and water;
3. biodiversity pool, such as habitats, species and genes;
4. physical and cultural environment for humans and human activities;
5. source of raw materials;
6. acting as a carbon pool;
7. archive of geological and archaeological heritage.
The EU Soil Thematic Strategy was developed in parallel with the Millennium Ecosystem Assessment initiated by the United Nations in 2000. Within the goals of the MA, there is assessment of the consequences of changes in soil use to lay the scientific basis for actions that would promote conservation and sustainable use of related supporting ecosystem services.

6) Habitat provision

A. *Question:* At what scale is the geosite supporting the habitat provision?
First, it is necessary to define what a habitat is. It is " a physical location where environmental factors (abiotic and biotic) support the life and the development of one species".

B. *Geological processes which influence the services:*
The PhD team's preliminary question: Are there habitats within the geosite?
Gray's definition of "Habitat": the spatial-temporal interrelated site factors of river-floodplain-systems (geomorphology, geology and soil diversity) that provide habitat heterogeneity.

C. *Abiotic factors influencing the process. Scale and assessment.*
By literature, the higher the geodiversity assessed in an area, the higher its potential biodiversity and consequently the habitat provision (Matthews, 2014; Zwolinski et al., 208). Therefore, we need to start from the abiotic factors which concur to geodiversity. They have been described as "Essential Geodiversity Variables" (EGVs) by Schrodt F. et al., 2019 and summarized within these classes: geology (hard rock, unconsolidated deposits, geophysical processes), geomorphology (landform distribution), soil (chemistry, physical state), and hydrology (surface water, ground water).
All these EGVs must be considered abiotic factors contributing to biodiversity and to the related supporting services, such as habitat provision (8).

Given that the higher the geodiversity, the higher the biodiversity. By rating the impact of single factors detected as elements that influence geodiversity, we will be able to assess at what scale the geosite contributes to supporting habitats.

a) Type of Geology

1) Hard Rock fossils, mineral and ornamental stone distribution and diversity.

Is the geosite characterized by a "relevant" presence of fossils or mineral-ornamental stones?

Scale and score:
Number of fossils-minerals-ornamental stones

- 0-2 = 10
- 2-4 = 30
- 5-7 = 80
- 8-10 = 100

1) Unconsolidated deposits

Material derived from the disintegration and erosion of consolidated rocks on the land's surface, as well as sediments deposited by coastal and glacial processes. Unconsolidated materials are included, in order of increasing grain size, clay, silt, sand, and gravel. Within the geosites, are there relevant traces of clay, silt, sand or gravel deposit?

Scale and score:
Number of relevant size gravel deposits.

- 0-2 = 10
- 2-4 = 40
- 5-7 = 70
- More than 7 = 100

2) Geophysical processes

They measure the variability of the intensity of geophysical processes: earthquakes, volcanic eruptions, earth radioactivity, thermal energy, and land subsidence. At a physical level, because of their structural properties and relative resistance to erosion, some rocks produce features of relief within the landscape (e.g. cliffs, hills, etc.). These features, in turn, provide heterogeneity with respect to the physical conditions that support plant and animal communities and biodiversity.
How many geophysical processes influenced the geosites during the last geological period? (Number of relevant events).

Scale and score:
Number of relevant geophysical processes.

- 0 = 10
- 1-5 = 50
- 6-10 = 100

b) Geomorphological processes

1) Erosion and deposition, see criteria and score described above for service N5.

c) Soil diversity

Soil diversity plays a crucial role in the support of habitats. The way in which a rock weathers and acts as parent material for soil formation is perhaps the most direct and obvious mechanism for influencing plant species and their growth. The main parameters that rock type influences are soil chemistry, texture, grain size and, therefore, porosity. These aspects are all of importance in setting the boundary conditions for plant growth. Without the diversity of rock type and physical form created by rocks, the conditions available to organic life would be significantly reduced; in essence, the biodiversity that we observe is a direct function and consequence of geological form and processes (Cottle, 2005).

The following soil maps from Europe and previous maps applied for "Soil processes" have been consulted to answer the related questions and to give the correct score.

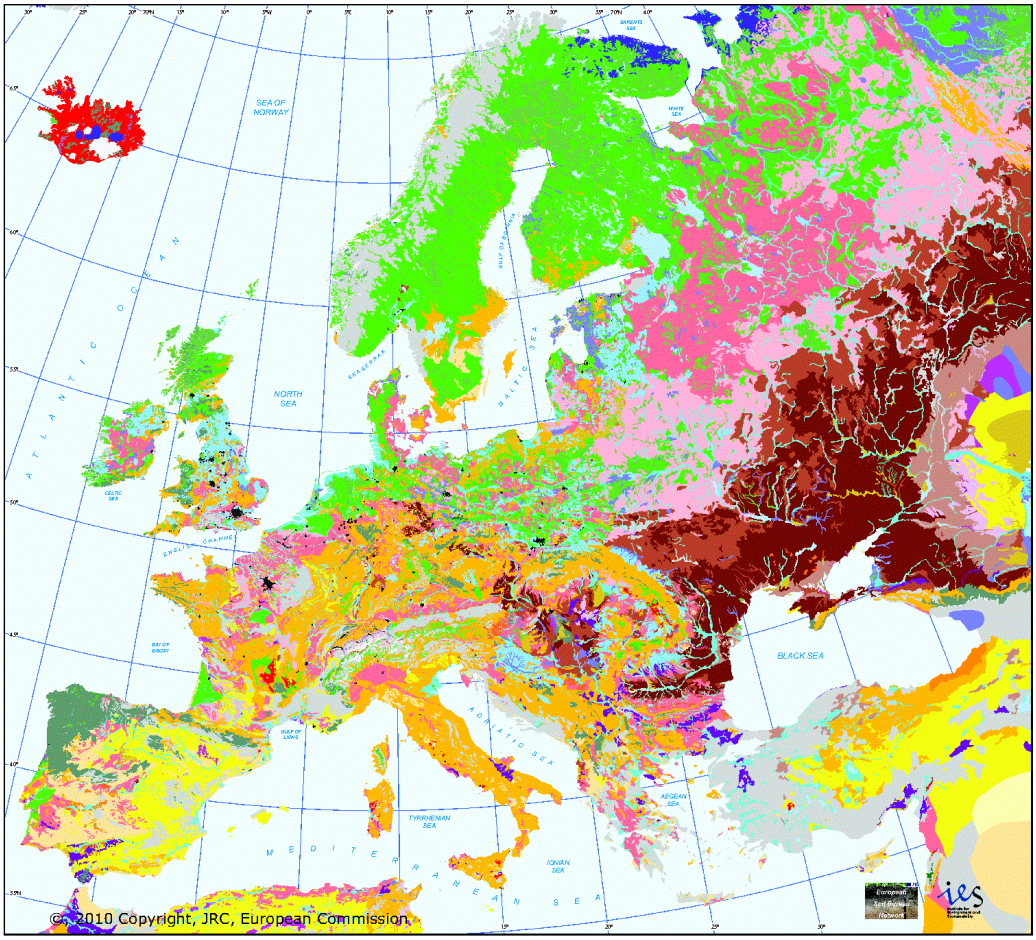

Figure 39 - Soil Map- European Commission, 2010

a) The bedrock characterising the geosite's influence, as mentioned above.
The presence of soil depends on the index of erosion of the bedrock in a specific geosite.

Scale and score:
What minerals are there and what are the structural properties of the most common rocks within the geosite?
The lower the erosion index, the lower the quantity of soil eventually produced.

- Rocks made of clay = 100
- Limestone = 80

- Low metamorphic rocks = 30
- Magmatic rocks =10

b) Soil coverage
The soil coverage index is the base factor used to calculate the soil diversity.

Scale and score:
The higher the soil coverage is, the higher the soil diversity.
At what grade is the geosite covered by soil?
- Totally − most of the geosite is covered = 100
- Partly covered = 50
- No soil presence = 10

c) Drop in temperature and permeability of the rocks type.
Relevant drops in temperature within the season/year have been investigated for the geosites (Figs 40-41).
Drop in temperature phenomena, exposure, and permeability of the bedrock need to be considered together.

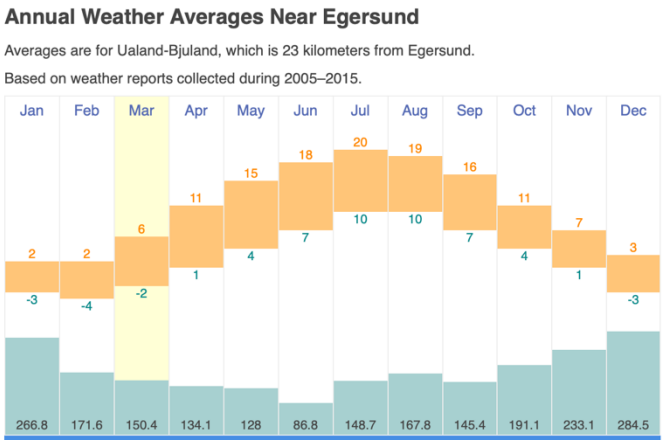

Figure 40 - Average temperature-Egersund, https://www.yr.no/en

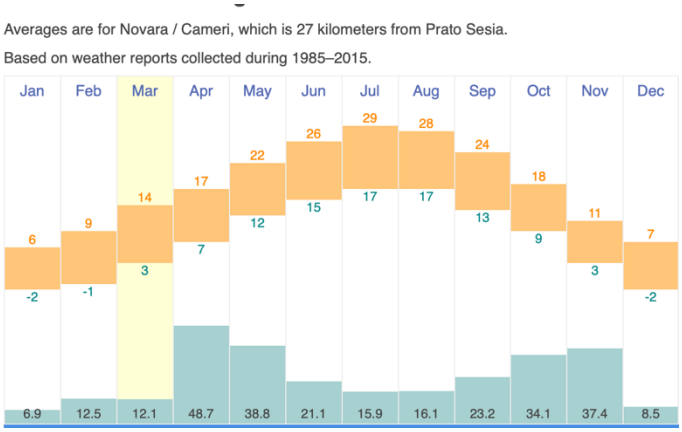

Figure 41 - Average temperature Prato Sesia

Scale and score:
Is the geosite subject to a drop in temperature and permeable rocks?
- Yes, with high exposure =100
- Medium exposure = 50

- Low exposure = 30
- No exposure or no permeability = 10

d) Washout or average precipitation.
Precipitation and washout are factors which influence the amount of soil formation in a site.

Scale and score:
Is the geosite subject to high precipitation or washout (average) during the year?
- Yes, with high intensity = 100
- Medium intensity = 50
- Low intensity = 30
- No = 10

e) Wind exposure.
Wind exposure influences soil formation.

Scale and score:
Is the geosite subject to wind exposure?
- Yes, high exposure to wind = 100
- Average exposure = 50
- Low exposure = 30
- No, highly protected from the wind = 10

f) Steepness of the slope.
Steepness of the slopes within the geosite influences the erosion and the soil formation.
We consider the average dip angle of the geosite as a measure of the critical angle of repose, i.e. the dip angle of the geosite's material can be piled without slumping or resists shear strength.
However, several factors influence the angle such as density, moisture, grain size, stratification, etc.
The research calculates an average of 35%. (Mehta & Barker, 1994)

Scale and score:
How steep is the geosite (average)?
- Above 37% = 100
- Under 37% = 10

d) <u>Geomorphology</u>

Landform distribution is crucial for the development of geodiversity and biodiversity.

a) Number of relevant landforms within a geosite.
See (AAVV, Landform of the World).

How many landforms can we eventually detect in a geosite?
- 1 = 10
- 2-3 = 30
- 4-5 = 50
- 6-8 = 80
- From 9= 100

e) <u>Hydrology</u>

a. Rock properties
The presence of certain types of rocks relates to the permeability of the rocks and, consequently, the presence and quality of aquifers and underground drinking water.

Scale and score
Is the geosite mainly characterized by limestone, dolomite or gypsum?
- Yes = 100
- No = 10

Are the geosites mainly characterized by gypsum or iron sulphated?

- Yes = 100
- No = 10

c) Fresh water presence (lakes, springs, rivers, glaciers).
The presence of freshwater reservoirs is the most important parameter for the overall analysis of the hydrology of the geosite.

Scale and score
The higher the number of reservoirs, the higher the score.
Do any freshwater reservoirs exist within the reservoir?
- More than 5 = 100
- between 3-5 = 70
- between 1-3 = 50
- No = 10

d) River dynamics
The river dynamics influence the overall hydrology of the geosite. We considered the average river discharge per month as a measure of the river dynamics.

Scale and score
The higher is the river discharge, the higher the score is/

Flow dynamic: expressed in m^3/s, average discharge per month.
- No river within the geosite = 10
- Small river, less than 10 m^3/s = 30
- Small to medium river 10-100 m^3/s = 50
- Medium river 100-500 m^3/s = 80
- Large river, above 500 m^3/s = 100

e) Presence of dams
A dam interferes with the natural hydrology of the geosites, thus influencing the river flow and dynamics.

Scale and score
- The higher the number of dams, the lower the score.
- No dam = 100
- Between 1 to 3 dams along the river = 50
- More than 4 dams = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Sheet 4"- Column C)
Total score evaluation: the higher the score, the higher the geosite contribution to soil processes, agriculture and forestry.

From the application of the above parameters and scores (indicators), we can deduce the following results:

Eigerøy: 38.1%
Prato Sesia: 77,2%
Jøssingfjord: 60%
Crevola: 64.5 %

In **Eigerøy**, the soil's scarcity (low soil diversity), the low permeability of the bedrock, and the limited presence of freshwater reservoirs leads to a low contribution from the geosite to the habitat provision service.

In **Jøssingfjord**, the geosite is characterized by the presence of soil and one dam; at least four different geomorphological features can be detected (bay, fjord, ocean, waterfall); for these factors, the geosite contributes highly to this service.

Crevola scored slightly higher than Jøssingfjord due to higher erosion, transportation and deposition, thanks to the river characterized by the highest water flow compared to the stream in Jøssingfjord. Scarcity of soil also influences the habitat provision in Crevola.

Prato Sesia has a higher score due to the high presence of soil, forests and freshwater reservoirs not regulated by a dam. The river activities guarantee a high number of debris and a consistent number of unconsolidated deposits.

E. *Benefits for society*
Habitat provision. The supporting services (abiotic and biotic) which concur to the creation of "habitats" are crucial for societal development at all scales. Humans, like all animals, have a favourable ecosystem to live in, which is the natural habitat. Geodiversity influences the heterogeneity of habitats and biodiversity; consequently, biodiversity affects the loss of geodiversity. Destruction and degradation of natural ecosystems are the primary causes of declines in global biodiversity (Haddad et al., 2015). Habitat loss, stemming from destruction, fragmentation, or degradation, threatens these sanctuaries of diversity and is often the result of human activities. Loss in habitat size, increased isolation of habitats from one another, and increases in negative edge effects (where one habitat begins and another ends) characterize fragmentation. These elements cause changes to the delicate biological and physical properties of habitats, decrease genetic diversity, introduce pathogens and invasive species, and lead to human-wildlife conflict. All the advantages which guarantee abiotic and biotic factors linked with habitat provision are evident from the negative effects caused by the loss of biodiversity and geodiversity.

7) Land as a platform for human activities

A. *Question:* What human activities are influenced by the land?

B. *Geological processes which influence the services:*
The PhD's preliminary definition: a) Presence of a land platform which contributes to the development of different human activities
Gray M.'s definition: b) Land surface: different activities require different types of platform.

Human activities on the Earth's surface are linked to the various types of land uses. Different types of activities correspond to different types of land use. Most of the human activities are performed on artificial surfaces (the soil's function is to support construction), the other activities are linked to agriculture and forestry (the land function is to support the crops, breeding, trees, and plants). In the research, we are detecting four main types of "land-supporting use": agriculture, breeding, forestry, and construction.

C. *Abiotic factors influencing the process. Scale and assessment*:

a) Agriculture

What are the factors which influence the "land" as a platform for agricultural activities? The presence of soil is the main requirement together with the climate factors (all described above in relation with "soil" and "climate" abiotic services). However, in this research, we decided to take into consideration the existence of active agricultural activities.

Here are the selected scale and scores:
Are agricultural activities active within the geosite (crop cultivation, vineyard, orchard)?

- More than 80% of the geosite is occupied by cultivation = 100
- Between 60-80% is occupied by cultivation = 80
- Between 10-60% = 30
- No cultivation =10

b) Animal husbandry and cattle farming activities
The science of animal husbandry relates to the business of producing domestic livestock species, including but not limited to beef cattle, dairy cattle, horses, poultry, sheep, and swine.

Here are the selected scale and scores:
Is there any active animal husbandry and cattle farming activity in the geosite?

- Yes, more than half of the hectares are used for husbandry-farming = 100
- Partly, less than 30% of the hectares are used = 50
- No surface used for this purpose = 10

c) Presence of activities related with forest management

The presence of a forest is one of the most relevant supporting services within "land as a platform for human activities". Forests are managed for specific goals and objectives set by the landowner. Management ranges from custodial, where little or no action is taken, such as in designated wilderness areas, to intensive active management where timber is continually grown, harvested or replanted.

Here are the selected scale and scores:
Are any activities related with forest management within the geosite?

- Yes, more than half of the hectares = 100
- Partly, less than 30% of the hectares = 50
- No forest = 10

d) Presence of artificial buildings

Here are the selected scale and scores:
Are any artificial buildings in the geosite?

- Town presence = 100;
- Presence of a village = 80;
- Presence of several separate houses = 30
- No settlements = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C). Total score evaluation: a higher score is equal to a higher geosite contribution to flood control: high score is equal to high contribution of the geosite to the service.
From the application of the above parameters and scores (indicators), we can deduce the following results:
Eigerøy: 37.5%
Prato Sesia: 20%
Jøssingfjord: 35%
Crevola: 15%

At **Eigerøy,** the presence of animal husbandry and cattle farming activities is the prevalent activity within the geosite; the land also supports several summer houses and is the most active geosite in supporting the service.
At **Jøssingfjord,** the presence of husbandry and cattle farming activities is lower than in Egersund, while forest management land use is present; however, the geosite contribution to the service is lower than Eigerøy.
In the **Prato Sesia** and **Crevola** geosites, the land does not support any human activities related with agriculture, husbandry, cattle farming, and forestry, except for the support to the dam construction along the Sesia river in Crevola.

E. *Benefits for society*
Land as a platform for human activities is important on a local, regional, national, and international scale; in fact, most of the human activities are directly linked with land use. It is crucial to understand what factors influence the land use to better plan the cities and communities. At all levels, the impact of the land as supporting services for human activities is important for monitoring world activities and the distribution of economic activities within different areas. Proper monitoring for land use helps policy makers make better choices for planning.

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8) Burial and storage

A. *Question:*
Is there a burial and storage deposit within the geosite?

B. *Geological processes which influence the services:*
The PhD's preliminary definition: a) are there any underground storage or human burials within the geosite?
Gray M.'s definition: b) the physical resources of the land have long been used for human burial- stones as stonemasons for gravestones.
Waste materials are also buried in the ground or above the ground. Ground acts also as a store for water, oil, gas, carbon, and carbon dioxide emissions.

Which abiotic factors influence the service?
Three main human uses characterize the storage services provided by abiotic nature: a) human burial, b) radioactive deposit, and c) ground storage.

C. *Abiotic factors which influence the process. Scale and assessment*:

a) Human burial
The use of rocks for gravestone is linked with the presence of durable and malleable rock types available in the geosite. Gravestones are made of all types of rocks, even if some dominate the landscape in a cemetery. Gravestones can be made from plutonic rocks, like gabbro and granite, metamorphic rocks, like slate and marble and more rarely of sedimentary rocks, like sandstone and limestone. The choice depends significantly on aesthetic values and practical use. Granite can be of various colours, dotted with the black mica nests. Limestone is easy to work and sculpt and can display interesting bands or layers or colour. The most appreciated colour is white to grey, but bluish, reddish, and yellow limestone and marble types also exist (Bressan D. 2006). Other factors linked to cultural backgrounds influence this human activity.

Here are the selected scale and scores:
Are there any human burial sites which adopted gravestones within the geosite?

- Yes = 100
- Partially = 50
- No = 10

b) Waste deposit
These are the most relevant abiotic factors which influence the support for waste deposit and its safety:
a) very low permeability b) good thermal conductivity c) sufficient plasticity to limit the risk of fractures d) high capacity of ionic absorption e) low solubility, f) geo-mechanically favourable conditions to maintain cavities e) stability of all the properties when (pressure, temperature, ionic radiations and mechanical effort) mutate f) sufficient rock volume located at the right depth, g)homogeneous distribution of the rocks properties h) low degradability, i) low and stable geodynamics in a long term

Here are the selected scale and scores:

Is the geosite within any waste deposit?
- Yes = 100
- Partially = 50
- No = 10

c) Ground storage
- Regional efficacy of the caprock
The caprock efficacy may vary laterally and can exclude large areas of the reservoir rock from consideration.
- Geology of the reservoir: the geology of the reservoir determines the efficiency of the various trapping mechanisms and thus allow calculation of Theoretical maximum amount of CO2 that can be stored.

Here are the selected scale and scores:

Is the geosite within any ground store for water, oil, gas, carbon, and carbon dioxide?
- Yes = 100
- Partially = 50
- No = 10

d) *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Total score evaluation: a higher score is equal to a higher geosite contribution to the service.
From the application of the above parameters and scores (indicators), we can deduce the following results:
Eigerøy: 10%
Prato Sesia: 10%
Jøssingfjord: 40%
Crevola: 10%

Jøssingfjord, is the geosite which contributes more to the present service, due to the presence of the waste deposit from the Titania factory within the geosite buffer zone.

All other analysed geosites not contributing to the present service.

e) *Benefits for society*
The right use of storage rocks and waste deposits are crucial for the safety of the population.

9) Food and drink

A. *Question:*

B. *Geological processes which influence the services:*
The PhD's preliminary definition: a) Type of abiotic element which influences drink and food production.
Gray M.'s definition: b) Quantity and quality of abiotic elements influencing drink and food production

What abiotic factors influence the service? The physical environment provides groundwater, aquifers, rivers, glaciers, and lakes. We consider calcium carbonate and salt like food products.

C. *Abiotic factors influencing the process. Scale and assessment*:
The main abiotic factors influencing the provisioning of food and water are the grade of the soil's fertility, the parameters involved in the water regulation processes already analysed within the supporting service (mineralogical properties, permeability), the presence of freshwater reservoirs, the temperature and climate (regulating service).

a) Soil fertility
We measured the presence of fertile soil through the analysis of the number of agricultural activities or cultural landscapes within the geosite.

Concerning Sesia Valgrande Geopark, the Europe- Corine Landcover Map (Fig. 42) shows the type of land cover use. (https://land.copernicus.eu/pan-european/corine-land-cover/clc-2000)

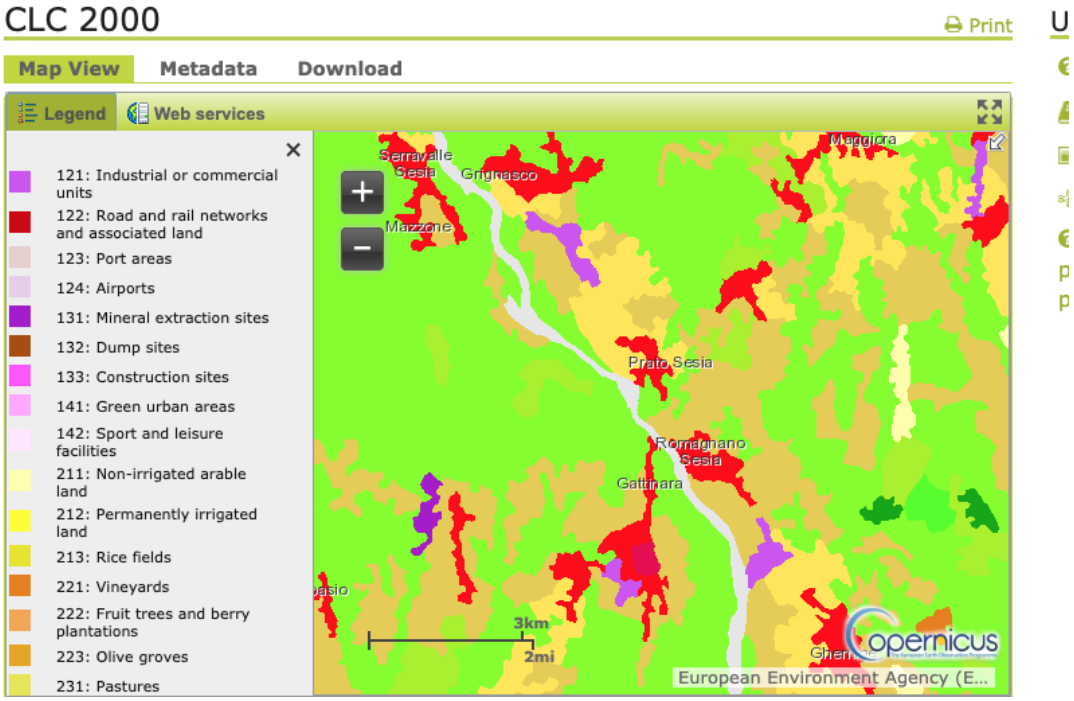

Figure 42 -Corine Landcover Map- Prato Sesia, geosite in blue.

Magma Geopark land use is very well-explained by the Norwegian Environmental Atlas (https://www.environment.no). An excerpt is presented for the Jøssingfjord area (Fg. 43).

Figure 43 - Jøssingfjord soil use (orange for cultural landscape, geosite in red)- Norwegian Environmental Atlas

Here are the selected scale and scores:

Is the geosite directly affected by agricultural activities and/or classified as a cultural landscape?

- Yes = 100
- Partially = 50
- No = 10

Soil pollution influences the use of the soil of water and food as provisioning services.
The data from Magma Geopark is available in the Environmental Department Atlas. (https://miljoatlas.miljodirektoratet.no/KlientFullEN.htm), The data from Jøssingfjord reveals the pollution linked with the ongoing extraction activities (Fig. 44).

Figure 44 - Jøssingfjord soil pollution-Environmental Atlas (Crux and triangle in yellow, geosite in red)

The data about Sesia Val Grande comes from the Arpa Piemonte Database (http://www.arpa.piemonte.it/approfondimenti/temi-ambientali/siti-contaminati/la-gestione-dei-siti-contaminati/Anagrafe); therein, neither of the two geosites are included in the list regarding the "polluted" sites.

Here are the selected scale and scores:

Is the geosite directly affected by soil pollution
- Yes = 10
- Partially = 50
- No = 100

Is the geosite indirectly (nearby) affected by soil pollution?
- Yes = 10
- Partially = 50
- No = 100

b) Water regulation

These are the most relevant abiotic factors: Mineralogic properties and Permeability.

Mineralogic properties influence the quality of soil and water. We already considered them within service n.6 – "Habitat provision" for the analysis of hydrology, by introducing parameters for "rock properties".

Similarly, for permeability, we followed the same procedure of the evaluation of the ecosystem service n.6 – "Habitat provision" by using the parameter included in "soil diversity".

Here are the selected scale and scores:

Mineralogical properties:
Is the geosite characterized by limestone, dolomite, or gypsum?
- Yes = 100
- No = 10

Is the geosite characterized by gypsum or iron sulphate?
- Yes = 100
- No = 10

Permeability:
Is the geosite characterized by gravel?
- Yes = 100
- Medium = 60 No = 10

Characterized mostly by sand?
- Yes = 100
- Partially = 50
- No = 10

Characterized by clay?
- Yes = 100
- Medium = 60
- No = 10

c) Presence of fresh water
The presence of fresh water influences the provisioning of food and water. The presence of lakes, ice sheets or rivers in the vicinity are positive factors for the water provisioning service.

Here are the selected scale and scores:

Are there any lakes, ice sheets or rivers in the vicinity?
- Yes, at least one of the three features = 100
- No lakes, ice sheets or rivers = 10

d) Temperature-climate
For permeability, we consider service n.1 – "Atmospheric and oceanic processes" and all the related subfactors: altitude; latitude; mountain presence; water proximity; wind exposure; and slope exposure.

The higher the score, the higher the influence is on the climate.

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Total score evaluation: the higher the score, the higher the geosite's contribution to the service.

From the application of the above parameters and scores (indicators), we can deduce the following results:
Eigerøy: 24%
Prato Sesia: 46.4%
Jøssingfjord: 44.2%
Crevola: 47.1%

Eigerøy is the geosite which contributes the least to the provisioning of food and water: there are no fresh water sources in the area nor are there soil or agricultural activities.
Jøssingfjord got a higher score thanks to the presence of the river and the presence of agricultural activities in parts of the site.
Among selected geosites, **Prato Sesia** and **Crevola** equally offer higher contributions to the abiotic ecosystem service N9.

E. *Benefits the society*

The main elements which influence drink and food production at local, regional, and national level are soil, climate and habitat. Institutions and communities must develop specific legislation and actions regarding soil protection, by following the example from the European Soil thematic Strategy (https://ec.europa.eu/environment/soil/three_en.htm). The recent Farm to Fork European Strategy (https://ec.europa.eu/food/farm2fork_en) is also going in this direction, focusing on the use of chemical pesticides, avoiding excess nutrients, restoring soil health, and improving soil management. The EU Commission proposed a Directive concerning soil protection and regeneration (Thematic Strategy for Soil Protection -Summary of the impact assessment (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52006SC1165)

The Italian regions have adopted different legislation concerning soil protection and use, following the European example.

In Norway, soil use is regulated by the Land Act (https://www.regjeringen.no/en/dokumenter/The-Land-Act/id269774/), whose purpose is to provide suitable conditions to ensure that the land areas in the country including forests and mountains and everything pertaining thereto (land resources) may be used in the manner that is most beneficial to society and to those working in the agricultural sector.

Soil protection relates to the preservation of habitats, since geodiversity, geological heritage and the use of the soil are also connected with the food and drink provision. Climate plays a key role in provisioning food and drink for the human population; climate change is the main challenge that humanity is facing.

10) Nutrients and minerals for healthy growth

Humans obtain minerals and nutrients generally from food. Food absorbs minerals from the soil and about 17 elements are thought to be essential for plant and animal life.

The 17 essential elements present in plants are: nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, boron, chlorine, iron, manganese, zinc, copper, molybdenum, and nickel.

These 14 elements − along with carbon, hydrogen, and oxygen − are called the 17 essential inorganic nutrients, or elements. Some of the essentials are needed in larger amounts than others and are called the macronutrients; those needed in lesser amounts are the micronutrients. All elements are needed in specific amounts.

A. *Question:*

PhD's preliminary question: Is the geosite directly involved in provisioning nutrients and minerals for human activities, such as agriculture?

B. *Geological processes which influence the services:*

Conditioning factors are rock type, erosion-deposition and transport phenomena.

Soils develop from rocks containing mineral elements which, for the most part, are locked in a crystalline matrix, thus unavailable to plants until physical and chemical weathering loosens the chemical bonds. The nutrients must be released into the soil water before plant roots can absorb them. Those nutrients that become soluble are often leached out of the root zone before roots or soil organisms can absorb them.

C. *Abiotic factors influencing the process. Scale and assessment*:

The main abiotic factor influencing service N10 is the type of bedrock within the geosite; in fact, each kind of bedrock is characterized by different chemical elements.

Here are the selected scale and scores:

a) Is the geosite characterized by limestone, dolomite, or gypsum?
   - Yes, all three = 100
   - two of them = 50
   - One of them = 30
   - None = 10

b) Are geosites characterized by gypsum or iron sulphate?
   - Yes, both = 100
   - One of them = 30

- one = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 10%
Prato Sesia: 20%
Jøssingfjord: 10%
Crevola: 20%

Eigerøy and **Jøssingfjord** contribute very little to the service, due to the presence of intrusive rocks with low level of erodibility.
Prato Sesia and **Crevola** offer higher contributions thanks to the presence of limestone.

E. *Benefits for society*
Nutrients and minerals for healthy growth (in this case soil protection policies) play a crucial role in preserving the soil's benefits, including the amount of nutrients. (See "Soil processes"). Chemical fertilizers and over fertilization of soils leads to soil and deep-water pollution.

11) <u>Mineral fuel</u>

A. *Questions:*
a) The PhD's team preliminary question: Is the geosite positioned within an energy producing area? Does the geosite provide energy?
b) Gray clarifications: Presence of energy resources within the geosite (coal and peat, petroleum, and renewable energy).

B. *Geological processes which influence the services:*
Mineral fuels originate in underground conditions from the anaerobic decomposition of buried dead organisms. The first condition for the services is the presence of fossils, i.e. remains of dead plants and animals containing organic molecules. The transitions from these source materials to high-carbon fossil fuels usually requires long-term geological processes able to transfer heat and pressure through the Earth's crust. Considering their long term, mineral fuels are viewed as not renewable resources.
On the contrary, other Earth surface phenomena such as landforms, geomorphic processes and agents (river falls, wind, tides …) can influence renewable energy production.

C. *Abiotic factors influencing the process. Scale and assessment*:
Peat formations depending on the type of source of water and the presence of organic material.
Coal formation depends on anaerobic conditions, type of source of water, presence of organic material, pressure, and temperature.
Petroleum: organic material (sapropel), sediment deposits on sandstone (mother rock) acting with pressure and temperature, and gas. The Earth's movements lift the hydrocarbons; otherwise, they get stored into layers of waterproof rock.
Uranium: radioactive decay
Renewable energy: Geothermal, hydroelectric (altimetric falls or within river drainage) wave and tidal power (coastal condition), and wind power (higher in upland and coastal situations).

Here are the selected scale and scores:

Is the geosite characterized by (coal and peat, petroleum, or renewable energy plants)?
- Yes, all three = 100
- Two of them = 50
- One of them = 30
- None = 10

D. *Assessment* results (see calculation Excel sheet n.4)
Eigerøy: 30%
Prato Sesia: 10%
Jøssingfjord: 50%
Crevola: 30%

Prato Sesia does not contribute to the service.
Eigerøy contributes to the service for 30% due to the wind power.
Crevola supports the service at the same level as Eigerøy due to the hydro-power station within the river.
Jøssingfjord has the highest contribution to the service thanks to both wind power and hydropower.

E. *Benefits for society*
Mineral fuels are the most important source of fuels for all the communities at all levels. Coal and peat, petroleum, and renewable energy are constantly monitored by international, national, and regional Institutions and Organizations. Data from the European Mineral Map reveal a low presence of minerals in the Sesia Val Grande geosite, while industrial minerals are present in Eigerøy and Jøssingfjord. (http://www.europe-geology.eu/mineral-resources/mineral-resources-map/)

12) Construction minerals

A. *Questions:*
a) The PhD team's preliminary question: Presence of a quarry or other sources for construction material.
b) Gray clarifications: building stones, aggregates, limestone, structural clay, gypsum, sand, volcanic products, and bitumen.

B. *Geological processes which influence the services:*
The construction minerals are the following:
a) Building stones − factors that make a rock become a building stone are structural strength, durability, appearance, ease of working, and availability. The following types of rock originate from them: sedimentary rocks, igneous rocks-granite, and dimension stones.
b) Aggregates − collection of rocks particles.
c) Limestone − like cement and volcanic ash.
d) Structural clay − like clayey sediment.
e) Gypsum − like plaster, glass sand.
f) Volcanic products −volcanic ash provides clay fraction in cement production.

C. *Abiotic factors influencing the process. Scale and assessment*:
Abiotic factors which influence the provisioning of construction minerals are based on the rock type within the geosite. The assessment for this service takes into consideration the Geoparks' geological description.

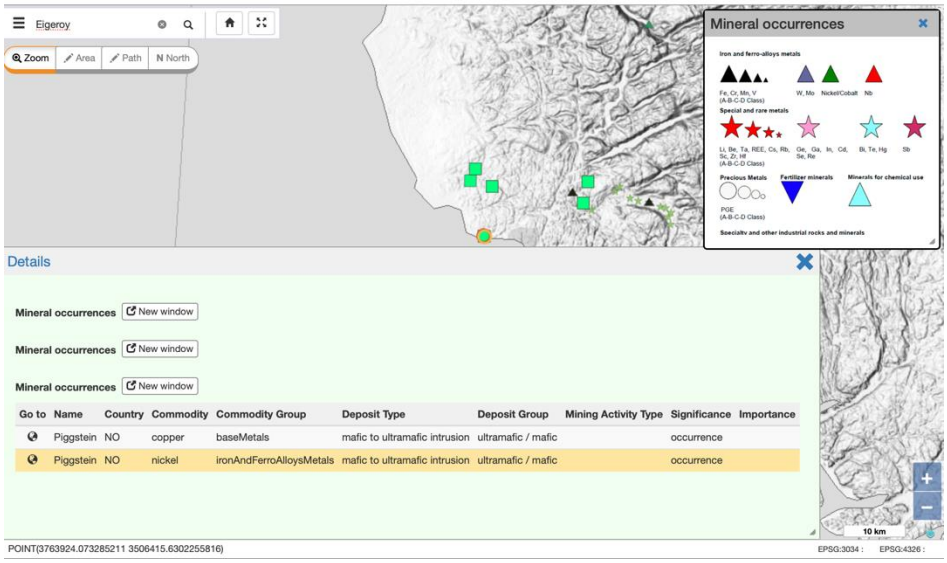

Figure 45 - Mineral occurrences in Eigerøy-Mgp, NGU 2019, available online

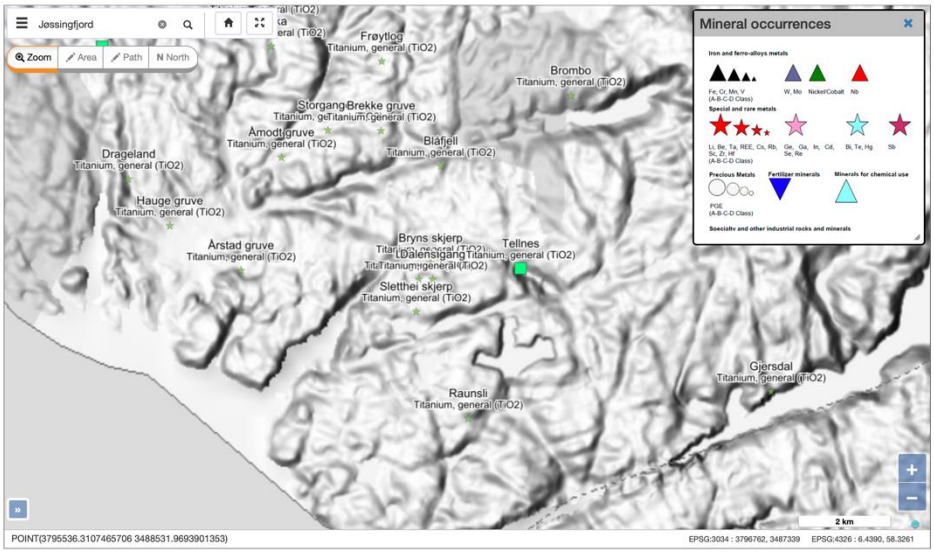

Figure 46 - Mineral occurrences in Jøssingfjord-Mgp, NGU 2019, available online.

Here are the selected scale and scores:
Is any extraction of minerals and/or rock mined for its non-metallic value (salt, sulphur, and stone areas) within the geosite?

- Three or more = 100
- Between one to three = 50
- One = 30
- None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 30%
Prato Sesia: 10%
Jøssingfjord: 30%
Crevola: 10%

The **Eigerøy** and **Jøssingfjord** geosites contribute to the service thanks to the presence of industrial minerals in the related buffer zones.
No relevant mineral has been detected in the **Prato Sesia** and **Crevola** geosites.

E. *Benefits for society*
Construction minerals, building stones, aggregates, limestone, structural clay, gypsum, sand, volcanic products, and bitumen are constantly monitored by international, national, and regional Institutions. Minerals and their extraction are sources of income and could be beneficial in terms of jobs for the local population. Mineral provision is crucial for modern society; however, the extraction and delivery processes should lead to sustainable practices.
The European Commission, through the H2020 Programme, finances several projects focusing on sustainable use of natural resources, i.e., the Arctic Hub project led by the Natural Resource Institute of Finland, which involves as partners both the Sesia and Magma UGGp. The project, regarding the mining industry, aims at analysing not only the "*economic or developmental viability of mining but view associated socio-cultural and political factors*" (https://projects.luke.fi/arctichubs/)

13) Industrial minerals

A. Questions:
a) The PhD team's preliminary question: Is the geosite located within a mineral extraction area?
b) Gray clarifications: presence of a mineral quarry.

B. *Geological processes which influence the services:*
Industrial minerals are any mineral, rock, or other naturally occurring material of economic interest except gemstones, metallic ores, or minerals. Minerals and rocks mined for their non-metallic value such as salt, sulphur, and stone. (Dictionary of Gems and Gemmology, 2019).

C. *Abiotic factors influencing the process. Scale and assessment*:
Abiotic factors which influence the provisioning of construction minerals are based on the rock type within the geosite. The assessment for this service takes into consideration the Geoparks' geological description.
To assess both the Geoparks mineral resources, we have been consulting the European Map for mineral resources (Geological Survey of Europe).

Here are the selected scale and scores:
Are any minerals and/or rocks mined for their non-metallic value such as salt, sulphur, and stone areas within the geosite?
- Three or more = 100
- Between one to three = 50
- One = 30
- None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 10%
Prato Sesia: 10%
Jøssingfjord: 30%
Crevola: 10%

Jøssingfjord is the geosite that most contributed to the service thanks to the ilmenite deposit.
The other geosites do not contribute to the service.

E. *Benefits for society*
Industrial Minerals and their extraction are sources of income and could be beneficial in terms of jobs for the local population if properly managed and agreed with by local stakeholders. Mineral provision is crucial for modern society; however, the extraction and delivery processes should lead to sustainable practices.

The European Commission, through the H2020 Programme, finances several projects focusing on sustainable use of natural resources, i.e., the Arctic Hub project led by the Natural Resource Institute of

Finland, which involves as partners both the Sesia and Magma UGGp. The project, regarding the mining industry, aims at analysing not only the "*economic or developmental viability of mining but view associated socio-cultural and political factors*" (https://projects.luke.fi/arctichubs/)

14) Ornamental products

A. *Question:*
The PhD team's preliminary question: Are there any gemstone extraction areas within the Geopark?
Gray's clarifications: presence of gemstones.

B. *Geological processes which influence the services:*
Gemstones are natural inorganic minerals that are used as precious stones in jewellery or ornaments. Although coloured gemstones and diamonds can both be considered gemstones, they are often treated differently as their supply chains vary noticeably (Cartier L. 2019).
Most gemstones are found in igneous rocks and alluvial gravels, but sedimentary and metamorphic rocks may also contain gem materials.

C. *Abiotic factors influencing the process. Scale and assessment*:
The abiotic factors influencing the service are related with the geology of the area. For the assessment, we have been using the European Map for mineral resources (Geological Survey of Europe).

D. Here are the selected scale and scores:
Is the geosite characterized by extraction activities of ornamental gemstones?
Three or more = 100
Between one to three = 50
One = 30
None =10

E. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
   a) **Eigerøy: 10%**
   b) **Prato Sesia: 10%**
   c) **Jøssingfjord: 10%**
   d) **Crevola: 10%**

No selected geosite contributes to the service. In any case, it is worth noting that both Geoparks have relevant N15 services offered by other geosites.

F. *Benefits for society*
Ornamental products are constantly monitored by international, national and regional levels institutions. The direct benefit coming from the extraction and the selling of the ornamental products.

15) Fossils

A. *Question:*
a) The PhD team's preliminary question: does the geosite overlapping an extraction area for fossil- fuel?
b) Gray clarifications: Presence of fossils.

B. *Geological processes which influence the services:*
The Cambridge Dictionary defines a fossil as: "The shape of a bone, a shell, or a plant or animal that has been preserved in rock for a very long period". Geological history and geological heritage influence the presence of fossils. Almost all fossils are preserved in sedimentary rock. Organisms that live in topographically low places (such as lakes or ocean basins) have the best chance of being preserved.

C. *Abiotic factors influencing the process. Scale and assessment*:
The two Geoparks selected do not contain any sedimentary rocks since they are mostly made of igneous rocks from molten rock. The metamorphic rocks have been put under great pressure and fossils do not usually survive these extreme conditions.
Is the geosite characterized by the extraction activities of fossils?

Here are the selected scale and scores:
- Three or more extraction points = 100
- From two to three = 50
- One extraction point = 30
- None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 10%
Prato Sesia: 10%
Jøssingfjord: 10%
Crevola: 10%

No geosite contributes to the service.

E. *Benefits for society*
Conservation strategies linked with fossil findings are important for educational activities and for increasing the awareness of local people and preserving heritage for future generations.

5.7.3 Cultural Services

The geosite buffer zone is the area considered for the assessment of cultural services.
The scale for cultural services takes into consideration 100 as maximum scale, -60 as a "high" scale" -30 as a medium and 10 as minimum points for all the services.

16) <u>Environmental quality</u>

A. Questions:
a) The PhD team's preliminary question: is the geosite contributing to the aesthetic value of the area by providing diverse landscape morphology?
b) Gray clarifications: Visual aesthetic appeal of the landscape, landform which enriches our spirit.

B. *Geological processes which influence the services:*
Landscapes have aesthetic appeals; some geomorphological features can be defined as components of characteristic landscapes of some countries, and they represent the "environmental quality" service (Coleman1996; Norton, 1988).

C. *Abiotic factors influencing the process. Scale and assessment*:
The geological processes which contribute to the service are the so-called "aesthetic values", defined as "additional values". The visibility of a site is made up of two criteria: viewpoints (VP) and space structure (STR).
VP: the first criterion considers the visibility of a site. A site covered by a forest or very difficult to access would, in this case, have a lower score than a site visible from several viewpoints.
STR: the second criterion focuses on research about landscape perception, which indicates that contrasting landscapes, landscapes with a vertical development, or landscapes with individual elements that give that space structure are generally considered the nicest.
Consequently, sites with colour contrasts (e.g., contrasts due to lithological changes), with high vertical development (e.g., peaks) or with spatial structures (e.g., morainic arcuate ridge that closes a valley, braided rivers) will receive a higher score than monotone reliefs (e.g., alluvial plain, large plateau) characterized by no evident contrast. (Reynard, 2009)

Here are the selected scale and scores:
The visibility of a site (is the site "clean" from vegetation?) is made of two main factors:
"Viewpoints" and "Space structure".

Viewpoints: How many viewpoints (free of sight obstacles) within the geosite?
- More than 10 = 100
- Between 4-10 = 60
- Between 1-3 = 30

- None = 10

Space structure: number of individual elements which give the idea of "space structure ", like colour contrasts (e.g., contrasts due to lithological changes), high vertical development (e.g. peaks) and spatial structures (e.g. morainic arcuate ridge that closes a valley, braided rivers)

How many elements like colour contrast, mountain peaks, or specific spatial structures are within the geosite?

- More than 10 = 100
- Between 4-10 = 60
- Between 1-3 = 30
- None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 70%
Prato Sesia: 60%
Jøssingfjord: 75%
Crevola: 30%

Jøssingfjord provides the higher contribution to the service since it is clean from vegetation but the mountain peak and fjord valley contrast with the shoreline creates high value.
Eigerøy provides high contribution to the service, thanks to no vegetation, and several contrastive elements such as the colour contrast between anorthosite and the sea: the contrast between potholes, cracks, and the landscape.
The **Prato Sesia** geosite is characterized by high visibility while the river band creates a slight contrast opposite to the mountain background.
The visibility in **Crevola** is not good: the geosite is covered by vegetation; the river band is in contrast with the mountain on the back.

E. *Benefits for society*
Benefits linked with cultural and knowledge services cover the local, regional, and national level. The aesthetic values of the landscape come directly from the biotic and abiotic services; however, they do not give directly benefit to society but are indirectly linked with tourism and leisure possibilities, which are crucial in UNESCO Global Geoparks.

17) Geotourism and leisure

A. Question:
a) The PhD team's preliminary question: Is there the presence of leisure activities connected with the geosite's geodiversity?
b) Gray clarifications: Tourism based on an area's geological or geomorphological resources, which attempts to minimise the impact.

B. *Geological processes which influence the services:*
Geotourism is a form of tourism focused on geology and landscape. This is the essence of geotourism, which starts with the understanding of geology interpreted through its components of Form (landforms and landscape), Process (how the landforms originated) and Time (when these processes occurred and how long they lasted). This forms the basis of a more holistic understanding of the environment and its component parts and thus, provides residents or tourists with a greater connection to the environment in which they live or are visiting (Dowling, 2014). The geological processes influencing the service are the different landforms and the geomorphological processes over time.

D. *Abiotic factors influencing the process. Scale and assessment*:
We have detected three main factors which are: landforms, the geological era represented, and the number of leisure activities within the geosite.
Here are the selected scale and scores:

How many landforms-landscapes are visible within the geosite?
- None = 10
- From 1-3 = 30
- From 4 to 8 = 80
- 9 or more = 100

How many geological Eras and Periods are represented?
- More than 10 = 100
- Between 4-10 = 60
- Between 1-3 = 30
- None = 10

How many leisure outdoor activities are in the geosite?
- None = 10
- 8-9 = 80
- 5-7 = 60
- 3-4 = 50
- 1-2 = 30

E. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 56.6%
Prato Sesia: 53.3%
Jøssingfjord: 30%
Crevola: 30%

Eigerøy is the geosite with the highest contribution to the service, thanks to its landforms: kettle, moraine, fjord, islands, and glacial erratic. Three periods are represented: Precambrian, Proterozoic and Quaternary. Five leisure activities run within the geosite: hiking, climbing, swimming, kayaking, and coasteering.
Jøssingfjord contributes to the service close to the same level as Eigerøy. Landforms include kettle, moraine, fjord, islands, glacial erratic, screes, and mountain. The periods represented are Precambrian, Proterozoic and Quaternary. Three activities are present: hiking, climbing, and kayaking.
Prato Sesia and **Crevola** give equal contributions to the service since the number activities developed in the site are equal and they are also characterized by the same types and numbers of landforms.

F. *Benefits for society*
Recreation and nature-based tourism are important sources of income and employment in many places around the world. The total value of international tourism exceeds $444 billion (World Bank, 1999). Nature-based tourism (sometimes called environmental tourism or ecotourism – although strictly speaking, the latter is a subset of nature-based tourism and includes certain ethical considerations) may comprise 40 – 60% of this total. The recreational benefit from nature also contributes to the health and social relations dimensions of well-being, as there is a correlation between green areas, good air quality, and human health-linking Ecosystem Services and Human Well-being

18) <u>Cultural-spiritual and historical factors</u>

A. Questions:
a) The PhD team's preliminary question? How many spiritual factors are linked within the geosite?
b) Gray clarifications: presence of myths, historical facts, archaeological features, and spiritual heritage connected with the geosite.

B. *Geological processes which influence the services:*

C. *Abiotic factors influencing the process. Scale and assessment*:

Concerning the "cultural" side, we have divided it into historical-archaeological artefacts and documented historical facts.

Here are the selected scale and scores:

Are historical-archaeological artefacts linked within the geosites?

- Yes, between 9-10 = 100
- 6-8 = 80
- 3-5 = 60
- 1-2 = 30
- None = 10

Is the geosite linked with specific historical known documented facts?

- Yes, between 9-10 = 100
- 6-8 = 80
- 3-5 = 60
- 1-2 = 30
- None = 10

Concerning the "spiritual" facts we consider those linked with individual cultural background It is therefore very complex to determine an omni comprehensive formula. We do not include the spiritual facts into the research.

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 30%
Prato Sesia: 10%
Jøssingfjord: 80%
Crevola: 10%

Jøssingfjord is the geosite which has the highest contribution to the service, thanks to the Helleren houses and WWII memorials: canons, buildings, and mines. Three historically documented periods are present in the geosite: the Altmark episode (WWI) ; the prehistoric settlements located underneath the geological formation, and the Helleren wooden houses from the XIX century.
Eigerøy shows evidence of WWII like bunkers and hangars. One historical period is documented.
The **Prato Sesia** and **Crevola** geosite do not give any contribution to the service.

E. *Benefits for society*
Benefits for society related with the cultural and historical values of the biotic and abiotic services are strictly connected with their interpretation and valorisation at national, regional and local level; of course, the higher the effort for interpretation, the higher is the possibility to increase the awareness and the economic benefits for the territory.

19) Artistic inspiration

A. *Questions:*
a) The PhD team's preliminary question. What is the number of known paintings, art installations within the Geopark, using the geological landscape as a source of inspiration?
b) Gray clarifications: presence of art related to the geosite.

A. *Geological processes which influence the services:*

B. *Abiotic factors influencing the process. Scale and assessment*:
Within this service, we have been taking into consideration the number of known paintings, art installations within the Geosite, with the geological landscape as source of inspiration.

Here are the selected scale and scores:

- From 9-10 art installations/art pieces = 100
- From 6-8 = 80
- From 3-5 = 60

- From 1-2 = 30
- None = 10

C. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 30%
Prato Sesia: 10%
Jøssingfjord: 30%
Crevola: 10%

Eigerøy and **Jøssingfjord** contribute equally to the service thanks to the art installation inside the lighthouse and the wooden sculpture within the fjord-landscape art.
Prato Sesia and **Crevola** do not contribute to the service.

D. *Benefits for society*
Benefits for society related with cultural, historical values of the biotic and abiotic services are strictly connected with their interpretation and valorisation at national, regional and local level; of course, the higher the effort for interpretation is, the higher the possibility to increase the awareness and the economic benefits for a territory.

20 <u>Social development</u>

A. *Questions:*
The PhD team's and Gray preliminary questions: Presence of local activities promoting communities and personal development based on the geosite's contents (local geological related activities, voluntary groups).

B. *Geological processes which influence the services:*

C. *Abiotic factors influencing the process. Scale and assessment*:
Within this service, we have analysed the number of specific activities linked with the geosite that contribute to social development like folklore, fairs, art performances, and local voluntary associations. Here are the selected scale and scores:

- From 9-10 art installations/art pieces = 100
- From 6-8 = 80
- From 3-5 = 60
- From 1-2 = 30
- None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 30%
Prato Sesia: 10%
Jøssingfjord: 30%
Crevola: 10%

Eigerøy and **Jøssingfjord** contribute equally to the service thanks to the Eigerøy Festival and the wooden dancing platform on the fjord.
Prato Sesia and **Crevola** do not contribute to the service.

E. *Benefits for society*
The development of activities related with the geosite and geological heritage could support the strengthening of "sense of belonging" to the citizens which is crucial for successful development strategies and geoparks.

<u>21) Earth history</u>

A. *Questions:*
a) The PhD team's definition: the presence of geological elements which are of international value following the IUGS criteria (Mantovani *et al*., 2020; Richard, 2006)

b) Gray clarifications: Geological record as research value.

B. *Geological processes which influence the services:*

C. *Abiotic factors influencing the process. Scale and assessment*:

Number of international publications concerning the geosite by scientific experts who make a globally comparative assessment based on the peer-reviewed, published research conducted on geological sites within the area (Statute of the International Geoscience and Geoparks Programme).

Here are the selected scale and scores:
- From 9-10 international publication = 100
- From 6-8 = 80
- From 3-5 = 60
- From 1-2 = 30
- None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 100%
Prato Sesia: 100%
Jøssingfjord: 100%
Crevola: 100%

All the geosites actively contribute to the service due to their internationally recognized importance in scientific literature highlighting relevant facts of Earth History:
In **Prato Sesia** and **Crevola,** the caldera's collapse event (280Ma) is testified by ignimbrite megabreccias of the Sesia Supervolcano (Quick *et al.*, 2009).
In **Jøssingfjord** and **Eigerøy,** three main geological periods are represented: Pre-Cambrian, Permian deep chemical erosion, and the last is the quaternary ice age processes.

E. *Benefits for society*
The benefits are linked with the awareness of people concerning their heritage, which can lead to the establishment of local associations, groups or volunteers for its valorisation and protection. Educated citizens disseminate good practices concerning the environmental and geological heritage protection.

22) History of research

A. Questions:
a) The PhD team's definition: Presence of geological elements which are of international value following the IUGS criteria (peer reviewed and published research).
b) Gray clarifications: Geological record as research value.

B. *Geological processes which influence the services:*

C. *Abiotic factors influencing the process. Scale and assessment*:
Number of international publications concerning the history of the research connected with the geosite by scientific experts who make a globally comparative assessment based on the peer-reviewed, published research conducted on geological sites within the area (Statute of the International Geoscience and Geoparks Programme).

Here are the selected scale and scores:
From 9-10 international publication = 100
From 6-8 = 80
From 3-5 = 60
From 1-2 = 30
None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 80%

Prato Sesia: 100%
Jøssingfjord: 80%
Crevola: 100%

All the geosites actively contribute to the service due to their internationally recognized importance and due to scientific literature highlighting relevant advancements of History of geological research.
The **Crevola** and **Sesia** geosites highlight the presence of a unique deep geologic rock-forming process at the contact point between the supervolcano's magmatic chambers and the surrounding crustal rocks. This testifies the origin of Sesia migmatites, hybrid rocks from the anathexis of the kinzigites− metamorphic rocks with a scarcely evident schistose texture, of amphibolytic-granulitic facies (10 - 15 km depth) of pelitic rocks− thanks to the contact with melting plutonic gabbros of the basic complex. (Quick *et al.*, 2009).
Eigerøy and Jøssingfjord both contribute to the general understanding of the process going on inside the six magma chambers approximately one billion years ago and the anorthosite rock formation during that process. (Ashwal & Wooden, 1985)

E. *Benefits for society*
The benefits are linked with the awareness of people concerning their heritage which can lead to the establishment of local associations, groups or volunteers for its valorisation and protection. Educated citizens disseminate good practices concerning the environmental and geological heritage protection.

23) Monitoring and forecasting

A. *Questions:*
a) The PhD team's definition: Presence of monitoring station for sampling purposes or for meteorological purposes.
b) Gray clarifications: Record of sediments in lakes, bogs and ice cores, monitoring impact on human activities.

B. *Geological processes which influence the services:*

C. *Abiotic factors influencing the process. Scale and assessment*:
Number of monitoring stations for sampling or meteorological purposes.

Here are the selected scale and scores:

- From 9-10 = 100
- From 6-8 = 80
- From 3-5 = 60
- From 1-2 = 30
- None =10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 30%
Prato Sesia: 10%
Jøssingfjord: 30%
Crevola: 30%

Jøssingfjord and **Eigerøy** contribute to the services thanks to the weather station in Eigerøy and the monitoring pollution station active in the Jøssingfjord.
Crevola contributes to the services thanks to the hydropower monitoring station at the opposite Sesia riverbank.
Prato Sesia does not contribute to the service.

E. *Benefits for society*
The benefits are linked with the possibility of monitoring geohazards, phenomena, and human activities. Therefore, at all levels, proper monitoring is landing into protection of the local population and appropriate urban planning.

24) Geoforensics

A. *Questions:*
a) The PhD team's definition: Presence of evidence linked with a possible solution of a crime investigation
b) Gray clarifications: Linking suspects to crime scenes.

B. *Geological processes which influence the services:*

C. *Abiotic factors influencing the process. Scale and assessment*:
Number of evidence linked with a possible solution of a crime investigation.

Here are the selected scale and scores:

- From 9-10 = 100
- From 6-8= 80
- From 3-5 = 60
- From 1-2 = 30
- None = 10

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 10%
Prato Sesia: 10%
Jøssingfjord: 10 %
Crevola: 10%

The geosites do not contribute to the service.

25) Education and employment

A. *Questions:*
a) The PhD team's definition: presence of geological record with a role in education and training
PhD team: Presence of educational activities based on educational geosite contents.
b) Gray clarifications: presence of features with special educational and scientific values or interest, number of classes visiting, number of scientific studies.

B. *Geological processes which influence the services:*

C. *Abiotic factors influencing the process. Scale and assessment*:

Number of educational activities related with the geosite, run by the Geopark directly or in cooperation with the schools (from kindergarten to university grades).

Here are the selected scale and scores:

- From 9-10 = 100
- From 6-8 = 80
- From 3-5 = 60
- From 1-2 = 30
- None = 10

Accessibility:

- Accessible by anyone (including the disabled) on foot = 100;
- Accessible on foot but not for the disabled = 80
- Accessible by car with parking = 60
- Accessible by car without parking = 30
- Not accessible = 0

D. *Assessment* results (see calculation within Annex 6, Excel worksheet "Phase 4"; Column C)
Eigerøy: 70%
Prato Sesia: 45%
Jøssingfjord: 65 %
Crevola: 55%

Eigerøy contributes with three activities: the ornithological association (MGp stakeholder) activities, the teachOut app, and the Outdoor Organisation Association activities, which is owner of Magma Geopark.The site is accessible on foot but not for the disabled.
Jøssingfjord is contributing with two Geopark activities with the TeachOut App and the Outdoor Organization Association activities, the geosite is accessible on foot and to the disabled.
Prato Sesia and **Crevola** contribute with educational activities run directly by the Geopark staff.
After the flood of October 2020, Crevola has two possible access trails: public through the CAI (Alpine Italian Centre) path n. 605 and the Crevola-Bec trail accessible on foot but not to disabled people.

F. *Benefits for society*
The benefits are linked with people's awareness of their heritage, which can lead to the establishment of local associations, groups, or volunteers for its valorisation and protection. Educated citizens disseminate good practices pertaining to environmental and geological heritage protection.

5.8 Conclusions from the abiotic ecosystem assessment

Within the present research we have been first evaluating the overall approach suggested by Gray (2013,2015), where the 25 abiotic ecosystem services have been detected and their characteristics has been analysed, then after selecting specific geosite, both a related desk and field research took place.
Preliminary results were focusing mostly on qualitative data, describing the connection between each single geosite and each single service through observation of the landscape and comparison with the qualitative description given by Gray. However, as described in Chapter 5.2.1, the obtained assessment based only on qualitative approach cannot be considered sufficient for a complete understanding of the geosite connections and their role within abiotic nature. The preliminary assessment does not provide any measurable data which allow to compare geosite located in the same Geopark nor different geosite located in separate Geoparks.

The further assessment of the abiotic ecosystem services in Eigerøy geosite through the proposed abiotic services indicator assessment framework, gives the results available in the Chapter 5.4 and in the Annex 6-Sheet4.

Through this assessment it is possible to apply a quantitative method within the geosite, which allows us to measure, monitor and compare each single geosite contribution in each service both in the same and in different Geoparks.

Regulating Services: Following the scale developed, we can conclude that the Eigerøy geosite "poorly" contributes to the so-called "regulating factors" connected with atmospheric circulation; it does not contribute both to the so-called "terrestrial processes" nor to the "water regulation" services. Thanks to the methodology developed, it is in fact possible to identify the reasons for this shortcoming, which is mostly due to the absence of soil and the high presence of magmatic rock-types. It is now possible to demonstrate that Eigerøy is contributing for 53% to the so- called Regulating Services, while Jøssingfjord, Crevola and Prato Sesia are contributing on a scale of 60 % and 63% of the points available. We can conclude that Eigerøy offers less protection against factors linked with the atmospheric circulation phenomena in comparison with the other 3 geosites analysed.

Supporting Services: Considering e.g., the "Habitat provision", following the data from 5 factors (type of geology, geomorphological processes, soil diversity, geomorphology, and hydrology within the 17 variables detected, we can conclude that the geosite is contributing for only a 38% of the available total point to the provision of habitat. This is mainly due to the low geodiversity index, scarcity of soil and soil diversity, law number of landform characterising the landscape and most rocks classified as anorthosite which are impermeable to water.
Comparing the results with Prato Sesia, we can conclude that Prato Sesia is contributing with more than double available points (77%) to the provision of habitats due to higher geodiversity level, high rate of transportation and deposition, high presence of soil and landform.

Provisioning Services: Eigerøy geosite does not contribute at any relevant scale to the "Food and drink" service (24%) mainly due to scarcity of soil (nutrients and fertility) absence of fresh water, however it is scarcely contributed to other provisioning service as well, due to absence of mineral fuels, construction and industrial minerals, ornamental products, or fossils. Crevola geosite contributes for 47% of the available score to the service, thanks to the fertility of soil, the presence of fresh water, and climate regulation due to the proximity with a mountain chain.

Knowledge and Cultural services: The landscape around Eigerøy is aesthetically very appealing, clean from vegetation provides a very good example of geosite for educational purposes and the number of different visible landforms allow numerous geotourism activities which make the geosite the highest contributor to these services (Environmental quality 70% and Geotourism 56%).

The research shows that, thanks to the establishment of the methodology, it is now possible to analyse each variable influencing the service in detail, and to compare the contribution of geosites to the service, even though they are in different Geoparks characterized by different geographical characteristic, socio economic background and diverse geological and cultural heritage.

The method can apply to measure each service in each single geosite in the same Geopark area, in case it requires an assessment for interpretation purposes for development of specific plan for management or policy makers.

The possibility expressed by the research allows the scientific communities to further explore the investigation concerning more variables and indicators, to expand and refine the calculation further.

Chapter 6 – Examples of abiotic ecosystem service valorisation

6.1 The GEOfood initiative

The GEOfood initiative was established in 2015 in the MGp, Rokua UGGp-Finland, Odsherred UGGp in Denmark, and Reykjanes UGGp in Iceland as a brand reserved only for UNESCO Global Geoparks approved territories. The project leader for the initiative is Sara Gentilini, project manager in MGp since 2011

The idea comes from the need of having a common selected criteria for developing local food networks within UNESCO Global Geoparks and eventually valorising the common product within specific tourist offers dedicated to geological heritage and local food which could increase the Geopark's visibility and the people's interest in geological heritage. It is in fact mandatory for enterprises to explain the connection between the raw material and the geological characteristic of the area on the product and the menu: through food the initiative increases the awareness of people about importance of abiotic services to the community

The GEOfood brand, now owned by MGp, aims at collecting stories about local communities, local traditions, and the origin of the food raw material in connection with geological heritage of each UNESCO Global Geopark territories: its quality is based on the authenticity of the products, the heritage of local people, and the proximity of the ingredients. (Gentilini & Thjømøe, 2014)

The criteria are based on food proximity and all the food enterprises willing to use the GEOfood brand must use raw materials from the Geopark area, while the GEOfood restaurant should serve at least one seasonal menu. This criterion is chosen to guarantee the support to local farmers, to local entrepreneurs, and the integration of law scale economy strategies within the UNESCO Global Geopark. GEOfood is also contributing to empowerment of communities and kids, through educational programs linked with sustainability and climate change issues.
From 2015 till now, the GEOfood initiative has been a successful project: in May 2022, 32 UNESCO Global Geoparks embracing the brand, the criteria, and its values, developing more than 70 different local products and 30 local menus, which all explained the connection between the raw material and the geological heritage.
The UNESCO Global Geoparks which are part of the initiative at September 2022 are: Arouca, Azores, Cheongson, Cliffs of Fundy, Discovery, Estrela, Grevena, Grutas del Palacio, Hateg, Haute Provence, Idrija, Katla, Kutralkura, Langkawi, Las Loras, Lauhanvuori Mudeungsan,Natur und Geopark Steirische Eisenwurzen, Naturtejo,Novoharad- Nógrád, Qeshm, Rocca di Cerere, Rokua, Sesia Val Grande, Seridó, Stonehammer, Terras de Cavaleiros,The Burren and Cliffs of Moher,Thuringia Inselberg, Tuscan Mining,Villuercas, Vis Archipelago and Magma.

After signing an agreement with MGp, each Geopark is directly responsible for the selection of food enterprises, each Geopark can choose its own business model and management system for handling GEOfood certification at local level, including how to involve farmers and enterprises for its implementation.

In many UGGp, the adoption of GEOfood naturally involved students, schools and Universities into specific programmes, courses and initiatives which focused on using local food resources, reducing food waste, and discovering and maintaining local sustainable practices.

GEOfood has been also adopted as a best practice in several partner areas for involvement of local communities (Norway, Finland, Croatia, Canada), attracting resources for local projects linked with its values and principles.
In MGp, the RURITAGE project, financed by the European Commission and the GEOfoodEDU, financed by NORA, Nordisk Atlantic Cooperation examples of projects and external resources linked with the idea of local food as a driver for sustainable development and engagement of the young generation within food related issues.

The GEOfood initiative has been selected as a main subject for two master theses: in Finland, Austria and in Italy acting as a case-study for developing strategies to boost local economy.

In November 2021, GEOfood was selected by UNESCO Earth Department as one of the Geopark's best projects focusing on Actions related with Climate Change issues within COP26.

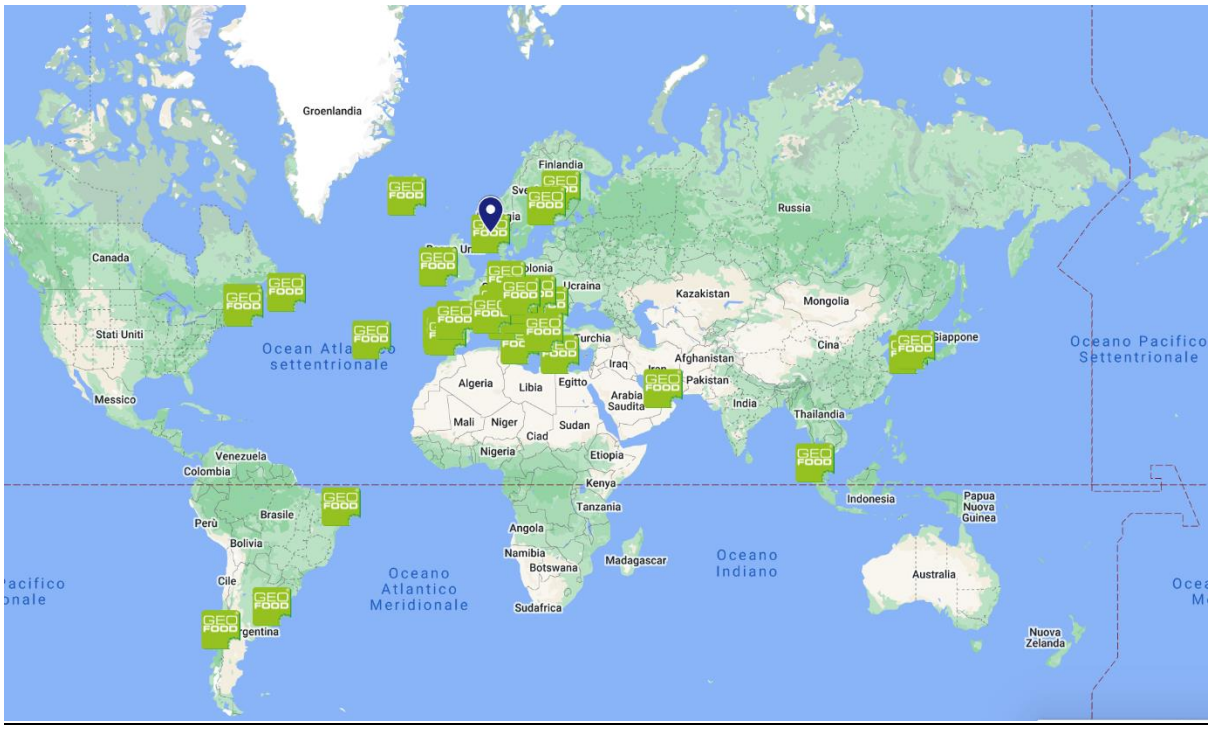

Figure 47 - GEOfood partners, Gentilini S., Sept 2022.

The concept is evolving over time, thanks to the participation of 22 Countries (Norway, Iceland, Italy, Spain, Portugal, Croatia, Slovenia, Germany, Greece, France, Korea, Uruguay, Canada, Chile, Slovakia, Hungary, Ireland, Malesia, Romania, Austria, Iran, Brasil) and the consequent exchange of ideas and experiences. The initiative encompasses three main themes: strengthening the local Geopark's food production and enterprises (tourism), increasing the awareness of geoheritage and abiotic factors (education), strengthening the meaning of the brand within research and innovation activities. (Gentilini S et al., 2021).

During 2021 the project got awarded from the International Geoscience Programme as the best project proposal under the "Sustainable development" topic (see 6.2.1). GEOfood has been presented in more than 100 events and conference from 2015.

6.1.1 The GEOfood contribution to the United Nation Sustainable Development Goals

During the United Nation Sustainable Development Summit run in September 2015 countries officially adopted the historic new agenda, entitled "Transforming Our World: The 2030 Agenda for Sustainable Development," which was agreed upon by the 193 Member States of the United Nations, and includes 17 Sustainable Development Goals (SDGs). The agenda is a result of three yearslong, transparent and participatory process led by the Open Working Group as an outcome of the Rio Conference in 2012.

It represents an unprecedented agreement, a roadmap with shared Global Goals and 169 targets, indicators and monitoring procedures to end global poverty, leaving no one behind, supporting dignity for all and strengthening planetarian effort towards green economy and sustainable living, supporting development without jeopardising the ability of future generations to meet their own needs.

The agenda is a call for action till 2030, focusing on five areas of critical importance: people, planet, prosperity, peace and partnership.

Figure 48 -United Nation Sustainable Development Goals , available on line at : https://www.un.org/fr/sustainable-development-goals.

In 2019, MGp in cooperation with Naturtejo UGGp established the "manifesto" of values including sustainability criteria for GEOfood companies, using references from the Food Agricultural Organization (FAO, 2018) and AGENDA 2030 (U.N., 2015).

The manifesto of values, now translated in 20 languages, includes information about the connection between the UNESCO Global Geoparks and the United Nation Sustainable Development Goals, with specific focus on the ones related with food, climate change and education, particular with SDGs ns.2, 3, 4 ,5, 8,11, 12, 13,14, 17.

In particular, GEOfood is contributing to the **Goal n.2:** "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" within the Target 2.3: "By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment".
GEOfood is in fact, involving local small-scale producers, women cooperative (ex. In Grutas del Palacio UGGp-Uruguay) empowering family farmers and local enterprises towards innovative opportunities linked with non-farm activities like food storytelling, tourism, and education.
GEOfood is contributing to the Target 2.4 "By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality", supporting local traditional agricultural practices linked with natural cycle and its changing linked with climate instability and extreme phenomena. The Target 2.5 "By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed" is also included within GEOfood main values. Several GEOfood company members are valorizing the wild species, supporting the use of diversity type of seeds promoting the utilization of genetic resources associated with traditional practices.
The Goal 3 is also fully included into the manifesto, in fact "Ensure healthy lives and promote well-being for all at all ages" is one of the main GEOfood sustainable food strategy development which is fully contributing to the Target 3.9 "By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination".
Education for local communities is part of the GEOfood initiative, so the contribution to the **UNSDG n.4** "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" is also relevant, especially within the Target 4.3 and 4.4. ensuring the equal access for all women and man to affordable educational programmes and increasing the number of people having relevant skills.
GEOfood aims at empowering women entrepreneurs, contributing to the **Goal n.5** "Achieve gender equality and empower all women and girls", supporting women cooperative and female entrepreneurs.

Within the **Goal 8:** "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all", GEOfood is supporting the Target 8.3, promoting job creation, entrepreneurship, creativity, and innovation for using local heritage as a tool for sustainable development, one of the GEOfood value is also connected with Target 8.8 to guarantee labour rights and proper job conditions, involving only companies following specific labour rules. Indirectly GEOfood is supporting the development of policies for sustainable tourism, directly promoting local cultures and products, fully in line with the Target 8.9. **Goal 11:** "Make cities and human settlements inclusive, safe, resilient and sustainable", GEOfood is aligned with the Target 11.4 aiming at protecting and safeguarding cultural and natural heritage, both intangible and tangible. Food is one of the most important aspects of cultural local heritage, raw material and respect for the environment is directly supporting the natural heritage in the countryside but also within urbanised areas. **UNSDG n.12:** "Ensure sustainable consumption and production patterns" includes Targets 12.1, 12.2 aiming at implementing sustainable consumption and management of natural resources: the main core of GEOfood is linked with the use of sustainable sourced local food with reduce use of pests and chemicals dangerous for human health (Target 12.4). Packaging and waste reduction (Target 12.5) is one of the requirements for adopting the GEOfood brand within UGGps. Target 12.8 "By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature" is fully included in the GEOfood concept of increasing people's awareness about nature, informing citizens through food storytelling and seasonal menus. The analysis of the GEOfood development can also be seen as a tool for monitoring impacts of sustainable development practices within UGGps (Target 12.b).
The Goal 13: "Take urgent action to combat climate change and its impacts' ' includes several targets linked with GEOfood in many aspects. The idea of GEOfood related with developing specific educational courses on food waste reduction and the related impact of use of local food regarding reduction of CO2 emissions is contributing to the Target 13.3. "Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning". The overall contribution of GEOfood concerning the reducing of pests in agriculture, the support to local SME´s and the use of local fish seasonal resources in the menu is also supporting the **Goal 14** of Conserving and sustainably use the oceans, seas and marine resources for sustainable development", especially targets 14.1,14.3. and 14.b "Provide access for small-scale artisanal fishers to marine resources and markets". **Goal 15**, "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss", is connected to the GEOfood principles of supporting the maintenance and valorization of traditional endogenous animal species. GEOfood is finally supporting the achievement of the **Goal n.17** revitalising the global partnership for sustainable development through the networking activities and exchange of good practices.

UNSDGs	GEOfood contribution
Goal 2	2.3 Involving local small-scale producers, women cooperative, empowering family farmers and local enterprises towards innovative opportunities linked with non-farm activities like food storytelling, tourism, and education. 2.4 Supporting local traditional agricultural practices linked with the natural cycle. 2.5 Valorizing the wild species, supporting the use of diverse type of seeds promoting the utilisation of genetic resources associated with traditional practices.
Goal 3	3.9 Sustainable food strategy development
Goal 4	4.3 and 4.4 Ensuring the equal access for all women and man to affordable educational programmes and increasing the number of people having relevant skills
Goal 5	5 Empowering women entrepreneurs
Goal 8	8.3 Promoting job creation, entrepreneurship, creativity, and innovation for using local heritage as a tool for sustainable development. 8.8 Guarantee labour rights and proper job conditions, involving only companies following specific labour rules. 8.9 Supporting the development of policies for sustainable tourism, directly promoting local cultures and products.
Goal 11	11.4 Protecting and safeguarding cultural and natural heritage, both intangible and tangible.
Goal 12	12.1-12.2 Implementing sustainable consumption and management of natural resources 12.4 Use of sustainable sourced local food with reduce use of pests and chemicals dangerous for human health
Goal 13	13.3 Courses on food waste reduction and the related impact of use of local food regarding reduction of CO2 emissions.
Goal 14	14.1-14.2-14b Concerning the reducing of pests in agriculture,

	Support to local SME´s and the use of local fish seasonal resources
Goal 15	Supporting the maintenance and valorization of traditional endogenous animal species
Goal 17	Revitalizing the global partnership for sustainable development through the networking activities and exchange of good practices.

Table 6 – Synergies UNsdgs and GEOfood, Gentilini S. 2022.

6.1.2 The GEOfood contribution to the abiotic ecosystem services

GEOfood interacts and contributes to several United Nation Sustainable Development Goals (Chapter 6.1.2), the abiotic ecosystem services have great potential for better planning, policy and decision making. Starting from the connection between GEOfood and SDGs, it is possible to underline the following interaction between the 25 abiotic services and GEOfood.

The GEOfood contribution to SDGs n.2, target 2.3 is connected to the involvement of local small-scale producers, women cooperative, empowering family farmers and local enterprises towards innovative opportunities linked with non-farm activities like 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 are contributing to Education and employment (Cultural Service).

The GEOfood is supporting the 2.4 target, sustaining local traditional agricultural practices linked with natural cycle", which is connected with Regulating processes: Terrestrial processes, Flood control, water quality regulation, but also with Supporting Service: Land as Platform for Human activities, Provisioning: Food and drink and Cultural service like: Environmental quality, Social development.

The target 2.5 achieved with the GEOfood action of valorizing the wild species, supporting the use of diverse types of seeds promoting the utilisation of genetic resources associated with traditional practices is linked with several ecosystem services: Habitat Provision, Food and drink, Environmental quality, Social development and Education and employment.

GEOfood is supporting Sustainable food strategy development (SDGs- target 3.9) which is connected directly with the cultural service Environmental quality.

The target goal 4.3 and 4.4 and the SDG n.5 are linked with the GEOfood educational actions and valorization activities which ensuring the equal access for all women and man to affordable educational programmes and increasing the number of people having relevant skills, directly in line with the ecosystem service Social development and Education and employment.

The GEOfood contribution to target 8.3 is linked with the promotion of job creation, entrepreneurship, creativity, and innovation for using local heritage as a tool for sustainable development and with the Ecosystem Services Social development, Earth history and Education-employment.

The support to target 8.8 though GEOfood is guaranteed through the involvement of companies following specific labour rules which connect with Ecosystem Services Social development, Earth history and Education-employment.

The GEOfood support to the development of policies for sustainable tourism, directly promoting local cultures and products is linked with SDG target 8.9 and with Ecosystem Services: Geotourism and leisure, Social development, Earth history and Education-employment.

GEOfood is supporting the Protection and safeguarding cultural and natural heritage, both intangible and tangible (Target 11.4) though the valorization and recording of intangible heritage and promotion of natural heritage as source for quality food, involving the Ecosystem services: cultural and historic and Environmental and forecasting monitoring.

The targets ns. 12.1-12.2-12.4 are connected to GEOfood thanks to its actions for the implementation of sustainable consumption and management of natural resources with reducing use of chemicals and pests, also

linked with the Provisioning Service: Food and drink, and Cultural Services: Environmental quality and the Environmental monitoring and forecasting.

GEOfood is empowering the Target 13.3 offering courses on food waste reduction and the related impact of use of local food regarding reduction of CO2 emissions, linked with Ecosystem services: Food and drink, Social development, Education and employment.

The SDG target 14.1is linked with the GEOfood strategy linked with the reduction of pests in agriculture enhancing the ecosystem service- Habitat provision.

GEOfood within the 14.2-14b SDGs target is supporting local SME´s and the use of local fish as seasonal resources, contributing to Food and Drink and Environmental quality.

GEOfood is contributing to the Goal n.15, supporting the maintenance and valorization of traditional endogenous animal species, linked with Habitat provision service while the connection with Goal n.17 is guaranteed through the networking activities contributing to Social development and Education-employment.

	GEOfood- UNITED NATION SUSTAINABLE DEVELOPMENT GOALS and TARGETS																			
REGULATING	2.3	2.4	2.5	3.9	4.3	4.4	5	8.3	8.8	8.9	11.4	12.1	12.2	12.4	13.3	14.1	14.2	14.b	15	17
The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, hazard regulation. water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination and natural																				
1) Atmospheric and ocean processes																				
2)Terrestrial processes		x																		
3) Flood control		x																		
4) Water quality regulation		x																		
SUPPORTING																				
They are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling.																				
5)Soil processes																				
6)Habitat provision			x													x			x	
7) Land as a platform for human activities	x	x																		
8) Burial and storage																				
PROVISIONING																				
The products obtained from ecosystems, including food, fibre, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and fresh water.																				
9)Food and drink	x	x	x									x	x	x	x	x	x			
10)Nutrients and minerals																				
11)Fuel (sources of energy)																				
12)Construction materials																				
13) Industrial minerals																				
14)Ornamental products																				
15)fossils																				
CULTURAL																				
The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences – thereby taking account of landscape values.																				
16) Environmental quality		x	x	x								x	x					x		
17) Geoturism and leisure									x	x										
18) Cultural spiritual and historic											x									
19) Artistic inspiration																				
20)Social development		x	x		x	x	x	x	x	x					x					x
21)Earth history								x	x	x										
22) History of research																				
23) Environmental monitoring and forecasting											x	x	x							
24) Geoforensis																				
25) Education and employment	x		x		x	x	x	x	x	x					x					x

Table 7 – Synergies Abiotic Ecosystem Services and GEOfood, Gentilini S. 2022.

6.2 The UNESCO International Geoscience Programme

6.2.1 Project 726： GEOfood for sustainable development in UNESCO Global Geoparks

Figure 49 - Project logo, Rodrigues J. 2021.

The International Geoscience Programme's main goal is to promote the sustainable use of natural resources, advancing new initiatives related to geo-diversity, geo-heritage, and geohazards risk mitigation. It serves as a UNESCO knowledge hub to facilitate international scientific cooperation in the geosciences across the World. Once a year, the Programme issues a call for proposals and issues financial support to specific projects regarding geoscience; the GEOfood initiative has been financed this year under the topic of "Sustainable Development".

The project, which was approved in 2021 and is led by Sara Gentilini on behalf of Magma UGGp, outlines the success of the GEOfood initiative. It will run for five years, involving 56 individual partner organisations including museums, universities, UNESCO Global Geoparks, aspiring Geoparks from 28 countries. (https://geofood.no/geofood-science/igcp-programme/). Members from aspiring Geoparks and Geopark projects are also included in the project and their contribution is especially relevant since one of the main project outcomes is to establish a tool for supporting territories in developing food networks and GEOfood products.

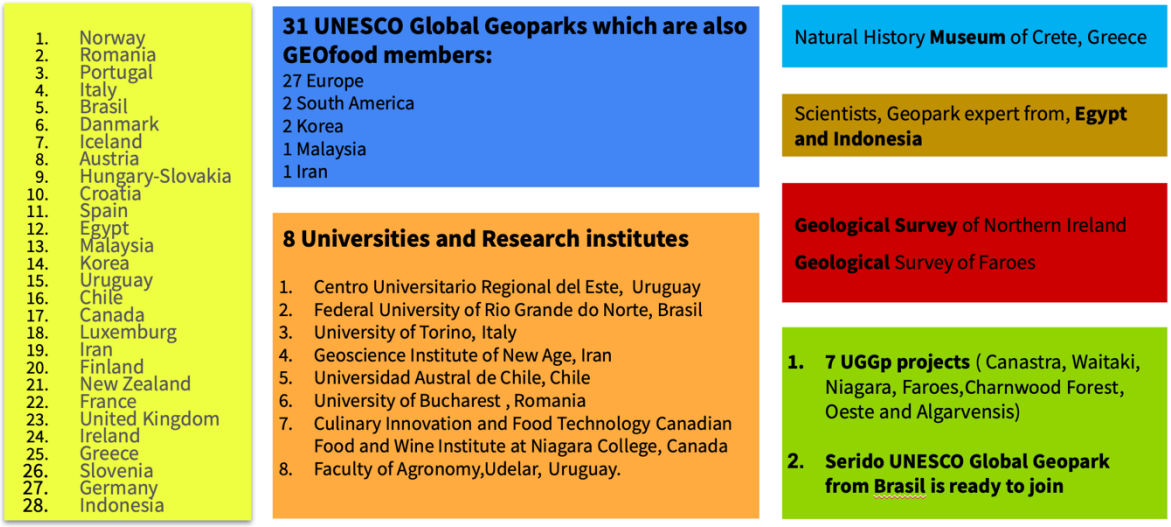

Figure 50 - Project members, Gentilini S. 2022.

This project proposes a scientific approach to GEOfood, starting from the connection between geoheritage, geodiversity, ecosystem services, food production and sustainable development. Based on this study, the project will establish methodologies for GEOfood assessment, implementation, and results.

The project goal is to carry out research on the link between geoheritage, geodiversity ecosystem services, food production and sustainable development through the implementation of an innovative brand – GEOfood.

Goals	ACTIONS	RESULTS
1.Gathering data, mapping the resources and conducting research	1.1. Establishing a baseline 1.2. Gathering data on local level 1.3. A comparative study 1.4. Meeting or Online tool	1.1. List of concepts and definitions 1.2. Database and spatial data 1.3. A scientific report 1.4.
2.Developing methodologies	2.1. Assessment methodology 2.2. Implementation methodology 2.3. Results evaluation methodology	Methodologies on GEOfood assessment, implementation, and results
3.Designing and producing a toolkit	3.1. Designing and producing a GEOfood toolkit	a GEOfood toolkit (on-line tools, guides, brochures, leaflets, maps, etc.)
4.Implementing on local level	4.1. Identifying potential local partners 4.2. Local activities 4.3. Evaluation of results	4.1. at least 5 potential partners for each territory 4.2. at least 1 local event, 3 on-line events, 1 press release and 1 certified product for each territory 4.3. 23 local evaluation reports, 1 overall evaluation report.
5. Disseminating the results	5.1. participating to events and writing articles	at least 3 conferences, at least 5 scientific articles, at least 30 media coverages

Table 8 - Project goals and outcomes, (Gentilini et al., n.d.)

Analysing these relationships in depth is essential to understand the local identity of a UGGp in all its cultural, social and economic aspects (i.e., use of natural-geological resources).

This will be used as a basis for developing strategies to fulfil the IGCP broad objective which aims at increasing the understanding of geological processes and concepts of global importance, including an emphasis on socially relevant issues.

The expected main outcomes of the project are shown in the webpage platform (www.geofood.no), the first project main result was the project baseline, product of overall efforts within all project members. 8 main concepts, linked with GEOfood values and definition have been detected: geology, geography, soils, agriculture, biodiversity, economy, geotourism and culture. For each of the concepts the teams detected the Definition, the Qualitative indicators and the Bibliography. Starting from the baseline the project will develop local research, collecting GEOfood best practices and methodologies already in use in UNESCO Global Geoparks, to develop specific tool kit as main second years outcome. Another outcome of the project first year was the GEOfood board game which has been realised by the Hateg County Geopark from Romania, with inputs from Magma and Naturtejo UGGps. The aim of the boardgame is to get to know the geoparks' economic framework, to familiarise with the geoproduct concept and to learn about GEOfood and is now available online for free use.

7 Conclusions and Final Remarks

7.1 A methodology for geosite assessments within UNESCO Global Geoparks

The research started from the desk analysis of the UNESCO Global Geoparks, which included the geosites' geological and cultural background, their classification adopted at the time of application to the UGGps, and the geosite methodology, which can be identified with the "Stakeholders consultation and object and targets identification" in the "Biodiversity Indicators Development Framework" described above.

The proposed methodology includes the selection of the "case study" geosites, field inspections regarding those selected geosites, and results in data; said results have been compared with the preliminary analysis of the abiotic ecosystem services and the related classification of 25 abiotic ecosystem services outlined by Gray. (Table 9-Green circles)

Through the collection of Data, Questions and Indicators, the field and desk research were combined and the preliminary classification of the representative geosites was gathered in a "database for geosite recording", considered to be a common framework for geosite classification between Italy and Norway; this record is the first product of this research (Blue Circle NI, Table 9).

The research on existing biotic ecosystem classifications and applications and its subsequent comparison within the already proven methodologies related with abiotic ecosystem services assessment results in the analysis of the overall qualitative characters of the selected geosites. (Blue Circle NII, Table 9).

The provisional analysis of the abiotic ecosystem (Blue Circle 2), the key questions and Indicator use and the application of existing scientifical biotic service approaches to the abiotic features of the Geopark selected led to the detection of a conceptual model based on provisional abiotic indicators.

The provisional model has been tested and refined with stakeholders (Yellow Circle 4A).

The gathering of data, the final provisional assessment, led to the development of the monitoring-reporting system, which constitutes the third product of this research (Blue Circle NIII).

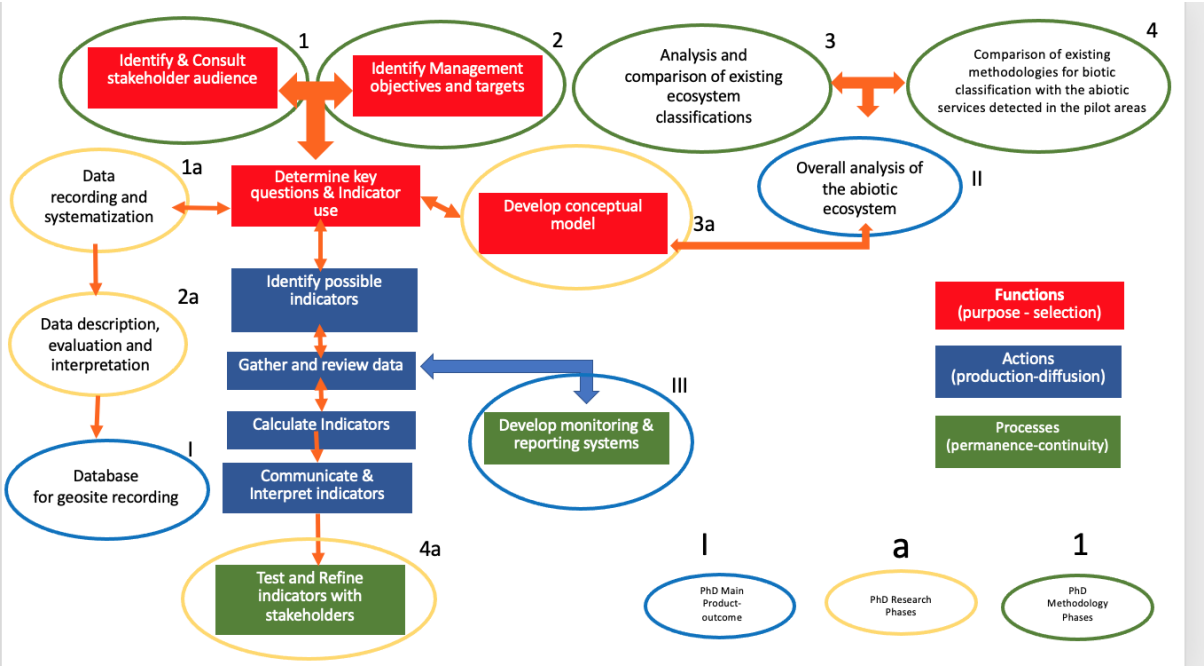

Table 9, Biodiversity Indicators Development Framework, from Biodiversity Indicators Partnership: (https://www.bipindicators.net/national-indicator-development) Adapted with PhD´s methodology, Research Phases and Product, Gentilini S.

7.2 Results within the UNESCO Global Geoparks investigated and in other IGCP projects.

The results obtained through this research could give a concrete benefit to the two Geoparks which were investigated. As the abiotic assessment shows, within the analysis of the four geosites selected (Annex 6), the abiotic ecosystem services play a relevant role in the interpretation, consequent geosite development, and overall land planning on behalf of Geopark managers and policy makers.

As a matter of fact, the research provides a planning tool for managers, supporting them to deliver appropriate budgets for Geopark planning, taking into consideration all the advantages but also all the threats brought by nature to human development.

The present research final assessment method allows managers and policy makers, with the support of a multidisciplinary team, to preliminarily assess the territory in an innovative way considering climate issues, land use, geohazards, soil presence, water and food provisions, education and culture, all in one.

The application of the abiotic service assessment could positively influence all the activities related with a UNESCO Global Geopark, from planning to delivering educational courses, visibility and interpretation panels, infrastructure and cooperating with local communities, and strengthening the bottom-up approach, which is crucial for successful Geopark territories.

In fact, thanks to a deeper analysis of the abiotic natural services, it would be easier to establish strong relationships with landowners, food producers, craft makers, and local stakeholders who are the custodians of intangible heritage and often feel mistreated by local planners.

The present preliminary definition of indicators for abiotic nature aims at incentivising a stronger cooperation between “bio” scientists and “geo” scientists, who are both equally important for understanding the nature around us.

The research is supporting the development of the IUGS Geological Heritage sites (with the project number 731) led by Dr. Asier Hilario Orús which aims to open a new opportunity for the global recognition of Geological Sites

of International Significance (IUGS Global Geosites) bringing together the experience and knowledge of different actors like geological surveys, UGGp and scientific organisations.

7.3 The Benefit to society from abiotic ecosystem services

The overall analysis carried out within this research has led to the main conclusion of the importance of mapping, assessing, and monitoring the abiotic ecosystem services characterising UNESCO Global Geoparks.

Benefits obtained by the systematic management of abiotic services and related planning actions are numerous and have important positive effects on local inhabitants.

The research shows that the benefits cover many beneficiaries and different economic and non-economic sectors.

Benefits deriving from "Regulating Services" are linked with Earth phenomena and are visible on a local and global scale both through climate cycles and weather forecasting. Terrestrial processes and water management also constitute Regulating Services; therefore, appropriate tools for service assessment represent concrete solutions for climate change mitigation, geohazard risk reduction, coast and land erosion, and extraordinary floods.

"Supporting Services" such as soil processes play an important role within national, regional and local communities: agriculture, forestry, fuel, and genetic resources are crucial for human development. Agriculture plays a key role in providing a wide range of ecosystem services, such as food, feed, fibre, and biofuel, thus contributing to the economic development of countries. Forestry, along with farming, remains crucial for land use and the management of natural resources in rural areas and as a basis for economic diversification in rural communities, especially for mitigation to climate change. The assessments of threats to soil functions leads to a need to formally identify the functions that the soil performs.

"Habitat provision" and the use of "Land as a platform for human activities" are two of the so-called "Supporting Services" (abiotic and biotic) which concur in the creation of "habitats". These are crucial for societal development at all scales: geodiversity influences the heterogeneity of habitats and biodiversity; as a consequence, therefore biodiversity is affecting the loss of geodiversity.

Habitat loss, stemming from destruction, fragmentation, or degradation, threatens these sanctuaries of diversity and is often the result of human activities. These elements cause changes to the delicate biological and physical properties of habitats, decrease genetic diversity, and increase water pollution introducing pathogens and invasive species, as COVID-19 is showing. All the advantages to guaranteeing the abiotic and biotic factors linked with habitat provision are evident from the negative effects caused by the loss of biodiversity and geodiversity.

Concerning the "**Provisioning Services",** food is one of the most important services that nature provides humans with: the main elements influencing drink and food production at a local, regional, and national level are soil, climate and habitat. Institutions and communities must develop specific legislation and actions regarding soil protection, by following the example from the European Soil thematic Strategy (https://ec.europa.eu/environment/soil/three_en.htm).

The recent Farm to Fork European Strategy (https://ec.europa.eu/food/farm2fork_en) is also going in this direction, focusing on use of chemical pesticides, avoiding excess nutrients, restoring soil health, and improving soil management. The EU Commission proposed a Directive concerning soil protection and regeneration (Thematic Strategy for Soil Protection − Summary of the impact assessment.

In Norway, soil use is regulated by the Land Act (https://www.regjeringen.no/en/dokumenter/The-Land-Act/id269774/) whose purpose is to provide suitable conditions to ensure that the land areas in the country including forests and mountains and everything pertaining thereto (land resources) may be used in the manner that is most beneficial to society and to those working in the agricultural sector.
Soil protection relates to the preservation of habitats, since geodiversity, geological heritage and the use of the soil are also connected with food and drink provision. Climate has a key role in provisioning food and drink for the human population and climate change is the main challenge that humanity is facing.

Mineral fuels are the most important source of fuels for all the communities at all levels. Coal, peat, petroleum, and renewable energy are constantly monitored by international, national and regional Institutions and Organizations. Data from the European Mineral Map reveals low presence of minerals in the Sesia Val Grande geosite, while industrial minerals are present in Eigerøy and Jøssingfjord. (http://www.europe-geology.eu/mineral-resources/mineral-resources-map/) . Construction minerals, building stones, aggregates, limestone, structural clay, gypsum, sand, volcanic products, bitumen and industrial minerals are constantly monitored by international, national and regional Institutions. Minerals and their extraction are sources of income and could be beneficial in terms of jobs for the local population. Mineral provision is crucial for modern society; however, the extraction and delivery processes should lead to sustainable practices.

The European Commission, through the H2020 Programme, financed several projects focusing on the sustainable use of natural resources, i.e., the Arctic Hub project led by the Natural Resource Institute of Finland, which involves as partners both the Sesia and Magma Geoparks. The project pertaining to the mining industry aims at analysing not only the "*economic or developmental viability of mining but view associated socio-cultural and political factors*"(https://projects.luke.fi/arctichubs/)

Benefits linked with **"Cultural and Knowledge Services**" cover the local, regional, and national level. The aesthetic values of the landscape derive directly from the biotic and abiotic services; however, they do not directly benefit society but indirectly through tourism and leisure possibilities, which are crucial in UNESCO Global Geoparks. Recreation and nature-based tourism are important sources of income and employment in many places around the world. The total value of international tourism exceeds 4.7 trillion U.S. dollars in 2020 https://www.statista.com/markets/). Nature-based tourism (sometimes called environmental tourism or ecotourism, although strictly speaking, the latter is a subset of nature-based tourism and includes certain ethical considerations) may comprise 40-60% of this total. The recreational benefit from nature also contributes to health and well-being, as there is a correlation between green areas, good air quality, and human health, linking Ecosystem Services and Human Well-Being. Furthermore, the development of activities related with the geosite and geological heritage could strengthen the "sense of belonging" of its citizens, which is crucial for successful development strategies and geoparks.
The benefits are linked with the possibility of monitoring geohazards phenomena and human activities. Therefore, at all levels, proper monitoring includes protecting the local population and appropriate urban planning. Scientific research and educational activities are linked with strengthening people's awareness: educated citizens disseminate good practices and support actions related with geo-conservation strategies.

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Annexes

1) **Geosite classification framework-Output 1**
2) **Geosite classification in Sesia Val Grande**
3) **Geopark localities classification in Magma Geopark**
4) **Preliminary abiotic ecosystem assessment -Eigerøy geosite**
5) **Registration schema from UniTO**
6) **Assessment Methodology for abiotic services -Output 2**
7) **Databases comparison schema**

Annex 1

Information inventory

Metadata
- Picture
- Paper
- Map

Shape typology
- Point
- Line
- Area
- Viewpoint
- Landscape

Type of geosite
- Bedrock
- Pre quaternary landscape development
- Quaternary

Scientific interest
- Stratigraphic
- Geomorphological
- Sedimentological
- Paleontological
- Paleoenvironmental
- Tectonical
- Magmatic
- Metamorphical
- Geobiosphere
- Geoarcheological
- Submarine
- Geohazard
- Geomosaure
- Geocultural
- History of science
- Pedological (soil science)
- Climate change
- Petrographical
- Mineralogical

Geological environment
- Glacial
- Fluvial
- Coastal
- Marine
- Chemical dissolution
- Subsurface magmatic
- Slope movement
- Other

Era
- Precambrian
- Paleozoic
- Mesozoic
- Cenozoic

Period
- Quarternary
- Tertiary
- Cretaceous
- Jurassic
- Triassic
- Permian
- Carboniferous/Pennsylvanian
- Carboniferous/Mississippian
- Devonian
- Silurian
- Ordovician
- Cambrian
- Precambrian

Value-ratio
- Limited
- Good
- Very good
- Not valued

Existing Dissemination
- Leaflets
- APP
- Virtual Reality contents
- App and leaflets
- Leaflets and VR
- App,leaflets and VR
- Signboard
- Signboard and leaflets
- Signboard and APP
- Signboard and VR
- Signboard, APP, leaflets and VR
- Signboard, App, VR
- Signboard, APP, leaflets

Conservation Stat/Visual Value
- Limited
- Good
- Very Good
- Not valued
- Not visible
- Obstructed
- Good
- Excellent

Other values
- Historical
- Nature and biology
- Urban area and infrastructure
- Sport and recreational
- Egeological
- Intangible heritage
- Other values

Natural treats
- Erosion and weathering
- Overvegetation
- Water and flood
- Landslide
- Icefall
- Other
- None

Human treats
- Infrastructures
- Urban infrastructure
- Quarring
- Deposit
- Pollution
- Scientific sampling
- None
- Infrastructure-pipelines
- Urban area

Level of treat
- Low
- Middle
- High
- Not valued

Need for landscape management
- No need
- Middle need
- Big need
- Noone

Site manager measures
- Vegetation
- Shielding
- Cleaning
- Protection measures
- Site manager measures
- None

Protection status
- Local protection
- Regional protection
- National
- International
- Noone

Need for protection
- yes
- no
- More info required

Accessibility
- Easy
- with some challenges
- difficult
- not valued

International scientific publications
- None
- Between 1 and 5
- More than 5
- Stratotype

Land use
- Wood
- Cultivated
- Terraced
- Sivuage
- Urbanized
- Rocks
- Debris
- Canine
- Reference
- Landcover
- Posture

Exposure
- Natural
- Artificial
- Collection

Property
- Public
- Private
- Mixed

Category of protection
- Landscape planning
- Geological
- Urban planning
- Cultural heritage
- Other
- None

Improvement suggestions
- Info center
- Leaflets
- Signboards
- App
- Signpost
- Information board
- Virtual Contents

Lithology
- acidic igneous material
- acidic igneous rock
- alkali olivine basalt
- alkali feldspar granite
- alkali feldspar rhyolite
- alkali feldspar syenite
- alkali feldspar syenitic rock
- alkali feldspar trachyte
- alkali feldspar trachytic rock
- amphibolite
- andesite
- anorthosite
- anorthositic rock
- anthracite coal
- anthropogenic material
- anthropogenic unconsolidated material
- aphanite
- aplite
- arenite
- ash and lapilli
- ash breccia bomb or block tephra
- ash tuff lapillistone and lapilli tuff
- basalt
- bauxite
- basanitic foidite
- basic igneous material
- basic igneous rock
- basalte
- biogenic sediment
- biogenic silica sedimentary rock
- bituminous coal
- boulsite
- boulder gravel size sediment
- boundstone
- breccia
- breccia gouge series
- calcareous carbonate sediment
- calcareous carbonate sedimentary material
- calcareous carbonate sedimentary rock
- carbonate mud
- carbonate mudstone
- carbonate ooze
- carbonate rich mud
- carbonate rich mudstone
- carbonate sediment
- carbonate sedimentary material
- carbonate sedimentary rock
- carbonate wackestone
- carbonatite
- cataclasite series
- chalk
- chemical sedimentary material
- chlorite actinolite epidote metamorphic rock
- clastic conglomerate
- clastic mudstone
- clastic sandstone
- clastic sediment
- clastic sedimentary material
- clastic sedimentary rock
- clay
- claystone
- coal
- cobble gravel size sediment
- composite genesis material
- composite genesis rock
- compound material
- crystalline carbonate
- dacite
- diamictite
- diamicton
- diorite
- diorritic rock
- diorritoid
- doleritic rock
- dolomitic or magnesian sedimentary material
- dolomitic or magnesian sedimentary rock
- dolomitic sediment
- dolostone
- duricrust
- eclogite
- evaporite
- exotic alkaline rock
- exotic composition igneous rock
- exotic evaporite
- fault related material
- fine grained igneous rock
- foid bearing alkali feldspar syenite
- foid bearing alkali feldspar trachyte
- foid bearing anorthosite
- foid bearing diorite
- foid bearing gabbro
- foid bearing latite
- foid bearing monzodiorite
- foid bearing monzogabbro
- foid bearing monzonite
- foid bearing syenite
- foid bearing trachyte
- foid diorite
- foid diorritoid
- foid gabbro
- foid gabbroid
- foid monzodiorite
- foid monzogabbro
- foid monzosyenite
- foid syenite
- foid syenitoid
- foidite
- foiditoid
- foidolite
- foliated metamorphic rock
- fragmental igneous material
- fragmental igneous rock
- framestone
- gabbro
- gabbroic rock
- gabbroid
- generic conglomerate
- generic mudstone
- generic sandstone
- glass rich igneous rock
- glassy igneous rock
- glaucophane lawsonite epidote metamorphic rock
- gneiss
- grainstone
- granite
- granitoid
- granodiorite
- granulites
- granulite
- gravel
- gravel size sediment
- high magnesium fine grained igneous rocks
- hornblendite
- hyaroles
- hybrid sediment
- hybrid sedimentary rock
- igneous material
- igneous rock
- impact generated material
- impure calcareous carbonate sediment
- impure carbonate sediment
- impure carbonate sedimentary rock
- impure dolomitic sediment
- impure dolostone
- impure limestone
- intermediate composition igneous material
- intermediate composition igneous rock
- iron rich sediment
- iron rich sedimentary material
- iron rich sedimentary rock
- kalsilitic and melilitic rock
- kamatitic rock
- latite
- latitic rock
- lignite
- limestone
- marble
- material formed in surficial environment
- metamorphic rock
- metasomatic rock
- meta-schist
- migmatite
- monzodiorite
- monzodioritic rock
- monzogabbro
- monzogabbroic rock
- monzogranite
- monzonite
- monzonitic rock
- mud
- mud size sediment
- mylonitic rock
- natural unconsolidated material
- non clastic siliceous sediment
- non clastic siliceous sedimentary material
- non clastic siliceous sedimentary rock
- ooze
- organic bearing mudstone
- organic rich sediment
- organic rich sedimentary material
- organic rich sedimentary rock
- orthogneiss
- packstone
- paragneiss
- peat
- pebble gravel size sediment
- pegmatite
- peridotite
- phaneritic igneous rock
- phonolite
- phonolitic basanite
- phonolitic foidite
- phonolitic tephrite
- phonolitoid
- phosphate rich sediment
- phosphate rich sedimentary material
- phosphorite
- phyllite
- phyllonite
- porphyry
- pure calcareous carbonate sediment
- pure carbonate mudstone
- pure carbonate sediment
- pure carbonate sedimentary rock
- pure dolomitic sediment
- pyroclastic material
- pyroclastic rock
- pyroxenite
- quartz alkali feldspar syenite
- quartz alkali feldspar trachyte
- quartz anorthosite
- quartz diorite
- quartz gabbro
- quartz latite
- quartz monzodiorite
- quartz monzogabbro
- quartz monzonite
- quartz rich igneous rock
- quartz syenite
- quartz trachyte
- quartzite
- residual material
- rhyolite
- rhyolitoid
- rock
- rock gypsum or anhydrite
- rock salt
- sand
- sand size sediment
- sapropel
- schist
- sediment
- sedimentary material
- sedimentary rock
- serpentinite
- shale
- silicate mud
- silicate mudstone
- siliceous ooze
- silt
- siltstone
- skarn
- slate
- spilite
- syenite
- syenitic rock
- syenitoid
- syenogranite
- tephra
- tephrite
- tephritic foidite
- tephritic phonolite
- tephritoid
- tholeiitic basalt
- tonalite
- trachyte
- trachytic rock
- trachytoid
- travertine
- tuff breccia agglomerate or pyroclastic breccia
- tuffite
- ultrabasic igneous rock
- ultramafic igneous rock
- unconsolidated material
- wacke

Missing UNITO
Missing NGU
Common to both
Added categories

Information inventory	Shape typology	Scientific interest	Era	Period	Value- ratio	Conservatior	Visual Value	Other values	Natural treats	Human treats
	Point	Sedimentological	Precambrian	Quarternary	Limited	Limited	Not visible	Historical	Erosion and weathering	Infrastructures
	Line	Paleoenvironmental	Paleozoic	Tertiary	Good	Good	Obstructed	Nature and bio	Overvegetation	Urban infrastructure
	Area	Tectonical	Mesozoic	Cretaceous	Very good	Very Good	Good	Urban area an	Water and flood	Quarring
	Landscape	Magmatic	Cenozoic	Jurassic	Not valued	Not valued	Excellent	Intangible herit	Other	Deposit
		Metamorphical		Triassic				Other values	None	Scientific sampling
		Geobiosphere		Permian						None
		Geocronological		Carboniferous/Pennsylvanian						Infrastructure-pipelines
		Submarine		Carboniferous/Missiddippian						Urban area
		Geohazard		Devonian						
		History of science		Silurian						
		Petrographical		Ordovician						
		Mineralogical		Cambrian						
				Precambrian						

Level of treat	Need for landscape management	Site manager measures	Protection status	Need for protection	Accessibility	Land use
Low	No need	Vegetation	Local protection	yes	Easy	Pasture
Middle	Middle need	Sheilding	Noone	no	with some challenges	
High	Big need	Cleaning		More info required	difficult	
Not valued	Noone	Protection measures			not valued	
		Site manager measures				
		None				

Missing UNITO

Shape typology	Type of geosite	Level of treat	Need for landscape management	Site manager measures	Protection status	Need for protection
Viewpoint	Bedrock	Low	No need	Vegetation	Local protection	yes
	Pre quarternary landscape development	Middle	Middle need	Sheilding	Regional protection	no
	Quarternary	High	Big need	Cleaning	National	More info required
		Not valued	Noone	Protection measures	International	
				Site manager measures	Noone	
				None		

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Scientific interest	**Geological environment**	**Other values**	**Natural treats**	**Human treats**	**Protection status**	**Land use**	**Exposure**	**Category of protection**
Pedological (soil science)	Glacial	Sport and ricreational	Landslide	Pollution	National	Wood	Natural	Landscape planning
Climate change	Fluvial	Speleological	Icefall		International	Cultivated	Artificial	Geological
	Coastal					Terraced	Collection	Urban planning
	Marine					Savage		Cultural heritage
	Chemical dissolution					Urbanized		Other
	Subsurface magmatic					Rocks		None
	Slope movement					Debris		
	Other					Corine		
						Reference		
						Landcover		

New categories

Existing Dissemination	International scientific publications	Improvement suggestions	Property	Lithology
Leaflets	None	Info center	Public	
APP	Between 1 and 5	Leaflets	Private	
Virtual Reality contents	More than 5	Signboards	Mixed	
App and leaflets	Stratotipe	App		
Leaflets and VR		Signpost		
App,leaflets and VR		Information board		
Signboard		Virtual Contents		
Signboard and leaflets				
Signboard and APP				
Signboard and VR				
Signboard, APP, leaflets and VR				
Signboard, App, VR				
Signboard, APP, leaflets				

Geographic information				Type of geosite				Geological tree		Representativeness		Quality			Enhancement potential				Supporting data								Landscape				Ecology	Description	References
Scientific interest																																
Name	Description	Author	Date	Main type	Main subtype	Secondary type	Secondary subtype	Name	Geological unit	Type	Description (for geological units)	Integrity	Rarity	Scientific value	Accessibility	Infrastructure	Vulnerability	Promotion	Use	Management	Stakeholders	Ownership	Land protection	Visitor regulations	Safety	Visitor facilities	Accessibility	Nearest city	Distance	Direction	Nearest airport	Distance	Direction
Volcano	Impressive volcanic cone	Maria Sánchez	2023-05-12	Geological	Volcanic	Geomorphological		Volcanic Belt	Stratovolcano	Holotype	Well-preserved volcanic structure	Excellent	Unique	Very High	Easy	Developed	Low	Public	Tourism	Protected	Government	National Park	Strict Protection	Restricted Access	Low	Visitor Center	Wheelchair Accessible	Quito	120	Northeast	Mariscal Sucre International	135	Northeast
Lava Field	Extensive basaltic lava flows	Carlos Mendoza	2023-06-03	Geological	Volcanic	Geomorphological		Shield Volcano	Lava Flow	Paratype	Type locality for basaltic andesite	Good	Common	High	Moderate	Developed	Medium	Private	Research	Protected	Municipality	Private Reserve	Limited Protection	Permit Required	Moderate	Interpretive Center	Partially Accessible	Cotopaxi	45	South	Tena Airport	180	East
Crater Lake	Deep volcanic crater lake	Ana Rodríguez	2023-06-18	Geological	Volcanic	Geomorphological	Crater	Caldera Complex	Pyroclastic Deposit	Isotype	Reference material for dating	Excellent	Rare	Very High	Moderate	Undeveloped	High	Community	Education	Co-managed	Community Group	Indigenous Territory	Cultural Protection	Seasonal Closure	Moderate	Trailhead	Limited Access	Otavalo	30	Northwest	Otavalo Airport	45	Northwest
Fossil Site	Rich fossil deposits	Luis Fernández	2023-07-02	Paleontological	Fossil	Invertebrate	Mollusk	Limestone Formation	Sedimentary Rock	Neotype	Redefined type specimen	Fair	Unique	Very High	Difficult	Undeveloped	Very High	Private	Commercial	Restricted	Mining Company	Corporate	Mining Concession	Strictly Prohibited	Hazardous	Observation Deck	Not Accessible	Machala	200	Southeast	Machala Airport	210	Southeast
Glacial Valley	U-shaped glacial valley	Sofía Herrera	2023-07-15	Geomorphological	Glacial	Erosional	Cirque	Metamorphic Complex	Schist	Hypotype	Illustrated specimen	Good	Common	Moderate	Easy	Developed	Low	Public	Tourism	Protected	Government	National Park	Strict Protection	Restricted Access	Low	Visitor Center	Wheelchair Accessible	Quito	120	Northeast	Mariscal Sucre International	135	Northeast
Waterfall	Spectacular waterfall	Miguel Torres	2023-08-01	Geomorphological	Fluvial	Erosional	Waterfall	Granite Intrusion	Igneous Rock	Lectotype	Designated from original series	Excellent	Rare	High	Easy	Developed	Low	Public	Tourism	Protected	Government	National Park	Strict Protection	Restricted Access	Low	Visitor Center	Wheelchair Accessible	Quito	120	Northeast	Mariscal Sucre International	135	Northeast
Limestone Cave	Karst cave system	Elena Vargas	2023-08-20	Geological	Karst	Subterranean	Cave	Limestone Formation	Sedimentary Rock	Neotype	Redefined type specimen	Good	Common	Moderate	Difficult	Undeveloped	Very High	Private	Research	Restricted	Mining Company	Corporate	Mining Concession	Strictly Prohibited	Hazardous	Observation Deck	Not Accessible	Machala	200	Southeast	Machala Airport	210	Southeast

Variables	Phase typology	Rock Type(S)	Scientific interest	Geological and Geomorphological Interest	Peculiarities	Value - set	Existing Characterization	Conservation Status	Visual Value	Other values	Natural Conditions	Related Activities	Land Use/Visual Quality/Landscape Unit/Legal Protection	Protection Status	Road Network and Infrastructure	Accessibility	International accessibility (airport)	Distance	Direction	Category	Category of Protection	Improvement Suggestions	Lithology
Volcano	Phase 1	Igneous	Geological	Geomorphological	Geomorphological	Geological	Geomorphological	Unclassified	Low	Historical	Natural Conditions	Cultural Activities	Land Use	Not Rated	Poor	Very Difficult	Over 200 km	Northeast	Public	Geological	Strict Protection	Improve Signage	Igneous
River	Phase 2	Sedimentary	Paleontological	Paleontological	Paleontological	Paleontological	Paleontological	Low	Moderate	Cultural	Natural Conditions	Cultural Activities	Land Use	Poor	Difficult	150-200 km	Southeast	Private	Geological	Strict Protection	Improve Signage	Sedimentary
Mine	Phase 3	Metamorphic	Hydrological	Hydrological	Hydrological	Hydrological	Hydrological	Moderate	High	Archaeological	Natural Conditions	Cultural Activities	Land Use	Moderate	Moderate	100-150 km	Southwest	Protected	Hydrological	Strict Protection	Improve Signage	Metamorphic
		Unknown	Archaeological	Archaeological	Archaeological	Archaeological	Archaeological	High	Very High	Paleontological	Natural Conditions	Cultural Activities	Land Use	Good	Good	50-100 km	West	Mixed	Archaeological	Strict Protection	Improve Signage	Unknown
			Mixed	Mixed	Mixed	Mixed	Mixed																
			Unknown	Unknown	Unknown	Unknown	Unknown																

Missing Info

Missing Part

Annex 2

																						CATEGORIES NOT INCLUDED IN THE APPLICATION						
NUMBER-Geopark Application (only for Geosites)	Phd team NUMBER				CLASSIFICATION IN THE APPLICATION	NAME	SHORT DESCRIPTION	MAIN TOPIC DESCRIPTION	OTHER DESCRIPTION	PROVINCE	*Coordinate Latitudine N (NW) (WGS84)*	*Coordinate Longitude E (WGS84)*	*Coordinate Latitudine N (NW) (WGS84) DECIMALI*	*Coordinate Longitude E (NW) (WGS84) DECIMALI*	Quote (m s.l.m.)	RANK (I=international; N=national; R=regional; L=local)	MAIN INTEREST (P=petrography; ST=structural; G=geology of the basement; GM=geomorphology; CH= Cultural Heritage, H=Historical; MP= Metamorphic Petrology, GM= Glacial Morphology, SG=Structural Geology, PMA=Permian Magmatic Acitivity, AG=Alpine Geology, GL=Glaciology, MI=Mining, PM= Peculiar morphology	OTHER INTEREST (SE=Science Education; E=Environmental A=archaeological; H=historical;N=naturalistic)	CONSERVATION ISSUE	HOW TO REACH THIS SITE	Dimensioni (m, dam, hm, km)	SITE INFRASTRUCTURES (ib= illustrative board; dp= display panel; pt= panoramic table; t= trail; ts= trail track; bl= bicycle lane)	SUPPORT MATERIAL (QR= QR code, GPS= GPS track, VR, ap= apps, mmt= multimedia track, web= web site, bg= book guide, pl= paper leaflet, mg= map guide; info)	SUPPORT STRUCTURES (vc= visitor centre, tl= thematic lab, m= museum, lo= landscape observatory, mh= mountain hut, af= accomodation facilities)	SUPPORT INITIATIVES (ep= educational program, sgt= self guided tour, ggt= geotourism guided tour)	LINK	GEOLOGICAL UNIT
	1				To be developed	ALAGNA	Alagna manganese mine			Feglierec, Otro, Alagna Va	45°50'46"N	7°55'35"N	45,846058	7,926491		R						t		m		www.alagna.it/estate/trekking-e-passeggiate/le-miniere-di-manganese/	Ocb
	2				Museum	Ecomuseum	ALAGNA	Walser Ecomuseum	Walser Museum																			
19	3					ANICETI – VARALLO	Mafic Complex	Intrusive igneous structures in the heart of the Mafico Complex: fine-grained porphyritic gabbro with plagioclase phenocrists.		Aniceti, Varallo, VC	45°49'28"N	8°14'52"N	45,824444	8,247778	476 m slm	I	G; P; SG	N;SE;E	NO			dp	bg		ep, sgt, ggt		IVMd
	4				To be developed	ARA "Giardino delle Grotte"	Basin of Dolomite rocks with the presence of karst caves			Ara, Grignasco, Parco naturale Monte Fenera, NO	45°41'46"N	8°19'42"N	45,696111	8,328333	415 m slm	R						t, ts	mg, info	vc, m	ep, sgt, ggt	www.piemonteparchi.it/cms/index.php/parchi-piemontesi/item/1006-grotte-di-ara-giardino-minerale	SA1
16	5					BALMUCCIA	The outcrop of Balmuccia peridotites	of the surface coat, in an excellent state of conservation. Massive, inhomogeneous body, of about 4 kmq of surface		Balmuccia, Varallo, VC	45°49'12"N	8°9'9"N	45,82	8,1525	555 m s.l.m.	I	G; P; SG	N; SE; E	NO		4000000 mq	t,dp	bg		ep, sgt, ggt	www.supervulcano.it/itinerari/76-balmuccia-e-dinelli	IVMp
	6				To be developed	BALMUCCIA	Geomorphological evidence	Geomorphological evidence of the reactivation of the Line insubrica del Canavese: fault scarp that cuts i river terraces of the Sermenza torrent and the riverbed of the Sesia river		Balmuccia, Varallo, VC	45°49'20"N	8°8'7"N	45,822222	8,135278	circa 580 m.s.l.m.	R					Area 1.810.000 mq; lu	bl, t, dp	mg, bg		ep, sgt, ggt		ZC4
	7				To be developed	BALMUCCIA – VOCCA (beneath Cima Lavaggio)	Contacts between peridotites and mafic complex			Balmuccia, Varallo, VC						I											
5	8					BED OF THE SAN BERNARDINO RIVER	Large reef with exposed the "Scisti dei Laghi"	Large reef with exposed the "Scisti dei Laghi", with a typical round-shaped morphology, due to the glacial abrasion (roches moutonnées)		San Bernardino Verbano,	45° 57' 22.52"	8° 31' 36.14" E	45,9562556	8,526705555	248 m slm	N	G; MP; GM;SG	N; SE; E	YES						ggt		LAM
	9				To be developed	BETTOLE	Limestone quarry	limestone quarry built to produce lime for contruction industries: the Antoniotti quarry		Borgosesia, VC						R											
	10				Religious Site	BOCA	Sanctuary of the Holy cross	Seventeen Century Sanctuary																				
20	11					BOCCIOLARO	Mixed diorite and mafic en	mixed diorite and mafic enclaves that emerge between Gabbro principal and "Dioriti"		Bocciolaro, Cravigliana, V	45°51'11"N	8°14'17"N	45,853055	8,238056	570 m slm	I	G; P; SG	N;SE;E	NO			dp	bg		ep, sgt, ggt		IVMd
32	12					BOCCIOLETO	Tower, shaped by glaciers and erosive water	Characteristic tower, shaped by glaciers and erosive water, immersed in a chestnut grove		BOCCIOLETO, VC	45°50'1"N	8°6'11"N	45,833611	8,103056	1060 m slm	R	PM; SG	N;H;E	NO		"Si alza per 75 m da un	t, ts, dp	GPS, mg, bg			www.comune.boccioleto.vc.it/It-it/vivere-il-comune/cosa-vedere/torre-delle-gavine	SLE
	13				To be developed	BOCCORIO	grey-green paragneiss	grey-green paragneiss								R											
	14		Castle-Fortifi	Museum	Religious Site	BORGOSESIA	Sant' Anna Shire	Museum of archeology	Castle-Fortifications-Montrigone																			
8	15				Geosite	CADORNA ROAD	Linear geosite situated around Mount Bavarione	Linear geosite situated around Mount Bavarione, unit where there are exposed all types of rocks of Zona Strona – Ceneri. It was also a system of fortifications during World War		Aurano, VB	From 46° 02'26.7	From 8°34'58.31	45,0407722	8,58091944	1357 m slm; 1505	I	G;SG;P;GM	N;SE;E	NO		Area 750.406 mq (Mor	t, dp, ts	bl, mg, web, mmt, app	vc, lo	sgt	www.regione.piemonte.it/retescursionistica/cms/index.php/archivio/278-la-linea-cadorna-nellalto-verbano	LAO
6	16				Geosite	CADORNA ROAD (OSPEDALETTO	The Lepynite - amphobolite	The amphobolite Group								R	GM;G;P	N;SE;E	NO								
	17				To be developed	CADORNA ROAD	M. Vadà	Augengneiss																				
	18				Ecomuseum	To be developed	CAMPELLO MONTI	Nichel quarry	Walser ecomuseum																			
	19				Museum	To be developed	CAMPERTOGNO	Terraces	Collection of Sacred art																			SLE
	20		Castles - Fortifications		Religious Site	Stones and Mines Heritage	CANNOBBIO	Orrido	Sant' Anna Church	Original centre of the town																		
2	21					CANDOGLIA	Marble quarry	for the Milan Cathedral, (the Venerable factory of the Milan Cathedral was born in 1387). Characteristic pink color		Mergozzo, VB	45°58'55"N	8°25'55"N	45,981911	8,431911	577 m slm	I	P,CH,H		YES			t	pl	m	ggt	www.parcovalgrande	IVKk
	22				Castles - Fortifications	Religious Site	CANNERO	Carmine Superiore Church	Castles of Cannero																			
	23					Museum	CARCOFORO	Natural History Museum																				
13	24					Castles - Fortifications	CASTLE OF VOGOGNA	Milonites on the Insubric L	Castle of Vogogna	Vogogna, VB	46°0'29"N	8°17'45"N	46,008108	8,295722	256 m slm	I	AG; P; SG	N;SE;E	NO			t, ts, dp		m	ep, sgt	www.parcovalgrande	IVKa
1	25					CHURCH OF ALBO	Kinzigiti	outcrop (schistose metamorphic rocks of the Ivrea area Verbano or "Dioritic-kinzigitic formation ivrea Verbano")		Mergozzo, VB - fraz. Albo	45°58'44"N	8°25'10"N	45,9788	8,419339	231 m s.l.m.	I	G; P; SG	N;SE;E	NO						ggt	www.visitossola.it/poi/chiesa-dellannunciazione/	IVKr
30	26					CIMALEGNA	high mountain geological-pedological track.	Glacial plateau shaped by glaciations and subsequent modeling action of snow and ice. It is located between the Massif Crystalline interior of Monte Rosa and the Piedmontese area of Calcescisti in Pietre Verdi		Alagna Valsesia, VC	45°52'25"N	7°52'33"E	45,873611	7,875833	(2800-3000 m s.l.r	N	GM; AG; P,SG	N;SE;E	NO		Area: 1.000.000 mq; lu	t, ts, dp	mg		ep, sgt, ggt	www.ativalsesiavercelli.it/itinerari_nel_parco_alagna_percorso_geologico_pedologico_di_cimalegna_ita www.areeprotettevallesesia.it	MR1
	27				Museum	CIVIASCO	Museum Durio Da Roc																				
21	28					CREVOLA-VARALLO	Contatto tra il complesso Mafico e le Kinzigiti	best exposures of the contact between the Mafic Complex and the Kinzigite Formation: amphibolite-facies migmatite		Crevola, Varallo, VC	45°48'38"N	8°15'25"E	45,8105556	8,25694444	455 m slm	I	G; P; SG	N; SE; E	NO			dp	bg		ep, sgt, ggt		IVK
	29				To be developed	DINELLI	Bridge- along the Sesia river canyon	bridge located at the Insubrica Line, on the Sesia river, which follows the path of this tectonic line (collision margin between the European and African continental plates)															t, ts, dp	mg			www.caivarallo.it/valsesia/sentieri-valsesia/sentieri-valsesia-dettaglio.php?sentiero=373	ZC4
4	30					FINERO	Complesso mafico-ultramafico di Finero	Peridotite quarry at the northern tip of the Ivrea-Verbano Zone, that consists in an intrusive magmatic sequence of mafic and ultramafic rocks.		Malesco, VB	46°6'31"N	8°33'12"N	46,108661	8,+AE66+Q32:AE32	1002 m slm	I	G; P; SG	N; SE; E	NO			dp			sgt	www.itinerarisenzafrontiere.net/index.php?option=com_content&task=view&id=80&Itemid=34	IVMp
	31				Museum	FOBELLO	Museo della Carestia																				
31	32					FUN D'EKKU* (C)-WOLD	Alpe Fondecco: Glaciological itinerary	Glaciological itinerary within the tectonostratigraphic unit of Monte Rosa, buys between the Meta-Ophiolitics of Antrona and Meta-Ophioltics of Zermatt-Saas		Parco Naturale Alta Valse	45°53'32"N	7°54'20"N	45,892222	7,905556		R	GM; SG	N;SE;E	NO		Area 2.393.322 mq; lungh. 3176 m;	8X dp, t, ts	mg	mh, m	ep, sgt, ggt	www.gulliver.it/itinerario/13554/	MR1, MR3
	33				To be developed	GAMBERARO	Granitic dykes	Granitic dykes inside the kinzigite formation.								N											

26	34					GARGALLO	caldera fill and caldera wall	In the proximity of the town , caldera fill ignibrite contrains stretched shreds of pumice termed fiamme		Province of Vercelli, Municipality Gargallo					526	I	G;P	N; SE;E	NO								
	35				Castels and Fortifications	GATTINARA	San Lorenzo Castle	San Lorenzo in Gattinara, erected in 1187 by the Municipality of Vercelli.																			
	36			Museum	Religious Site	GHIFFA	Sacro Monte WHS	Hat Museum																				
	37				Museum	GUARDABOSONE	Museum of Agriculture-traditional craft-natural history																					
	38				Museum	GURRO	Folk Museum				46°5'6"N	8°33'56"N	46,085047	8,565639							t		m	sgt, ggt			
	39				To be developed	ISOLELLO	kinzigiti contact with the Sesia Lanzo zone									R											
	40				To be developed	LAGO di SANT'AGOSTINO	spill way channel.			Rocca Pietra, Varallo, VC	45°47'0"N	8°16'56"N	45,783364	8,282279	493 m slm	R					lunghezza 300 m; larghezza 50 m, 5 m di profondità massima	t, ts	GPS, mg			www.caivarallo.it/valsesia/sentieri-valsesia/sentieri-valsesia-dettaglio.php?sentiero=24	GLA
	41				To be developed	LOCARNO	Marmo Rosa Locarno quarry			Locarno, Varallo, VC	45°46'43"N	8°13'42"N	45,778646	8,228327		L											IVK
	42				To be developed	MADONNA DELLA NEVE	incisioni rupestri sulle kinzigiti di Madonna della Neve									L											
	43			Museum	Ecomuseum	MALESCO	Soap Stone and Stonecutters	Natural Park Museum																			
	44			Ecomuseum	To be developed	MERGOZZO	Variety of granites	Variety of granites: Gray granite; Montorfano white granite; Green granite from Mergozzo. In addition, granodioritic varieties belonging to the Graniti dei Laghi Unit		Mergozzo, VB					intorno ai 400 m slm	N					t, dp	mg	m	sgt, ggt	www.ecomuseograniitomontorfano.it/	IVKk
	45				To be developed	MONTE FENERA (areale)	carbonate, metamorphic and volcanic rocks	Pseudo relief rounded: the only sedimentary complex of such significant size in Valsesia, carbonate, metamorphic and volcanic rocks		Parco Naturale Monte Fenera, Borgosesia VC	45° 71' 9.55'' N	8° 31.16' 9.49'' E			899 m s.l.m.	N				3378 ettari (33.78 kmq); Perimetro: 3977,6 m; diametro: 1254,72 m	Xt ts, bl, dp	mg	m, tl	ep, sgt, ggt	www.piemonteparchi.it/cms/index.php/parchi-piemontesi/item/1007-le-grotte-del-monte-fenera	SA2
	46				To be developed	MONTE FENERA CAVES	Natural caves in the western granite wall of the mountain	Natural caves in the western granite wall of the mountain, result of the morphogenetic action of water (hypogean forms of karst). They also present paleontological and archaeological finds		Parco Naturale Monte Fenera, Borgosesia VC	45°42'37"N	8°18'49"N	45,710367	8,313586	tra 650 e 770 m slm	I				Variano per ogni grotta	t, ts, dp	mg	m	ep, ggt	www.piemonteparchi.it/cms/index.php/parchi-piemontesi/item/1007-le-grotte-del-monte-fenera	SA2
28	47				Geosite	MONTE ROSA GOLD MINES	San Maurizio golden quarr	Gold mine at the foot of Monte Rosa: gold deposited during the Quaternary		Parco naturale Alta Valse	45°50'57"N	7°56'51"N	45,849167	7,9475	different elevatio	I	MI;SG	H,E	YES	20 kmq	t, dp	GPS, pl	m	ggt		MR1
27	48				Geosite	MONTE ROSA massif and its glaciers	Ghiacciaio delle Piode	Valley glacier along the south-east slope of the Monte Rosa Massif, which has great geomorphological interest (moraines and other forms of glacial and periglacial modeling)		Alagna, VC	45°54'45"N	7°52'58"N	45,912375	7,882834	2476-3800 m s.l.r	N	GL;GM;SG	N;SE;E	YES	Area: 1,73 kmq; lungh.	t, ts, dp	mg	mh, m	ep, sgt, ggt	www.rifugiimonterosa.it/it/web/le-salite	MR3
	49				To be developed	MT. CAPIO	Miniere di Campello Monti al monte Capio									R											
	50				To be developed	NIBBIO	Anfibioliti dei Corni del Nibbio									N											
	51	Religious Site	Museum	Stones and Mines Heritage	To be developed	ORNAVASSO	Pink Marble mines	Commissioned in 1985 by the will of some partisans of the Division Valtoce. Parish Museum of Sacred Art, which collects works of art placed first in the churches of the district	"Madonna del Boden" Sactuary		45°57'46"N	8°23'15"N	45,962711	8,387637		R										IVKk
	52				To be developed	OSPEDALETTO	Orthogneiss									N											
	53				To be developed	PIAN D'ARLA	scisti di pian d'arla			Aurano, VB						I					dp			sgt			
25	54				Geosite	PIANCONE	paragneiss included in gabb	paragneiss included in gabbroic rock: paragneiss layers, where norites, quartz-norites and charnockites are abundant and interlayered with paragneiss and amphibole gabbro		Trivero, VC	45°42'01"N	8°8'20"E	45,7002778	8,13888888	600 m slm	I	G;P;SG	N; SE; E	NO			bg				IVMg
	55				To be developed	PIEVE VERGONTE	Miniera d'oro di Val Toppa									R						t		m	ggt			
	56				To be developed	PIODE-PIETRE GROSSE	huge blocks of landslide.									L											
	57				To be developed	PIODE-MOLLIA-RASSA	orthogenesis and metagranites with large feldspars									L								m			SLE
12	58				Geosite	POGALLO VALLEY (lineare)-MYLONITES OF THE POGALLO LINE	Alpine valley formed by the river Pogallo	Alpine valley formed by the river Pogallo and tributaries rainage basin, result of the collision between Eurasian and Affrican plates paleomargins, occurred in the Cretaceous period		Cossogno, Miazzina, Valle	45°59'22.1"N	8°3	46,0247889	8,49313055	789 m slm	I	G; SG; P	N;SE;E	NO	Area 35.218.397 mq; L	t, ts, dp	mg	af, vc	sgt	www.in-valgrande.it/Val-Pogallo.html	LAO, SCG
9	59				Geosite	PONTE CASLETTO	Cenerigneiss di Ponte Casle	Roman bridge made up of Cenerigneiss, as a connection point between Verbania and the Val Grande.		San Bernardino verbano,	45°59'34"N	8°29'5"N	45,992778	8,484725	Tra i 420 e i 430 m	I	G; P; SG	N;SE;E	NO	943,9 mq; lungh. 20 m	t, ts	mg		ggt	https://www.in-valgrande.it/casletto-piana/Ponte-Casletto-In-la-Piana.htm	SCGs
7	60				Geosite	PONTE NIVIA	Banded amphibolites of the SCBZ	Ba+AE17+K62		Intragna, VB	45° 59' 22.77'' N	8° 34' 08.33'' E	45,9896583	8,56898055	474 m slm	I	G; P; SG	N; SE,E;A			t, ts			ggt		LAM
	61				To be developed	PIODE-MOLLIA-RASSA	canyon inside the diorite formation and well preserved diorite outcrop																					
24	62				Geosite	PRATO SESIA	Supervulcano Caldera	megabreccia outcrops riolite blocks, formed during the collapse of the caldera in which they are found. Different types of large rocks blocks		Prato Sesia, NO	45°39'31"N	8°21'32"N	45,658611	8,358889	290 m slm	I	G; P; SG	N;SE;E	NO		t, dp	bg, info		ep, sgt, ggt	http://www.supervulcano.it/itinerari/75-prato-sesia.html	POQ
	63				Museum	PRAY	"Fabbrica della Ruota"																				
3	64				Geosite	PREMOSELLO	outcrop of rocks	and rased on the surface thanks to tectonics and orogenesis; different lithologies. This is the contact between rocks of the continental crust and mantle rocks		Premosello-Chiovenda, V	46°0'19"N	8°19'17"N	46,005386	8,321492	circa 238 m slm co	I	G; P; SG	N;SE;E	NO	"Il sentiero ha una lun	t, dp	mg	vc	ep, sgt	parcovalgrande.it	IVKa
14	65				Geosite	PREMOSELLO – VOGOGNA (BETWEEN)	fossil earthquakes	fossil earthquakes: crushing product and friction, which induces fusion, along a fault surface during seismic events		Tra i comuni di Premosell	46°0'19"N	8°18'42"N	46,005378	8,311792	230 m slm.	I	G; P; SG	N;SE;E	NO	faglia da 4 a 5 km di pr	t, dp	mg		ep, sgt	parcovalgrande.it	IVKa
	66				To be developed	RASSA	Alpe Massucco white marble quarry.				45°45'3"N	7°58'42"N	45,750952	7,978324		L					dp			sgt			SLE
	67				Museum	RIMA	Gypsoteca																				
	68			Museum	To be developed	RIMELLA	outcrops of mylonites of the insubric line.	Ethnographic Walser museum								I										
	69			Museum	To be developed	RIMELLA	Soap stone quarry	Ethnographic museum								L										
	70				To be developed	RIVA VALDOBBIA	Outcrops of the second dioritic kinzigitic zone									L											
11	71				Geosite	ROAD PONTE SPOCCIA – SPOCCIA	Schists and paragneiss outc	Schists and paragneiss outcrop with subvertical foliation intruder from Permian mafia dams, along the CMB Line		Spoccia, VB	46°05'22.94"N	8°35'40.98"E	46,0897056	8,59471666	522 m slm	I	G; P; SG	N;SE;E	NO			pl		sgt		LAM
	72				Museum	ROASIO	Museo of the immigrants																				
	73				Museum	ROMAGNANO	Historical Museum of Ethnography																				
	74			Castels-Fortifications	To be developed	ROCCAPIETRA	White Granites and CMB Line.		Medieval Castle	Agnona, VC						N										
	75				To be developed	SAN BONOMIO	granite whic intruded the volcanic rocks.									N											
	76				Museum	SANTA MARIA MAGGIORE	Rossetti Valentini Museum)																				

15	77				Geosite	SCOPETTA - old bridge over the Sesia river	Mylonites of the insubric line	mylonites of the insubric line under an old bridge over the Sesia river.		Scopetta, Scopa, VC	45°48'25"N	8°7'26"E	45,069444	8,12388888	596 m slm	I	G; P; SG	N;SE;E	NO			dp	bg		ep, sgt, ggt		ZC4
	78				To be developed	SCOPELLO	(N): metamorphic rocks rich in glaucofane in Blueschist-eclogitic facies.		rich in glaucofane in Blueschist-eclogitic facies.							N											
	79				Museum	SERRA VALLE SESIA		Museum of history of art																				
10	80				Geosite	SPOCCIA – ORASSO	Contatto tra la linea CMB e intrusione mafica	mylonites of the CMB line with Appinitic dykes: schistose rocks of CMB Line intruded by thin mafic dykes		Cavaglio Spoccia, VB	46°06'00.97"N	8°36'18.93"E	46,1002694	8,60525833	896 m slm	I	SG; PMA; P	N;SE;E	NO				pl		sgt		LAM
29	81				Geosite	STOFFUL	Serpentinite with Talc (Soapstone)	Mountain area of the Austroalpine Unit Sesia-Lanzo in part. dioritic-kinzingitic zone. Important presence of quarries for the extraction of Serpentinite with Talc (Soapstone)		Alagna Valsesia, VC	45°52'7"N	7°55'3"N	45,868611	7,9175	Da 1734 m s.l.m. a	R	AG;CH;P;SG	N;H;E	NO		Area: 134.582,72 mq;	t, ts	GPS, mg, pl	af		http://www.caivarallo.it/valsesia/sentieri-valsesia/sentieri-valsesia-dettaglio.php?sentiero=115	ZS1
	82				To be developed	STOLEMBERG	Monte Stolemberg			Alagna Valsesia, VC	45°52'47"N	7°51'57"N	45,879722	7,865833		N											
23	83				Geosite	Under the bridge of AGNONA		Mining of mafic and acidic rocks boundary of lower and upper crust		Borgosesia, VC	45°43'25"N	8°15'44"N	45,723611	8,262222	368 m slm	I	G; P; SG	N; SE; E	NO			dp	bg		ep, sgt, ggt	www.evvivaborgosesia.it/borgosesia_cultura/it-ponte-di-agnona.html	GLA
33	84				Geosite	UNIPIANO	Varallo: paleo-valleybottom during the last glaciation.	Glacial terrace wreck with dioritic cover, raised above the valley floor, in the presence of a religious building "Sanctuary of the Madonna of the Unipiano".		Valmaggia, Varallo, VC	45°49'21"N	8°13'53"E	45,8225	8,231389	603 m s.l.m. circa	R	GM; SG	N;E	NO		Area: ca 70.000 mq - 0	t, ts	GPS, mg, bg			https://www.gulliver.it/itinerario/70674	IVMd
	85				To be developed	VAL D' OTRO	one of the most beautiful hanging valley from last glaciation.									not defined											
	86				To be developed	VAL LOANA	Limestones of the Canavese Zone.			Malesco VC						L						dp	pl	m	ep, sgt, ggt		
	87				To be developed	VAL LOANA (lago del Marmo)	Marble of the Ivrea-Verbano Zone.									R							pl		ep, sgt, ggt		
	88				To be developed	VAL LOANA (near "Le cascine")	Talc-bearing serpentinites "pietra ollare".									L							pl		ep, sgt, ggt		
	89			Museum	To be developed	VAL STRONA DI STRONA	Roof of the Mafic Complex.	Museum of Sacred Art								R											GLA
	90				Ecomuseum	VAL TOPPA	Gold mines	Mining area with historical buildings transformed in a museum which shows how the mining shaped the landscape																			
	91			Ecomuseum	To be developed	VALDUGGIA	Scisti dei Laghi as important metamorphic unit		Show the prevailing farming culture of this area. The "Taragn",a thatched roof structure, is the most representative.							R								m			LAO
	92				To be developed	VALLE MOSSO	lower contact of Valle Mosso granite intruded by mafic dykes.									N											
22	93				Geosite	VALSESSERA- LA FRERA	Recrystallized and foliate gabbro of the lower mafic complex,	the lower mafic complex, characterized by normal transverse faults		Trivero, VC	45°41'22"N	8°7'30"E	45,3561111	8,125	702 m slm	R	G; P; SG	N;SE;E	NO				bg				IVMa
	94				To be developed	VARALLO – CILIMO	cava di oficalce				45°49'24"N	8°15'27"N	45,823394	8,257611		R											IVK
	95				To be developed	VARALLO – CIVIASCO	marble and para-schyst	Marble and para-schyst in the kinzigite formation.			45°49'24"N	8°15'27"N	45,823394	8,257611		R											IVK
	96		Religious Site	Museum	To be developed	VARALLO (Sacro Monte)	Paleoglacial valley	It is the oldest of the italian sacred mountains,WHS- Located in a paleovalley including also a museum	Natural History Museum	Varallo, VC	45°49'5"N	8°15'20"N	45,818067	8,255596		R											IVk
	97			Museum	Religious Site	VERBANIA PALLANZA	San Remigio Church	Large collection of paintings	Landscape Museum																			
	98				Religious Site	VERBANIA Motto d' Unchio	Motto d' Unchio	Small oratory dedicated to the Virgin of the Cross																			
18	99				Geosite	VOCCA near the bridge on the Gavala stream	one of the various layers of paragneiss intercalated in the gabbro of the Basic Complex.	one of the various layers of paragneiss intercalated in the gabbro of the Basic Complex. about 50 meters over under bridge an abandoned nickel mine which was active until the Second World War		Balmuccia, Varallo, VC	45°49'32"N	8°9'55"N	45,825545	8,165273	556 m slm	I	G; P; SG	N;SE;E	NO			t, dp	bg		ep, sgt, ggt		IVMg
17	100				Geosite	VOCCA Near the village of Isola	A large outcrop of well-folied gabbros with isoclinal folds and boudinage of ultramafic	A large outcrop of well-folied gabbros with isoclinal folds and boudinage of ultramafic heaps, common at this depth in the Mafico		Balmuccia, Varallo, VC	45°49'35"N	8°10'14"N	45,826387	8,1705	536 m slm	I	G; P; SG	N;SE;E	NO			t, dp	bg		ep, sgt, ggt		IVMg
	101				To be developed	VOCCA-VALMAGGIA	Miniere abbandonate di Nichel a Vocca			Valmaggia, Varallo, VC	45°49'22"N	8°10'18"N	45,822778	8,171667		R											
	102				Castels-Fortifications	VOGOGNA	Castle of Cannero	Ruins of a fortress																			
																	22 G; 27 P; 30 SG, 1 MP, 7 GM, 2 CH, 1 H, 1 MP, 1PMA , 3 AG, 1 GL, 1 MI, 1 PM	28 SE; 32 E; 1A;3 H, 31N	4 YES						

COLOUR EXPLANATION	
	Geological sites within the proposed Geopark,
	Geosites preparation at present or for future development
	Stones and Mines Heritage
	Museums
	Religious sites
	Ecomuseum
	Castels-Fortifications

Annex 3

	NAME GEOSITE LOCALITY	DESCRIPTION	RANK			USE			Protection status					Availability limitations	Threatened		Other information			Facilities info from geosite MG decided in 2010 and sent to UNESCO as final										In also in the dossie	Source of info
			Internationa	National	Regional	Education	Geotourism	Science	Nature Protectio	Cultural Protectio	LNF area	Agreement with Landowne	No protection	Private property	Safety	Yes	No	Viewpoint	Historical interes	Archaeological intere	Prior arrangement	Accomodation	Rooms to let	Meals	Simple meal	Shop	Exhibition	Conducted Tours by arrangem	Activities by arrangemen	Marked path	Access for disabl	Handicap toilet	
1	Gloppedalsura	one of the largest rock falls in Europ	x			x	x							x			x														YES	Application dossier (42) WEBPAGE
2	Vinjakula	Highest peak in Magma Geopark									x			x													x		x			NO	WEBPAGE
3	Storrsheia	Prehistorical iron age settlement								x				x						x							x		x			NO	
4	Austdalen	Geological interest (Ra moraine)									x				x							x						x		x			NO	WEBPAGE and long geological description application
5	Ørsdalen-Gudlen	Hidrotermal quartz -citrine vein in gneiss			x		x							x		x				x						x	x		x			YES	Application dossier(1) Ørsdalen WEBPAGE
6	Ystebrød/Hagavatnet	Moonlike landscape									x			x					x								x		x			YES	Application dossier- Ystebrød- webpage
7	Salbjørgnipa	Remains from iron age								x	x			x						x							x		x			NO	WEBPAGE and leaflet
8	Odlanshøle	Geological interest									x			x													x		x			NO	WEBPAGE
9	Stoplesteinan-Saint Olav	Stone cycle from iron age		x			x				x			x			x		x								x	x	x			YES	WEBPAGE
10	Åsen -Ravnafjellet	House from 1740								x				x					x		x						x		x			NO	WEB PAGE
11	Tørland klopp	Old Stone bridge								x				x					x								x					NO	WEBPAGE
12	Vestlandske hovedvei	Old main road, anorthosite			x	x	x			x				x			x		x								x		x			YES	Application dossier (12) WEBPAGE
13	St. Olavsomen	Large esker	x			x	x		x					x			x										x		x			YES	Application dossier (45)
14	Storeknuten	Geological influx			x	x	x	x			x			x		x		x									x		x			YES	Application dossier (16) WEBPAGE
15	Hillforts	Defended archeological settlement								x				x						x							x					NO	WEBPAGE
16	Jonsokknuten- Mysinghåla	WW2 site and layered intrusion			x	x	x				x	x		x		x		x	x								x		x			YES	Application dossier (17) WEBPAGE
17	Mong and others	Basaltic dykes									x			x													x		x			NO	WEBPAGE
18	Løtoft	Layered intrusion									x			x					x								x		x			NO	WEBPAGE
19	Hesten Tagholt	Ancient ancient mine			x		x				x			x			x		x								x		x			YES	Application dossier (46) WEBPAGE
20	Rail road -Heilvik	den Gamle Jærbanen railroad			x	x	x			x		x		x			x	x	x													YES	Application dossier (11) WEBPAGE
21	Dalane Folkemuseum	Museum		x		x		x		x							x		x	x					x		x				x	YES	Application dossier -Non geological sites 15- WEBPAGE
22	Trollpikken	Geological phenomena									x			x													x		x			NO	WEBPAGE
23	Gullbergtuva	Regional geology centre of intrusion			x	x	x				x			x		x		x									x		x		x	YES	Application dossier (21) WEBPAGE
24	Egersy Fyr	Lighthouse				x	x	x	x	x	x	x		x		x		x	x								x		x	x	x	YES	Application dossier (5) WEBPAGE
25	Egersund	Old wooden house, viking town		x		x	x			x				x			x		x	x	x	x	x	x	x	x	x		x	x	x	YES	Application dossier (19 non geological table) WEBPAGE
26	Auglend	Old settlment in Eigersy			x	x	x	x	x					x			x	x	x	x							x		x			YES	Application dossier (9) WEBPAGE
27	Koldal-Ankerhus	Layered intrusion		x		x		x			x			x		x											x		x			YES	Application dossier (22) WEBPAGE
28	Gaudland	Anorthosite			x	x	x				x			x			x		x	x	x						x		x			YES	Application dossier (24) WEBPAGE
29	Glerhaug	Moonlike landscape			x	x	x				x			x			x	x	x	x	x						x		x			YES	Application dossier (20)
30	Gursli-Ulland mines	WW1 mines		x		x	x				x	x		x			x		x								x	x	x			YES	Application dossier (26) WEBPAGE
31	Lund bygdemuseum og kultur	Historical museum								x				x					x							x	x			x		NO	WEBPAGE
32	Syngjarstein	Singing rock			x	x	x				x			x		x			x	x									x			YES	Application dossier (55) WEBPAGE
33	Trønasen Bakke bru-Bringedal	Norway oldest suspension bridge			x		x			x	x			x			x		x								x	x	x			YES	Application dossier (5) Non geological site WEBPAGE
34	Kjørsfjell	Regional geology							x					x																		NO	WEBPAGE
35	Jibbeheia	system of granitic dikes									x			x			x	x									x		x			YES	Application (6) WEBPAGE
36	Rossland	Viking site and good like rock figure		x		x	x			x	x			x		x			x	x							x		x			YES	Application (56) WEBPAGE
37	Blåfjell mines and Ruggestein	Old titanium mines - rocking stone	x			x	x		x		x	x		x			x(Blåfjell	x(Ruggesteinen)									x		x			YES	Application (28-51) WEBPAGE
38	Sogndalstrand	Old harbour town		x		x	x			x				x			x		x		x	x	x	x	x	x	x	x		x	x	YES	Application (18) non geological sites WEBPAGE
39	Jøssingfjord and Hellerøen	viewpoint, outdoor activities, old ho	x			x	x				x						x		x	x							x	x	x	x		YES	Application (13) and WEBPAGE
40	Hellersheia	Fjord -anorthosite									x			x													x		x		x	NO	WEBPAGE
41	Tellnes	Open pit mining site	x			x	x	x						x			x		x								x					YES	Application (34)
42	Brufjell cave	potholes and caves							x					x													x		x			YES	Application (43) and WEBPAGE
43	Gården Li-Li farm	Regional geology- outdoor activities							x					x							x	x					x		x			NO	WEBPAGE
44	Kirkehamn-Hidra feldspar	Viking age and fortress		x			x							x			x	x														YES	Application (25)Non geological heritage
45	Flekkefjord line	Old railway draisine biking		x		x	x			x				x			x		x								x		x			YES	Application (4) WEBPAGE
46	Flekkefjord	Old wooden houses		x		x		x		x				x	x		x		x	x	x	x	x	x	x	x	x	x	x	x	x	YES	Application (20) WEBPAGE
Total			5	11	24	23	25	7	7	16	27	5	0	2	10	20	11	27	8	8	8	4	3	4	3	6	41	8	38	6	6	29	

Legend
Geology
Culture
Geology and Culture
Localities from Application

WEBPAGE: WWW.MAGMAGEOPARK.COM

Annex 4

Map of the geosite

Information inventory sheet			
Compiler	Sara Gentilini - Marco Giardino - Pål Thjømøe		
Authority compiler	Magma Geopark		
Cataloguer			
Authority catologuer			
Data of compilation	03-04-2019		
Data acquisition	Survey	Bibliography	
Disclosable	Yes	No	Partially

Information Geosite	
Geosite code within the UGGp	24
Name	Eigeroy fyr /lighthouse
Description	Anorthosite landscape and historical lighthouse

Geosite dimension

Area (mq)	working on google earth
Lenght (m)	
Height (m)	
Thickness (m)	

In this case the geosite dimension is overlapping the buffer zone. See definition in “methodology” sheet attached.

Buffer site dimension	
Area (mq)	
Lenght (m)	
Height (m)	
Thickness (m)	

Scientific information									
First scientific interest*									
Geomorphologic	Geological (1)	Geomining	Hydrogeological	Paleontological	Pedological	Petrographic (2)	Mineralogical (3)	Stratigraphic	Cultural geology

Level of scientific interest	High
Notes about scientific interest	First level of interest is **geological.** Second level is p**etrographic** Third level is **mineralogical** The Eigeroy geosite is located in an area characterized by prevaling anorthosite unit: the rock is an anorthosite with orthopyroxene megacrystals, associated with brecciated anorthosite. Tis unit is part of the Egersund-Ogna anorthosite complex which represents the products of magma cooled slowly in a huge chamber at app 20 km below the surface of the earth about 930 million years ago. Anorthosite is the rock characterizing the Magma Geopark area. The point on the map are overlapping the point detected by the Geopark within the “Eigerøy itinerary” which is available as a leaflet, APP and virtual reality. The geosite is made of 8 “stops” detected following “geological scientific importance” and included into the minimum size rectangular of inclusion which overlap the buffer zone. STOP 1 Stop at top of small hill after going through gate Anorthosite. The rock type here is anorthosite. Rocks are made of minerals. Anorthosite is an unusual rock type in that it consists dominantly of a single mineral called plagioclase. On fresh surfaces the anorthosite has a greyish colour. On weathered surfaces the colour changes to pinkish-grey. Here it is clear that the weathered surface forms a skin that is a few millimeters thick. Sub-circular patches of pale green lichen develop on many of the weathered surfaces. The pinkish-grey colour of most of the rocks that you can see from here is therefore only “deep skin”. STOP 2 Just after gate No 3. Exposure ca. 3 m to

left of road. Stops 2, 3 and 4 are between gates No. 3 and 4.
Here there is a contact between anorthosite and a very coarse grained rock. The coarse grained rock occurs as veins and dykes that cut across the anorthosite. Three minerals can readily be identified in the coarse grained rock: grey plagioclase, dark brown to black orthopyroxene (both up to several cm across) and smaller grains of black, metallic ilmenite. The large crystals are in a matrix of smaller plagioclases. A rock that consists mainly of the minerals plagioclase and orthopyroxene is called norite (named after Norway by Esmark in 1823 based on observations along the Rogaland coast). Rocks that are very coarse grained are called pegmatites. So this rock is an ilmenite norite pegmatite. Only one contact of the dyke is visible; the other contact is hidden beneath the grass or road.

STOP 3

Outcrop to left of road near top of hill.
To the left of the road there are several 1-3 m wide dykes of norite pegmatite. Contacts between the very coarse grained norite and finer grained anorthosite are exposed in several places. When the magma from which the norite crystallized was injected into the anorthosite, the latter must have been solid and able to fracture. The very coarse grained nature of the norite implies that the magma cooled very slowly so that the crystals had time to grow to a large size. This in turn implies that the host anorthosite was still very hot.
The broad dyke here can be followed into outcrops to the north-east (across the road) where it gradually thins out, and to the west (parallel with the road) where it can be followed for ~50 m. A branch of the dyke is obvious in outcrops on the northern side of the road.

The dyke continues across the road; it can be followed for several 100 m.

STOP 4

On corner ~100 m before gate No. 4.
Alteration Fresh exposures (formed as a result of blasting when the road was constructed) reveal the nature of alteration of anorthosite. The fresh, greyish anorthosite is cut by thin joints on either side of which it has been altered to a white rock in

a zone a few cm-thick. (see fig. 4). The alteration is clearly related to the joints. The plagioclase has been altered to another mineral (called clinozoisite) whose composition is very similar, but contains some water in its structure. The alteration was caused by reaction between hot water and plagioclase; the water migrated along the joints. This reaction takes place at 200-300°C and water can only reach such high temperatures at high pressure, so this alteration must have taken place several kilometers below the surface when hot water was available, probably many hundreds of millions of years ago. Some of the anorthosite alters to a greenish mineral (called epidote) that contains iron and is produced from orthopyroxene and/or ilmenite. The whitish colour of some outcrops is because the shape of an outcrop is locally controlled by joints, and the joint surfaces have been altered.

Thin joint on either side of which the anorthosite has been altered to a white rock in a 2-3 cm thick zone.

STOP 5
Top of small hill between gates No. 4 and 5.
rock inclusion The outcrop on the left of the road, which can be followed for ~25 m, consists of a new rock type. The rock has a very streaky appearance with light (plagioclase-rich) and dark (orthopyroxene-rich) bands. Towards the top of the outcrop the banding appears to be slightly folded. The outcrop to the right of the road consists of anorthosite. Before construction of the road the soil extended ~1 m above the present base of the outcrop – up to where the outcrop has spots of green lichen. “White anorthosite” along a joint surface has also been exposed as a result of blasting during road building.
The streaky rock (a gneiss) is part of a large fragment of the rocks (known as “country rocks”) into which the anorthosite was intruded. Some 930 million years ago, ~20 km below the surface, a huge magma chamber developed. The chamber grew largely by pushing up its roof, but some fragments of the country rocks occasionally became detached and fell into the magma. Here they sank until they reached the fl oor where anorthosite was crystallizing; they became “included” in the anorthosite. The streaky appearance of the country rock inclusion has been preserved, but the extremely high temperatures (1100-1200°C) to which

it was subjected have resulted in its mineralogy resembling that of the host rocks.

Inclusion of country rock gneiss.

STOP 6 On top of small hill ca. 200 m after gate No. 8.
Breccia: In the outcrops to the right (west) of the road it is evident that the proportion of norite pegmatite has increased considerably. The very coarse grained norite now appears to form the matrix to blocks of anorthosite. The blocks are generally between 1 and 10 m across, and most of them are quite angular. It appears that the norite has been injected into and fragmented the anorthosite. A rock consisting of angular fragments in a matrix of different material is called a breccia. (see fi g. 6).
Noritic magma was intruded into solidifi ed anorthosite in a series of dykes. At the level we see here, the intruding magma had suffi cient pressure to break the anorthosite into angular blocks. Some of the blocks look as if they can be fi tted together, and they all resemble the adjacent host anorthosite, so it is unlikely that they were transported very far by the invading noritic magma. Brecciated anorthosite covers an area of more than 3 km2, so this is not just a local feature in the Egersund-Ogna anorthosite.

STOP 7 At viewpoint ca. 200 m after gate No. 10, near gun site from the Second World War.
The Ice Age The Egersund-Ogna anorthosite, which continues to the south beneath the sea, was formed about 930 million years ago, but the shape of the landscape was largely formed in geologically much more recent times - during the last Ice Age. About 20,000 years ago, Norway was entirely covered by ice. Here the ice sheet was about 2 km thick. The ice sheet spread as huge glaciers and carried rocks of all sizes that it had plucked from the surface underway. Rock fragments at the base of the ice scraped against the outcrops of solid rock as the glacier advanced and produced a series of scratches. These glacial striations on rock outcrops, which are close to horizontal, indicate the direction of movement of the ice sheet. Here this was generally from NE to SW. There are also some characteristic crescent-shaped scratches on some of the outcrop surfaces. These formed when

a large, sharp-edged block carried by the ice caught on the bedrock floor. Pressure built up until the rock failed, giving a crescent-shaped gouge. This process was commonly repeated to give a series of nested cracks.

Crescent-shaped mark. The movement of ice was to the left.

STOP 8

The overall shape of many of the rock outcrops was influenced by the long-lasting effect of the ice movement. Many of the outcrops form elongated ridges that have been “smoothed” by the ice. The ice flowed up over rock outcrops, but commonly “plucked” rock fragments from the other end to produce a characteristic outcrop form that resembles that of a sheep sitting in a field (called “roche moutonnée” which is French for “sheep rock”).
A few kilometers offshore here there is a moraine ridge that extends from Lista in the east to Jæren in the west where it goes ashore. This large end moraine was formed about 14,000 years ago when glaciers from the north were stationary (actually when the rate of movement and melting balanced) for long enough that a significant ridge of moraine material could form. The moraine material consists of a mixture of all particle sizes, from boulders through cobbles, stones, gravel, sand and silt to clay. This mixture is commonly called “boulder clay”.
Looking towards the east and northeast it is notable that, for as far as you can see, all the hilltops are at about the same level. This fairly flat landscape has, of course, many deep valleys that were accentuated during the Ice Ages. This type of landscape feature is called a “peneplain”. The land surface became planed off by long-lasting erosion so that no major hilltops remained. Rogaland has been above sea level, and therefore subject to erosion, for hundreds of millions of years, and this peneplain developed over a very long period of time.
Feel free to make the trip all the way out to the lighthouse, the path has been upgraded with steps and bridges.

Text from:“Eigerøy Fyr” info leafelt.

Contextual information								
Contextual interest								
Cultural	Sports	Educational	Landscape	Geohazard	Climate change	Historical	Speleological	Naturalistic
Notes about contextual interest	Sports like hiking, coasteering and diving are common in this area. From the cultural point of view, the lighthouse is one of the oldest in Norway. The geosite is used for educational activities : rocks are very visible and the site is characterized by good accessibility. The geosite has a good naturalistic interest due to the nesting of several birds, is an official monitoring station. the local Ornithologists Association promoted the area with game and information to get people aware of the birds species which populate the area.							

Characteristic elements								
Litology	Anorthosite and anorthosite with leucoronite , gneiss and dike inclusions							
Chronostratigraphy	Proterozoic							
Era of the process	930 million years							
Land use								
Wood	Cultivated	Terraced	wild	Meadow	Urbanized	Infrastructure	Rocks	Debris
Shape typology	Single	Multiple	Complex	System				
Shape	Point	Line	Areal	Mixed				
Exposure	Natural	Artificial						
Property	Public	Private	Mixed					

Existing legal constraints					
Legislation Level		local	regional	National	International
Included in a protected area		Yes	No	Partially included	
Typology of the protected area	Cultural site	National-Regional Park	SIC	ZPS	Wetland
Category of legislation regulating the area		Landscape planning	Geological	Urban planning	Cultural	Nature
Notes	The area between the car park and the lighthouse is privately owned. However, positive land-owners have kindly given permission for us to use this superb road to the lighthouse. One of their conditions, however, is that dogs are not allowed in the period 15th March to 15th October when there are many grazing animals. Dogs are allowed (on a leash) for the rest of the year.				

	Some points to remember: • Do not frighten the animals • Close the gates after you • Do not leave any rubbish • Keep to the path on your way to the lighthouse • Avoid field trips to the lighthouse during strong wind conditions

Information about the site						
District	Rogaland					
Municipality	Eigeroy					
Locality						
Detail						
Coordinate East	5 51 55 Rectangular vertices					
Coordinate Nord	58.26 30					
Reference	WGS84	UTMED50	Gauss-Boaga	Geographical		
Section or geographical map						
Type	CTR		IGM		Other	
Scale	1:10.000	1:25.000	1:50.000	1:100.000	1:250.000	1:500.000

Cartographic information				
Author	Geological Survey of Norway			
Data of publication	2003			
Title or caption	Geological Map of Rogaland anorthosite province			
Reference	NGU Special Publication 9			
Typology	Topographical	Geologic	Geomorphological	Other

Bibliographic information	
Authors	Richard Wilson - Text: and photos: Dr. J. Richard Wilson, Aarhus University and Pål Thjømøe, Magma Geopark
Year of publication	2008
Title	GEOTUR Geosite guide and Eigeroy tour leaflet
Magazine or book	
Publisher	Magma Geopark
Pages	

Bibliographic information	
Authors	Local Hornitologist Association
Year of publication	
Title	

Magazine or book	
Publisher	http://www.nofdalane.net/?1
Pages	

Iconographic information				
Authors				
Data of publication				
Title or caption				
Reference				
Typology	Printing	Digital	Slide	Other

Diversi stop nel sito- foto

Accessibility information

Plane. From Stavanger
Bus-Train- Stavanger-Eigeroy
Electric bike : from the Egersund centre from july 2019
Car: Accessible through the main National road
The access to the geosite is provided with a parking place, signboards and toilet .
Here you find an explanation panels about the Geopark and the Egeroy trail.

App or the leaflet from the Magma Geopark webpage are available

Information on hazards-natural impacts

The geosite is dangerous in case of rain and wind.
It is exposed along the coast, so it can be waves , storms, lightening

Information on natural vulnerability-human impact

Path is cutting the rocks and the fences modified the nature

Mitigation suggestions

Natural impact - avoid to be there in not favourable weather
Human Impact- the old building can create dangerous situation, it should be removed.

Valorization suggestions

The geosite is 7 km far from the main city centre- Egersund.
Tourist-visitors will get electric bike from July 2019 to reach it from the station.

Evaluation sheet

Scientific evaluation

Integrity	**Evaluate the status of conservation of the site**	
	Poor	0
	Decent	0.33
	Good	0.67
	Excellent	1
Notes	The geosite is in excellent state of integrity	

Rarity	**Evaluate how many times the same geological features appears in the Geopark**	
	More than 5 times	0
	Between 3 and 5	0.33
	Less than 3	0.67
	Unique	1
Notes	Breccia and noritic dike you can find only here.	

Representativeness	**Evaluate how much the site is representative in the Geopark**	
	Low	0
	Medium	0.33
	Good	0.67
	High	1
Notes	The area is characterized by beautiful anorthosite outcrops which has high value of representativeness in the Geopark because this is the most common rock type in the area.	

Other geologic interests	**Evaluate if in there are other than geological interest within the Geopark**	
	Nothing	0
	One element	0.33
	Two elements	0.67
	More than 3 elements	1
Notes	Cultural- historical -war history Natural	

Paleogeographic value	**Evaluate if the geosite has important aspects related with ancient geographical condition**	
	No importance	0
	A bit of importance	0.33
	Important	0.67
	Fundamental	1
Notes	Glacial morphologies (grooves, crescent marks) related with ancient landscape	

Scientific publications	**Evaluate if the geosite is important considering the scientific publications**	
	Noone	0
	Between 1 and 5 national publications	0.25
	Between 1 and 5 international publications	0.50
	More than 5 international publications	0.75
	Internationally famous (stratotype)	1
Notes		

Educational evaluation

Educational value	**Evaluate if the geosite could be useful in a didactic way**	
	Low interest	0
	Difficult interpretation	0.33
	Good interest	0.67
	High interest	1
Notes	App- geoVR connected	

Publications	**Evaluate how many times the geological feature appears in publications**	
	Nobody	0
	At least one	0.33
	Between one and three	0.67
	More than three	1
Notes		

Aesthetic evaluation

Visibility	**Evaluate the visibility of the site**	
	Invisible	0
	Obstructed	0.33
	Good	0.67
	Excellent	1
Notes	The visibility of the geosite is excellent	

Contrast	**Evaluate the chromatic contrast with the environment**	
	No contrast	0
	Little contrast	0.5
	Evident	1
Notes	There is little contrast between the geosite and the landscape around	

Point of view	**Evaluate the number and the distance of the point of views**	
	Only one point	0
	More points but the distance is more than 1000 metres	0.33
	More points but the distance is more than 500 metres	0.67
	More points but the distance is less than 500 metres	1
Notes		

Landscape relevance	**Evaluate if the geosite could be relevant, considering the landscape, in the Geopark**	
	Not relevant	0
	Low relevance	0.33
	Good relevance	0.67
	High relevance	1
Notes		

Obstacles	**Evaluate if in the geosite there is any obstacles or old useless structure, that preventing the right observance of the geosite itself.**	
	Very high impact	0
	High impact	0.33
	Low impact	0.67
	No impact	1
Notes		

Ecological evaluation

Ecological interest	**Evaluate the ecological interest of the site**	
	No interest	0
	Low importance	0.33
	Animals and plants are important in the area	0.67
	There are endemism and nesting sites in the area	1
Notes	The Magma Geopark flower is a protected endemic specie	

Protected area	**Evaluate if the site is in a protected area or it is near the protected area**	
	Not in a protected area	0
	Near a protected area	0.33
	Partially included a protected are	0.67
	Totally inside a protected area	1
Notes	You cannot build anything along the coast - 100 meters belt	

Historical and cultural evaluation

History-Culture	**Evaluate the historical profile of the site**	
	No links	0
	Indirect link	0.5
	Direct link	1
Notes	Direct link with the Lighthouse	

Religion	**Evaluate the links with the religion**	
	No links	0
	Indirect link	0.5
	Direct link	1
Notes		

Art and literature	**Evaluate the links with art, and literature**	
	No links	0
	Indirect links	0.5
	Direct link	1
Notes		

Accessibility evaluation

Access	**Accessibility of the geosite from the main road**	
	Accessibility for mountain bike, enduro or trucks	0
	Not bus and camper	0.33
	Dirt road but accessible cautiously	0.67
	Without limitations	1
Notes	The geosite is accessible only by walk	

Distance by walk	**Evaluate the distance by walk if the geosite is not directly accessible**	
	More than 2000 metres	0
	Between 2000 and 1000 metres	0.33
	Less than 1000 metres	0.67
	Less or equal to 100 metres	1
Notes	From the parking to the geosite	

Difficulty of access	**Evaluate the difficulty of the trail**	
	Specific equipment	0
	Expert excursionist	0.33
	Excursionist	0.67
	Simple	1
Notes		

Difficulty of access by National Outdoor Organization	**Evaluate the difficulty of the site if you reach it by walk**	
	EEA – Expert excursionist with equipment	0
	EE – Expert excursionist	0.33
	E- Excursionist	0.67
	T – Tourist	1
Notes		

Access for disabled	**Evaluate the access for disabled**	
	The site is not accessible for disabled	0
	The site is accessible but the disabled can't enjoy it totally	0.50
	The site is accessible for disabled too	1
Notes	Can be visible through geoVR virtual reality tool	

Food service and overnight	**Evaluate the presence of services**	
	More than 10 km	0
	Between 10 and 5 km	0.33
	Between 5 and 1 km	0.67
	Less than 1 km	1
Notes		

Dangerousness, vulnerability, Human impacts evaluation

Dangerousness	**Evaluate the real and potential dangerousness. Consider lithology, morphology and meteo**	
	Widespread dangerousness	0
	Moderate dangerousness	0.33
	Dangerous only in difficult weather conditions	0.67
	Not dangerous	1
Notes		

Natural vulnerability	**Evaluate the natural vulnerability**	
	Possible lost	0
	Directly vulnerable	0.33
	Indirectly vulnerable	0.67
	Not vulnerable	1
Notes		

Human impacts	**Evaluate the possible human impacts**	
	Possibile lost	0
	Directly vulnerable	0.33
	Indirectly vulnerable	0.67

	Not vulnerable	1
Notes		

On the geosite

Geosystem services		
Regulating	1	Atmospheric and oceanic processes
	2	Earth processes
	3	Flood regulation
	4	Water quality regulation
Supporting	5	Soil processes
	6	Habitat provision The geosite provides habitat for birds and sea animal.
	7	Land and water as platform for human activities This is apparently the most relevant service The geosite provides platform for the lighthouse building and related activities connected with the coastal landscape.
	8	Burial and storage
Provisioning	9	Food and drink
	10	Nutrients and minerals
	11	Fuel
	12	Construction materials
	13	Industrial minerals
	14	Ornamental products The geosite provides with caoline-clay for making the local traditional pottery
	15	Fossils
Cultural	16	Environmental
	17	Geotourism and leisure
	18	Cultural spiritual and historic From the historical point of view: Eigerøy lighthouse was built in 1854 and is the oldest cast iron lighthouse in Norway. It is 32.9

		meters high and has one of the strongest lights in Europe. The lighthouse was automated in 1989. Cultural point of view: The old, local legendary explanation for the norite dykes is that they represent wheel tracks left by a chariot belong to Tor, the god of thunder.
	19	Artistic inspiration The geosite has inspired several local artists
	20	Social development
Knowledge	21	Earth history The geosite is important for the Earth history related with the Egersund-Ogna anorthosite: it represents the products of magma that cooled slowly in a huge chambre 20 km below the surface about 930 million years ago. The geosite is representative for the above describe phenomena.
	22	History of research Harrison Schmitt was born in the United States on July 3, 1935. He went to Oslo University to study geology in the late 50s, and visited Egersund in connection with field studies of the Moon rock Anorthosite. Later he was employed by the Geological Surveys (NGU) for drawing geological maps. Schmitt is the only scientist who has been on The Moon. He was on the Apollo 17 mission. During three days in December 1972, he gathered 110 kg moonstone, including anorthosite. He holds the record for the longest stay on the lunar surface. He collected the samples in Magma Geopark, in the Eigeroy geosite´s neighbouring (see MagmaUGG geosite n6)
	23	Environmental monitoring and forecasting There is a weather-temperature and wind power station inside the lighthouse
	24	Geoforensis
	25	Education and employment The site is well used for educational purpose, is part of the Magma Geopark educational offer and it is included into the APP and virtual reality.

On the geosite

	At present	Potential	Short explanation	Specific targets addressed
1No poverty	0	0		
2 Zero hunger	1	3	By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment. The geosite, with its extensive possibility for local agricultural activities can contribute to increase income from small scale productions and supporting the consume of local food.	2.3
3 Health-Well being	0	0		
4 Education	3	5	By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development. The geosite is actively contributing through several educational activities to support education for sustainable development	4.7

5 Gender	0	0		
6 Sanitation	0	0		
7 Clean Energy	0	0		
8 Work	1	3	By 2020, substantially reduce the proportion of youth not in employment, education or training The geosite offer the possibility for new job within the local tourism industry By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products The geosite is creating new jobs and potentially could create even more.	8.6,8.9
9 Innovation				
10 Inequalities	0	0		
11 Cities	4	5	Strengthen efforts to protect and safeguard the world's cultural and natural heritage The geosite is contributing to safeguard and valorize the local heritage By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities the geosite is accessible for disable and disadvantages people from all over the World through geoVR technologies	11.4 11.7
12 Production	2	4	By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature	12.8

			The geosite is contributing the increase the awareness of local people on sustainability Develop and implement tools to monitor sustainable development impacts for sustainable tourism that creates jobs and promotes local culture and products The geosite within the UGGP is included into the mobile APP and the virtual reality tool available on line. The tool can be useful to monitoring the amount of tourist	12.B
13 Climate action	2	4	Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning The geosite is supporting the education on climate change mitigation through the educational activities related to it.	13.3
14 Life below water	0	0		
15 Life on land	0	0		
16 Peace	0	0		
17 Network	0	0		

Annex 5

Map of the Geosite
Notes

Map of the Geosite area and the buffer zone.

The buffer zone area is defined as the area including processes which influence directly the geosite.
Accessibility visibility

Pictures

Registration sheet

Information inventory sheet			
Compiler			
Authority compiler			
Cataloguer			
Authority cataloguer			
Data of compilation			
Data acquisition	Survey(1)	Bibliography(2)	
Disclosable	Yes	No	Partially

Information Geosite	
Geosite code within the UGGp	
Name	
Description	

Geosite dimension	
Area (mq)	
Lenght (m)	
Height (m)	
Thickness (m)	

Scientific information									
First scientific interest									
Geomorphologic	Geological	Geomining	Idrogeologic	Paleontological	Pedological	Petrographic	Mineralogical	Stratigraphic	Cultural geology
Level of scientific interest									
Notes about scientific interest									

Contextual information								
Contextual interest								
Cultural	Sports	Educational	Landscape	Geohazard	Climate change	Historical	Speleological	Naturalistic
Notes about contextual interest								

Characteristic elements								
Litology								
Chronostratigraphy								
Era of the process								
Land use								
Wood	Cultivated	Terraced	Savage	Meadow	Urbanized	Infrastructure	Rocks	Debris
Shape typology	Single	Multiple	Complex	System				
Shape	Point	Line	Areal	Mixed				
Exposure	Natural	Artificial						
Property	Public	Private	Mixed					

Like Eigerøy

Existing legal bonds					
Legislation Level	Local	Regional	National	International	
Included in a protected area					
Typology of the protected area	National-Regional Park	SIC	ZPS	Wetland	Cultural site
Category of legislation regulating the area	Landscape planning	Geological	Urban planning	Cultural	Nature
Notes					

Information about the site						
District						
Municipality						
Locality						
Detail						
Coordinate East						
Coordinate Nord						
Reference	WGS84		UTMED50		Gauss-Boaga	Geographical
Section or geographical tablet						
Type	CTR		IGM		Other	
Scale	1:10.000	1:25.000	1:50.000	1:100.000	1:250.000	1:500.000

Cartographic information				
Author				
Data of publication				
Title or caption				
Reference				
Typology	Topographical	Geologic	Geomorphological	Other

Bibliographic information	
Authors	
Year of publication	
Title	
Magazine or book	
Publisher	
Pages	

Iconographic information				
Authors				
Data of publication				
Title or caption				
Reference				
Typology	Printing	Digital	Slide	Other

Accessibility information

Information on hazards-natural impacts

Information on natural vulnerability-human impact

Mitigation suggestions

Valorization suggestions

Evaluation sheet

Scientific evaluation

Integrity	**Evaluate the status of conservation of the site**	
	Poor	0
	Decent	0.33
	Good	0.67
	Excellent	1
Notes		

Rarity	**Evaluate how many times the same shape appears in the geopark**	
	More than 5 times	0
	Between 3 and 5	0.33
	Less than 3	0.67
	Unique	1
Notes		

Representativeness	**Evaluate how much the site is representative in the geopark**	
	Low	0
	Medium	0.33
	Good	0.67
	High	1
Notes	From the “cultural geology” point of view the site is high representative	

Other geologic interests	**Evaluate if in the site there are other geologic interests**	
	Nobody	0
	One element	0.33
	Two elements	0.67
	3 elements or more	1
Notes		

Paleogeographical value	**Evaluate if the site has important paleogeographical aspects in the area of study**	
	No importance	0
	A bit of importance	0.33
	Important	0.67
	Fundamental	1
Notes		

Scientific publications	**Evaluate if the site is important considering the scientific publications**	
	Noone	0
	Between 1 and 5 national publications	0.25
	Between 1 and 5 international publications	0.50
	More than 5 international publications	0.75
	Internationally famous (stratotype)	1
Notes		

Educational evaluation

Educational value	**Evaluate if the geosite could be useful in a didactic way**	
	Low interest	0
	Difficult interpretation	0.33
	Good interest	0.67
	High interest	1
Notes		

Publications	**Evaluate how many times the geosite appears in publications**	
	Nobody	0
	At least one	0.33
	Between one and three	0.67
	More than three	1

Notes		

Aesthetic evaluation

Visibility	**Evaluate the visibility of the site**	
	Invisible	0
	Obstructed	0.33
	Good	0.67
	Excellent	1
Notes		

Contrast	**Evaluate the chromatic contrast with the environment**	
	No contrast	0
	Little contrast	0.5
	Evident	1
Notes		

Point of view	**Evaluate the number and the distance of the point of view**	
	Only one point	0
	More points but the distance is more than 1000 metres	0.33
	More points but the distance is more than 500 metres	0.67
	More points but the distance is less than 500 metres	1
Notes		

Landscape relevance	**Evaluate if the site could be relevant, considering the landscape, in the area of study**	
	Not relevant	0
	Low relevance	0.33
	Good relevance	0.67
	High relevance	1
Notes		

Obstacles	**Evaluate if in the site there is an impact created by obstacles, old useless structures…**	
	Very high impact	0
	High impact	0.33
	Low impact	0.67
	No impact	1
Notes		

Ecological evaluation

Ecological interest	**Evaluate the ecological interest of the site**	
	No interest	0
	Low importance	0.33
	Animals and plants are important in the area	0.67
	There are endemism and nesting sites in the area	1
Notes		

Protected area	**Evaluate if the site is in a protected area or it is near the protected area**	
	Not in a protected area	0
	Near a procted area	0.33
	Partially included a protected area	0.67
	Totaly inside a protected area	1
Notes		

Historical and cultural evaluation

History	**Evaluate the historical profile of the site**	
	No links	0
	Indirect link	0.5
	Direct link	1
Notes		

Religion	**Evaluate the links with the religion**	
	No links	0
	Indirect link	0.5
	Direct link	1
Notes		

Art and literature	**Evaluate the links with art, history and literature**	
	No links	0
	Indirect links	0.5
	Direct link	1
Notes		

Accessibility evaluation

Access	**Considering the roads evaluate the accessibility**	
	Accessibility for mountain bike, enduro or trucks	0
	No bus and camper	0.33
	road but accessible cautiously	0.67
	Without limitations	1
Notes		

Distance by walk	**Evaluate the distance by walk if the site is not directly accessible**	
	More than 2000 metres	0
	Between 2000 and 1000 metres	0.33
	Less than 1000 metres	0.67
	Less or equal to 100 metres	1
Notes		

Difficulty of access	**Evaluate the difficulty of the trail**	
	Specific equipment	0
	Expert excursionist	0.33
	Excursionist	0.67
	Simple	1
Notes		

Difficulty of access by the CAI	**Evaluate the difficulty of the site to reach it by walk**	
	EEA – Expert excursionist with equipment	0
	EE – Expert excursionist	0.33
	E- Excursionist	0.67
	T – Tourist	1
Notes		

Access for disabled	**Evaluate the access for disabled**	
	The site is not accessible for disabled	0
	The site is accessible but the disabled can't enjoy it totally	0.50
	The site is accessible for disabled too	1
Notes		

Food service and overnight stays	**Evaluate the presence of extra services**	
	More than 10 km	0
	Between 10 and 5 km	0.33
	Between 5 and 1 km	0.67
	Less than 1 km	1
Notes		

Dangerousness, Vulnerability, Human impacts		

Dangerousness	**Evaluate the real and potential dangerousness. Consider lithology, morphology and meteo**	
	Widespread dangerousness	0
	Moderate dangerousness	0.33
	Dangerous only in difficult weather conditions	0.67
	Not dangerous	1
Notes		

Natural vulnerability	**Evaluate the natural vulnerability**	
	Possible lost	0
	Directly vulnerable	0.33
	Indirectly vulnerable	0.67
	Not vulnerable	1
Notes		

Human impacts	**Evaluate the possible human impacts**	
	Possibile lost	0
	Directly vulnerable	0.33
	Indirectly vulnerable	0.67
	Not vulnerable	1
Notes		

3) Preliminary assessment of abiotic ecosystem services.

Geosystem services		
Regulating	1	Atmospheric and ocean processes Hydrological cycle
	2	Earth processes Geohazards
	3	Flood regulation
	4	Water quality regulation
Supporting	5	Soil processes
	6	Habitant provision Birds
	7	Land and water Sanctuary is builded on top of the hill
	8	Burial and storage - To be asked
Provisioning	9	Food and drink
	10	Nutrients and minerals
	11	Fuel
	12	Construction materials
	13	Industrial minerals
	14	Ornamental products
	15	Fossils
Cultural	16	Environmental quality
	17	Geoturism and leisure
	18	Cultural spiritual and historic
	19	Artistic inspiration
	20	Social development
Knowledge	21	Earth history Paleo valley- post glacial modelling
	22	History of research
	23	Environmental monitoring and forecasting
	24	Geoforensis
	25	Education and employment

Buffer zone

Geosystem services		
Regulating	1	Atmospheric and ocean processes
	2	Earth processes
	3	Flood regulation Within the “mastallone” bridge
	4	Water quality regulation
Supporting	5	Soil processes
	6	Habitant provision
	7	Land and water
	8	Burial and storage
Provisioning	9	Food and drink
	10	Nutrients and minerals
	11	Fuel
	12	Construction materials
	13	Industrial minerals
	14	Ornamental products
	15	Fossils
Cultural	16	Environmental
	17	Geoturism and leisure
	18	Cultural spiritual and historic
	19	Artistic inspiration
	20	Social development
Knowledge	21	Earth history
	22	History of research
	23	Environmental monitoring and forecasting
	24	Geoforensis
	25	Education and employment

Annex 6

CATEGORIES	EXAMPLES (Gray M. 2015-2018)	Phd PRELIMINARY QUESTIONS	PRELIMINARY INDICATORS FOR ABIOTIC NATURE
REGULATING			
The benefits obtained from the regulation of ecosystem processes, including air quality regulation, climate regulation, hazard regulation. water regulation, erosion regulation, water purification, disease regulation, pest regulation, pollination and natural			
1) Atmospheric and ocean processes	Atmospheric CO2 for regulating temperature and shielding ozone and providing atmospheric circulation; from ocean streams to hydrological cycle	Is the geosite's geomorphology influencing air and water quality- circulation through Earth and Ocean ?	Mitigation actions/effects/processes provided by the characteristic of the geosites to the community
2)Terrestrial processes	Carbon cycle , erosion , transportation, deposition and uplift processes that reniew co	Is the geosite involved in present day activity of the geological cicle?	Presence of active geological phenomena that reniew properties of Earth materials
3) Flood control	Soil- clay can reduce the erosion, natural physical barriers (river levees, single beach ri	Is the geosite influencing the flood regulation?	Landforms and Geomorphological processes regulating geohazards
4) Water quality regulation	Soil, sediments and rock attenuate polluting substances and helping the water quality	Is the geosite influencing the water quality?	Geomaterials improving the quality of water
SUPPORTING			
They are necessary for the production of all other ecosystem services including soil formation, photosynthesis, primary production, nutrient cycling and water cycling.			
5)Soil processes	Soils provide with different services: habitat, interact with many other parts of the en	Is soil or pedological processes available?	Quantity of soil offering weathering material
6) Habitat provision	The spatial-temporal interrelated site factors of river-floodplain-systems (hydrology in combination with climate, geomorphology, and soil)	Are there habitats in the geosite?	Presence of hydrological factors in combination with climate, geomorphology, and soil which provide habitats for the community
7) Land as a platform for human activities	land surface: different activities required different typers of platform	Is the geosite has a role on the setting up of a platform for human activities?	Presence of land platform which contribute to the development of different human activities
8) Burial and storage	Physical resources of the land used as human burial and storage underground	is there any undeground storage or human burials?	Presence of human burial or of waste underground disposal
PROVISIONING			
The products obtained from ecosystems, including food, fibre, fuel, genetic resources, biochemicals, natural medicines, pharmaceuticals, ornamental resources and fresh water.			
9)Food and drink	Physical environment provides groundwater, acquifer rivers, galciers, lakes, ice sheet. Calcium carbonate and salt are considered as food	Has the geosite a direct or undirect impact on production of food and drink?	Quantity and quality of abiotic elements influencing drink and food production (ex. terroire)
10)Nutrients and minerals	About 17 elements are though to be essential for plant and animal life	Is the geosite directly involved into provisioning of nutrients and minerals for human activities, like agriculture?	Quantity and quality of nutrients within rocks and soils
11)Fuel (sources of energy)	Mineral fuel, coal, peat deposit, petroleum, uranium,renewable energy sources	Is the geosite positioned within an energy producing area? Does the geosite provide energy?	Presence of energy resources within the geosite
12)Construction materials	Geological materials, building stones, gypsum, limestone, structural clay	Is the geosite a source of construction material?	Presence of a quarry or other surces for construction material
13) Industrial minerals	Presence of indusrial minerals, like pyrite, hematite,bauxite, ilmenite, gold, silver, copp	Is the geosite located within a mineral extraction area?	Presence of a mine or other sources
14)Ornamental products	Gemstone	Is the geosite rich in gemstones?	Presence of gemstones
15)fossils	Fossils	Is the geosite overlapping and extraction area for fossils?	Presence of fossils
CULTURAL			
The non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences – thereby taking account of landscape values.			
16) Environmental quality	Aesthetic appeal of the landscape, landform which enrich our spirit	Is the geosite contributing to the aesthetic landscape value of the area?	Presence of a natural feature which improves our lives in some non material way
17) Geoturism and leisure	Geoturism as an area that attempts to minimise the impacts of his tourism through g	Is the geosite contributing to recreation and leisure experiences?	Presence of leisure activities connected with the geosite's geodiversity
18) Cultural spiritual and historic	Geomithology, intangible heritage connected with geodiversity, archaeology, history,	Is the geosite contributing the cultural and /or spiritual experiences?	Presence of miths, historical facts, archeological features and spiritual heritage connected with the geosite
19) Artistic inspiration	Physical world as inspiration for artists	Is the geosite source for artistic inspiration?	Presence of art related with the geosite
20) Social development	Local geological related activities, voluntary groups	Is the geosite contributing to social development?	Presence of local activities promoting communities and personal development based on the geosite's contents
21)Earth history	Geological record as research value	Is the geosite significant for representing some stages of the Earth history?	Presence of geological elements which are significant for the Earth history
22) History of research	Geosite wich have played a part in the development of universally applied principles o	Has the geosite a role in the development of principles of geology ?	Presence of geological processes which contributed to establish principles of geology
23) Environmental monitoring and forecasting	Record of sendiments in lakes, bogs and ice cores, monitoring impact on human activi	Is the geosite providing data regarding records of human activities though pollution, vegetation, soil erosion?	Presence of monitoring station for sampling purposes in calculating the the human impact
24) Geoforensis	Linking suspects to crime scenes	Is the geosites providing data for solving crimes?	Presence of evidences linked with a possible solution of a crime investigation
25) Education and employment	Presence of geological record with a role in education and training	Is the geosite contributing the educational activities?	Presence of educational activities based on geosite contents

ABIOTIC SERVICE		BIOTIC SERVICES	BIOTIC INDICATORS
REGULATING			
1) Atmospheric and oceanic processes. , to be combined with biotic service 7		**7)Air quality regulation**	Capacity of ecosystems to extract aerosols and chemicals from the atmosphere.I: Leaf area index (Nox-fixation) Amount of aerosols or chemicals 'extracted'- effect on air quality
2)Terrestrial processes to be integrated with the biotic services: 9-10-12-13		**8)Climate regulation**	Influence of ecosystems on local and global climate through and cover and biologically mediated processes I: Greenhouse gas balance-quantity of greenhouse gases, fixed and or emitted effect on climate parameters
3) Flood control to be integrated with the biotic services: 9-10-12-13		**9)Natural hazard mitigation**	Role of forests in dampening extreme events, I:land cover characteristics and similar, reduction of flood danger and prevented damage to infrastructure
4) Water quality regulation: role of soils, sediment and rocks, Abiotic processes to be integrated with the biotic services: 10,12,13		**10) Water regulation**	Role of forests in water infiltration and gradual release of water, I: water storage capacity in mt3, quantity of water retention
		11) Waste treatment	Role of biota and abiotic processes in removal or breakdown of organic matter , xenic nutrients and compounds I:Max amount of chemicals that can be immobilized on a sustainable basis
		12) Erosion protection	Role of vegetation and biota in soil retention, I: Denitrification immobilazion in plants and soils ((kg N/ha/y);, amount of soil retained or sediment captured
		13)Soil formation and regeneration	Role of natural processes in soil formation and regeneration, I: vegetation cover root-matrix, amount of topsoil (re) generetad par ha/y
		14)Pollination	Abundance and effectiveness of pollinators I: Number and impact of pollinating species,
		15) Biological regulation	Control of pest populations through trophic relations ; I: Number and impact of pest-control species
SUPPORTING			
5)Soil processes. Abiotic process to be integrated with biotic N13		**16)Nursery habitat**	Importance of ecosystem to provide breeding, feeding or resting habitat for transient species, I: number of transient species, and individuals, dependece of other ecosystem ;
6) Habitat provision. abiotic processes to be integrated with biotic N17		**17) Genepool protection**	Maintenance of a given ecological balance and evolutionary processes ; I: Natural biodiversity (especially endemic species);
7) Land as a platform for human activities to be connected with biotic N.11,13,16			
8) Burial and storage.			
PROVISIONING			
9)Food and drink- to beconnected with biotic services N1,N2		**1)Food**	Presence of edible plants and animals- I: Total or average stock in kg/ha-
healthy growth,to be connected with Biotic service N.13		**2)Water**	Presence of water reservoirs; I: Total amount of water (m3/ha)
11)Mineral Fuel -to be connected with Biotic service N3		**3)Fibre and Fuel**	Presence of species or abitic components with potential use for timber, fuel, raw material, I: Total biomass, net productivity
12)Construction minerals		**4)Genetic materials**	Presence of species with potentiall use of genetic material, I: total "gene bank" value, maximum sustainable harvest.
13) Industrial minerals		**5)Biochemical products**	Presence of species or abiotic components with potentially useful chemicals and/or medicinal use ; Total amount of useful substances that can be extracted (kg/ha)
14)Ornamental products		**6) Ornamental spieces**	Presence of species or abiotic resources with ornamental use, I: Total biomass, maximum sustainable harvest
15)fossils			
CULTURAL			**Passing to the ecosystem services and human well being (cultural services-Gray) an introduction is required-every time you change service**
16) Environmental quality, to be connected with biotic service N8		**18)Aesthetic appreciation**	Biotic indicators; Aesthetic quality of the landscape, based on, structuraldiversity, "greenness", tranquillity**.** I: Number of area of landscape features with stated appreciation-expressed aesthetic value for example: number of houses bordering natural areas, number of users of scenic routes
17) Geoturism and leisure-biotic N. 19 to be connected with biotic service N19		**19)Recreational opportunities**	Recreational opportunities for tourism and recreational activities,I: Number/ area of landscape and wildlife features with stated recreational value. Maximum sustainable number of people and facilities.
18) Cultural- spiritual and historic- to be connected with biotic service N20		**20)Inspiration for culture and design**	Cultural heritage and identity: sense of a palce and belonging, I: number/area of culturally important lanscape features or spieces, number of people using forests for cultural heritage and identity or attach spiritual or religious significance
19) Artistic inspiration , to be connected with biotic service N20		**21)Cultural heritage**	Inspiration for culture, art and design, I: Number-area of landscape features or species with inspirational value, actual number of books, paintings using ecosystem as inspiration
20) Social development , to be connected with biotic service N23		**22)Spiritual and religious inspiration**	Landscape features or species with spiritual and religious value ; I: Presence of landscape features or species with spiritual value
21)Earth history , to be connected with biotic service N23		**23)Education and science for formal education**	Education and science opportunities for education and training, I: presence of features with special educational and scientific values or interest, number of classes visiting, number of scientific studies.
22) History of research, to be connected with biotic service N23			
23) Environmental monitoring and forecasting			
24) Geoforensis			
25) Education and employment			

ABIOTIC SERVICE	Time,Space dimension,Point of view	Definition of the services/Geological processes which are influencing the service		ABIOTIC factors influencing the process (and consequently the service)									BENEFIT FOR THE SOCIETY
		REGULATING											
1) Atmospheric and oceanic processes.	Point of view: in a specific geosite's spot - looking from the spot - Buffer zone	Phd Team definition: Mitigation actions/effects/processes provided by the characteristic of the geosites to the community; Gray M. definition: " The combination of oceanic and atmospheric circulation drives global climate by redistributing the heat".a) Phd team definition c)Gray	In order to understand ath what level-scale the geosite is regulating the climate is necessary to know how much is the geosite is influenced by the climate. Factors influencing the climate: altitude,climate zone, presence of mountain chain, slope's exposure (North/South), water proximity, wind expousure	**ALTITUDE -Exposure-** Higher the quote, lowest is the level of the protection from the atmospheric and oceanic process.	**CLIMATE ZONE**	**MOUNTAIN CHAIN** Presence of mountainous relief above the quote of the geosite (in its proximity)	**SLOPE EXPOSURE NOTHERN and SOUTHERN HEMISPHER:**	**SEA WATER PROXIMITY**	**WIND EXSPOSURE PROTECTION**				The abiotic factors regulating the climate give obvious benefits to the society both al local and regional-national and International levels. At **international** level the climate regulation influence the carbon cycle (sink on peat soils), the hydrogeological cyle and climate condition (precipitation and temperature) . At the **regional level** the abiotic element like the rising mountains (height and shape) influence the patterns which affect rates of erosion (that are depending by the amount and type of precipitation-rainfall erosivity). **Locally,** the mountain chain or mountain reliefs direclty affect the community' s life which is directly dependent from the amount of precipitation (water reservoire, agriculture), land erosion (landslides, amount of soils for agriculture). The regulation of the climate due to abiotic factors can influence also the implementation of renewable energy (wind, solar, waves, hydropower), explotation of specific minerals (presence of specific minerals are influenced by differentation of soils), the rate of nutrient cycle.
2)Terrestrial processes	We look at the geosite from "outside" view-Buffer zone	a)Presence at the geosite of active geological phenomena that reniew properties of Earth materials. b) Carbon cycle , erosion , transportation, deposition and uplift processes that reniew constantly with fresh rocks. a)Phd team definition b) Gray definition	In order to understand if the geosite is regulating the Earth phenomena for the renovation of Earth materials is necessary to know if there are any relevant active phenomena within it. The analysis started form the Lithological cycle. A geosite is considered "active" when it is affected by active volcanic processes or other phenomena like: rock weathering, erosion, transportation, deposition, uplift (role of rivers, sea waves, beaches, salt marshes) and geomorphological processes". Are any rock weathering, erosion, transportation, deposition,uplift (role of rivers, sea waves, beaches, salt marshes) and geomorphological processes.Is the geosites located in a river band, on a beach, or subject to erosion due to glacier, wind or current factors?	**CRUSTAL MOBILITY /UPLIFT** occurs when the geosite has been part of active tectonic processes within the antropocene a)Is the geosite included into uplifting phenomena going on? b)How fast is the crustal mobility?	**EROSION BEDROCK (Average)**	**TRANSPORTATION** due to water, ice, gravity transport-rock falls or debris flows .	**DEPOSITION occurs when the agent of erosion (wind or water) lay down sediments.** a)Are any "recent" sediment deposit within the geosite? **B) What is the deposition rate?**						The abiotic factors regulating the terrestrial processes have stronger direct impact at **global scale.** The release of carbon dioxide is activated by the plate tectonics (vulcanism) while the rock weathering contribute to its storage though limestone and carbonatic soils .Enhanced carbon sequestration is a major regulating service that helps mitigate global warming and can increase soil productivity.At **regional-local level** the abiotic terrestrial processes considered for a direct impact are:erosion, transportation , deposition and uplift. The regulation services linked with the **erosion** are affecting local population in terms of reducing the amount of exposed soils (shortage of sediment) : the erosion index depends also on the minerals and the rock's structural properties. Certain type of rocks have a crucial role in regulating erosion and can be used to create artifical barriers. The **transportation** of debris by the river is regulating the distribution and the energy from land towards the sea (sediment supply). The **deposition** could create barriers along the coasts that protect the ecosystem while sendiments deposition is influencing the diffusion of sysmic waves. Marine sediments are powerful containers for stocks, acting as regulators of climate change and greenhouse gases. transitional environments, in which water and sediments loaded by rivers are transported and de-posited in the plains, causing the soil to become quite rich.The community, through appropriate measurements need to become able to monitoring and consequently controlling the regulating phenomena provided by the geomorphology of the geosite: that would make the community able to act for coastal defence, to set up appropriate hazard risk assessment and a proper "land use" planning.
3) Flood control Abiotic processes to be integrated with the biotic services: 3-4-6-7	We observe the geosite from outside inside to find out which possible abiotic factors are regulating the risks of flood-Buffer zone	a)Landforms and Geomorphological processes regulating geohazards: the abiotic and the biotic systems working together for controlling the flood (ex.organic matter and inorganic clay)B) Soil- clay can reduce the erosion, natural physical barriers (river levees, single beach ridges). a)Phd team b) Gray definition	In order to understand if a geosite is regulating services to the community regulating geohazards- flood control, many factors need to be considered: **a)The presence of Landforms (artificial-natural)** like: river levees, beach ridges, salt marshes, barrier islands, dunes, human building. **b)Amount of precipitation par year:** amount of cm/year **c)Maximum water discarge:** qmt3/sec/ average par month		**a)N. Landforms** which oppose flooding (in case of river, lakes and sea)	**b)Amount of precipitation par year** (in case of river-lake)	**c)Flood return period** (in case of river-lake)	**d)Maximum Water discarge** (in case of river)	**e)Sea Tide** (in case of sea in the proximity)	**f) Average wind speed** (in case of sea in the proximity)			The regulation of Flood control has important consequences at **International-Regional-Local** level. At all level, controlling the flood allows the Governments to increase vulnerability to floods, to set up proper planning schema for better land use. In order to monitoring and to build infrastructures a proper analysis on landforms, geomorphological procees and index of erosion are needed.
4) Water quality regulation: role of soils, sediment and rocks	Point of view: We close observe the geosite considered as Buffer zone	a) Geomaterials improving the quality of water b) Soil, sediments and rock attenuate polluting substances and helping the water quality both surface and groundwater. a)Phd team b)Gray definition	How much the geosite is influencing the water quality regulation? There are several factors which influence it, the defintion of "water quality" We need to define "water quality" , we adopt the "definition for mineral water quality" by FAO and www.nadp.isws.illinois.edu (Mendeley). In the research We define the: "water quality-drinkable water" following standard for "mineral water" which normally contains: sodium, potassium, calcium, magnesium, chloride, sulfate, hydrogen carbonate.Mineral water comes from underground reservoirs.No two mineral waters are the same: the layers of bedrock that the water has flowed through in its source region determine the amount and composition of natural ingredients in the mineral water. The research analyse the aquifer groundwater quality. To define if a geosite is influencing the quality of the groundwater we need to analyse following factors: a) Properties of the rocks on surface-bedrock b) Permeability and porosity of the soil (higher is the porosity, higher is the permeability)		**MINEREALOGIC PROPERTIES OF THE ROCKS**	**PERMEABILITY**							The regulation of the quality of the water has relevant impact at **regional** and **local** scale. The analysis of the geological surface, the permeability , the porosoty of the soil are the important factors to be taken into consideration. The possiblity to calculate the specific water regulation quality service it gives to the authorities the chance to be aware of the presence of mineral water, its quantity and consequetly how to use it for communities supply.
		SUPPORTING											
5)Soil processes.	Time frame: At present	a) Quantity of soil offering weathering material b)Soil proccesses provide these services to the community a)agricolture b)forestry c)fuel d)genetic resource.	What are the abiotic processes influencing the soil processes? **a) erosion b) transportation e) deposition .** Calculating how much the abiotic factors influence the soil processes it also allow to understand at what scale the specific geosite could support the development of the three main activities related with soil processes, that are: **a)** agriculture **b)** forestry **c)** fuel and genetics. To calculate erosion index, transportation index and deposition within a specific geosite = calculate its tendency for supporting abiotic services linked with the soil process. Different soil processes supporting the a)b)c) at different scale, highest is the points from the erosion, transportation and deposition, higher is the predisposition for supporting agriculture, forestry and fuel-genetic of the geosite.	**EROSION a)**Is the geosites located in a river band or in the proximity of glaciar or on a shore? **b)**Which are the minerals and structural properties of the most common rock within the geosite? Index of erosion? **c)** Is the geosite covered by soil?**(biotic 7) For d) e)f)** the exsposure time (Short, Moderate, Long need to be considered **d)** Is the geosite subject to drop of temperature and permeable rocks? **e)** Is the geosite subject to high precipitation or washout? **f)**Is the geosite subject to wind exposure? **g)** Which kind of vegetation covering the geosite? **(biotic 3,4,6) h)**Stepness of the slope	**TRANSPORTATION (It happens if there is erosion in place or not) thanks to water, ice, gravity transport-rock falls or debris flows**	**DEPOSITION occurs when the agent of erosion (wind or water) lay down sediments.**		**In order to support the service AGRICULTURE, the soil need to be fertile. What are the factors which influence the fertility of the soil?** -To be calculated the quantity of chemicals and minerals included into soil maps within the geosite a)fertility- There are majorly 12 factors influence Soil fertility: Infiltration of water,Soil structure, Active Soil life,Content of organic matter,Minerals present in the soil, Acidity or Soil pH,Water Retention capacity of soil,Water draining ability of the soil, Nutrient release capability, highest is the fertility higter will be the points given. **Are within the geosite active agricultural activities (crop cultivation, vineyard, orchard)**	**What are the factors that influence the use of soil for FORESTRY ?** what are the abiotic and factors influencing the use of the soil for forestry- we want to understand if the geosite is providing with soils-forset is one of the use of soil. **Is the geosite hosting a wild or managed forest?**	**What are the factors that influencing Fuel and genetic resources** are considered "provisioning" services. They will be analysed in the "provisioning" section.			Soil processes have important impact within **National, Regional** and **local communities**. Soil processes are both involving abiotic and biotic services. Agriculture, forestry ,fuel and genetic resources are crucial for human development. **Agriculture** plays a key role in providing a wide range of ecosystem services, such as food, feed, fiber and biofuel, thus taking part in the economic development of countries.**Forestry** Forestry is the science or skill of growing and taking care of trees in forests, especially in order to obtain wood.(Collins Dictionary)Forestry, along with farming, remains crucial for land use and the management of natural resources in the EU's rural areas, and as a basis for economic diversification in rural communities, specially for mitigation to climate change (https://ec.europa.eu/eurostat/statistics-explained/index.php/Forests,_forestry_and_logging#Forests_and_other_wooded_land)
		a)Phd team preliminary question b) Gray Definition											Soil functions and ecosystem services The assessments of threats to soil functions leads to a need to formally identify the functions that the soil performs. The proposed Soil Framework Directive (CEC, 2006) of the European Union recognizes seven soil functions that are vulnerable to soil threats: 1. biomass production, including agriculture and forestry 2. storing, filtering and transforming nutrients, substances and water 3. biodiversity pool, such as habitats, species and genes 4. physical and cultural environment for humans and human activities 5. source of raw materials 6. acting as a carbon pool 7. archive of geological and archaeological heritage. The EU Soil Thematic Strategy was developed at the same time as the Millennium Ecosystem Assessment (MA, 2005) initiated by the United Nations in 2000. The goal of the MA was to assess the consequences of ecosystem change for human well-being and to lay the scientific basis for actions that would promote conservation and sustainable use of ecosystems. The MA was built on the framework for ecosystem services developed by Daily, Matson and Vitousek (1997) and Costanza et al. (1997). The categories of ecosystem services were formalized by the Millennium Ecosystem Assessment into four broad classes: provisioning, regulating, supporting, and cultural services. The range of major ecosystem services provided by soil, and the specific soil functions that enable those services, are summarized in Table 1.2. http://www.fao.org/3/i5199e/i5199e.pdf - Status of the World's Soil Resources
6) Habitat provision.	Space frame: Buffer zone	a) Are there habitats within the geosite? B) Habitat: Def.:the spatial-temporal interrelated site factors of river-floodplain-systems (geomorphology, geology and soil diversity that provide habitat heterogeneity) High geodiversity =high biodiversity (habitats) c) habitat: physical location where the environmental factors (abiotic and biotic) are supporting the life and the development of one specie.	Which are the abiotic factors influencing the habitat? : **geomorpholog**y (pysical environment: altitude, aspect), **geology** (type of rock) , **soil diversity**. Through the above examples, it is evident that geodiversity influences biodiversity at different spatial scales. **(Matthews2014).** At a broad spatial scale topography influences climate which is a major driver of biotic species distributions. At the landscape scale extreme events and disturbances, such as landslides, create habitat heterogeneity and influence community dynamics. Finally, at smaller scales, differences in edaphic conditions create a mosaic of habitat types and therefore niche availabil-ity **(Jonasson et al. 2005).** Geology - Hardrock,unconsolidated deposits, geophisical activity, landform distribution, chemistry, physical state, surface water, ground water **(Schrodt 2019)**		Highest geomorphology affetcs the rate of biodiversity in a specific environment. **What element concurs to the geodiversity?** See the **Essential Geodiversity Variable (Schrodt 2019) (Geology - Hardrock,unconsolidated deposits, geophisical activity, landform distribution, chemistry, physical state, surface water, ground water)** If a geosite is including all the factors we can say that the geodiversity is high. See "Working today for nature tomorrow" English Nature Research Reports Number 562	Geology	Geomorphology	Soil diversity	Hydrology				Habitat provision- the supporting services (abiotic and biotic) which concur to the creation of "habitats" are crucial for the society development at all scales. Humans, like all animals, have favourable ecosystem to live in which is the natural habitat. Geodiversity influences the hetereogeneity of habitats and biodiversity, consequenlty biodiversity is affecting the loss of geodiversity. Destruction and degradation of natural ecosystems are the primary causes of declines in global biodiversity(**Haddad et al. Sci. Adv. 2015)**Habitat loss, stemming from destruction, fragmentation or degradation, threatens these sanctuaries of diversity and is often the result of human activities. Loss in habitat size, increased isolation of habitats from one another, and increases in negative edge (where one habitat begins and another ends) effects, characterize fragmentation. These elements cause changes to the delicate biological and physical properties of habitats, decrease genetic diversity, introduce pathogens and invasive species, and lead to human-wildlife conflict.(**Humanitas Global Development)** All the advantages to guarantee the abiotic and biotic factirs linked with habitat provision are evident from the negative effects caused by the loss of biodiversity and geodiversity.
		a) Phd team preliminary question b) Gray definition c) General definition of habitat			**GEOLOGY** EGV a)**Hardrock fossils and mineral distribution** (geological material and their spacial distribution- natural resources, coal, gas, ore) b)**Unconsolidate Deposits** (surface distribution of parents materials resulting from geomorphological processes- distribution/scarcity o materials like sand-dynamics of surface materials-sedimentation), c)**Geophysical processes** (variability of the intensity of geophisical processes- earthquacke, volcanic eruptions, earth radioactivity, themal energy, land [illegible]								
					GEOLOGY -3 EGV 1)**Hardrock fossils,mineral and ornamental stones** distribution- is the geosite characterized by a "relevant" presence of fossils or minerals-ornamental stones? Are the minerals or/and the fossils/ornamental stone detected characterizing the overall Geopark' s geology (compared to the criteria adopted to become UGG)? 2)**Unconsolidate deposits,** Are present in the geosite any sedimentation process (not correct)? 3)**Geophysical processes** How often are happening the processeses detected in the geosite during the last geological period?(number of happenings) **GEO-MORPHOLOGY - 1 EGV** 1)Landforms distribution. How many landforms can we eventually detect in a geosite? (Aeolian Landforms, Coastal-Oceanic, Erosion, Volcanic- mountains, plain,hills, plateau buttles, canyon, valleys, caves,deserts, and basins) list at: http://worldlandforms.com/landforms/list-of-all-landforms/ **SOIL 2 EGV 1)Chemistry** -To be calculated the quantity of chemicals and minerals included into soil maps within the geosite **a)fertility-** There are majorly 12 factors influence Soil fertility: Infiltration of water,Soil structure, Active Soil life,Content of organic matter,Minerals present in the soil, Acidity or Soil pH,Water Retention capacity of soil,Water draining ability of the soil, Nutrient release capability, highest is the fertility higter will be the points given, **b)soil salinazation** (note colonna I) lowest is the salinization, higher will be the points given (eventhough for "human activies" we consider only agriculture there are others kind of activities which are siutabele for soils with high salinity), **c)pollutants (**Heavy metals, Polycyclic aromatic hydrocarbons, industrial wate, pesticides)- To be calculated the amount of these main pollutants in the soil sample within the geosite, highest level correspond to lower score **d)minerals -** Highest quantity of minerals correnspond to higher score,**2)Physical State a)Formation/degradation of soils/b)soil erosion** (index of erosion of te soils sample within the geosite, see above), highest is the erosion lower is the score. **HYDROLOGY 1)Surface water a)River dynamics** need to calculate the overall river dynamics within the geosite- to be calculated the average amount of rivers discharge, higher is the discarge highest is the score**, b)drinking water quality** (see criteria above)**, c)irrigation water volume** need to calculate the volume of water used for irrigation as important factor for the hydrology of the geosite - higher is the quantity higher is the score **d)dam construction** higher number of dams **negatively(?-always?)** influence the natural hidrology of the geosite, higher is the number lower is the score **2)Ground water** need to be calculated the quantity within the geosite, higher is the number higher is the score **a)Aquifer size and quality** need to be calculated the quantity within the geosite, higher is the size, highest is the score.		**GEO-MORPHOLOGY** - 1 EGV 1)Landforms distribution. How many landforms can we eventually detect in a geosite? (Aeolian Landforms, Coastal-Oceanic, Erosion, Volcanic- mountains, plain,hills, plateau buttles, canyon, valleys, caves,deserts, and basins) list at: http://worldlandforms.com/landforms/list-of-all-landforms/ From 1-2= 10 From 3-5= 40 From 6-8= 80 From 9-10= 100	**SOIL** 2 EGV 1)Chemistry -To be calculated the quantity of chemicals and minerals included into soil maps within the geosite a)fertility- There are majorly 12 factors influence Soil fertility: Infiltration of water,Soil structure, Active Soil life,Content of organic matter,Minerals present in the soil, Acidity or Soil pH,Water Retention capacity of soil,Water draining ability of the soil, Nutrient release capability, highest is the fertility higter will be the points given, b)soil salinazation (note colonna I) lowest is the salinization, higher will be the points given (eventhough for "human activies" we consider only agriculture there are others kind of activities which are siutabele for soils with high salinity), c)pollutants (Heavy metals, Polycyclic aromatic hydrocarbons, industrial wate, pesticides)- To be calculated the amount of these main pollutants in the soil sample within the geosite, highest level correspond to lower score d)minerals - Highest quantity of minerals correnspond to higher score,2)Physical State a)Formation/degradation of soils/b)soil erosion (index of erosion of te soils sample within the geosite, see above), highest is the erosion lower is the score.	**HYDROLOGY** [illegible]				
7) Land as a platform for human activities		a)Presence of land platform which contribute to the development of different human activities b)land surface: different activities required different type of platform.	How many human activities need "land" as platform and which factors are influencing them? Human activities on the earth's surface are linked to the various types of land uses. Different types of activites correspond to different type of land use. Most of the human activities are performed on artificial surfaces (the soils function is to support the construction), the other activites are linked to agriculture and forestry (land function is to support the crops, breeding, trees and plants).We can detect four main types of "land-supporting use":**agriculture, breeding, forestry** and **construction.**	**AGRICULTURE** What are the factors whihc influence the "land" as platform for agricutural activities? The presence of soil is the main requirements together with the climate factors (all described above in realtion with "soil" and "climate" abiotic services). To understand if and how much the geosite is supporting land for agriculture is necessary to analyse both the factors realted with soil **(see K-L 23)** or- Are within the geosite active agricultural activities (crop cultivation, vineyard, orchard) Yes= 100 No=20	**ANIMAL BREEDING** what are the biotic and abiotic factors influence the presence of breeding activities? Is the geosite supporting breeeding activities? Yes=100 No=20	**FORESTRY,** What are the abiotic and bioric factors influencing forestry?Is the geosite supporting land for forestry use? Yes=100 No=20	**CONSTRUCTION,** is the geosite supporting any building? Yes=100 No=20	Agriculture and forestry within the land as platform for human activites are not considering the chemicals quality of the soil, like it does in case of "soil" processes (NS).					Land as platform for human activities are important services at local, regional, national and international scale, in fact most of the human activities are directly linked with land use. It is crucial to understand what factors influenced the land use in order to better plan the cities and communities. At all levels the impact of the land as supporting services for human activities is important for monitoring the World activities and the distribution of economic activities within different area. Proper monitoring for the land use helps the policy makers to make better choice for planning
8) Burial and storage.		a) is there any undeground storage or human burials? b) The physical resources of the land have long been used for human burial- stones as stonemasons for gravestones. Waste materials are also buried in the ground or above the ground. Ground act also as store for water, oil, gas, carbon and carbon dioxide emissions.	Which are the abiotic factors influencing the service? The service is divided into: **a) human burial- gravestones b) waste deposits c) ground store**	**HUMAN BURIALS** The use of rocks for gravestone is linked with the presence of durable and malleable rock types available in the geosite. Gravestones are made of all types of rocks, even if some few dominate the landscape in a cemetery. Gravestones can be made from plutonic rocks, like gabbro and granite, metamorphic rocks, like slate and marble and more rarely of sedimentary rocks, likes sandstone and limestone. The choice depends quite of aesthetic values and practical use. Granite can be of various colours, dotted with the black mica nests. Limestone is easy to work and sculpt and can display interesting bands or layers or color. The most appreciated color is white to gray, but there exist also bluish, reddish and yellow limestone and marble types. (Bressan D. 2006). Other factors linked to cultural background influence this human activity.	**WASTE- rocks properties a)** very low permeability **b)** good thermal conductivity **c)** Sufficient plasticity to limit the risk of fractures **d)** High capacity of ionic absorption e) Low solubility, f) geomechanically favourable conditions to mantain cavities **e)** stability of all the properties when (pressure, temperature, ionic radiations and mechanical effort) mutate **f)** Sufficient rock volume located at the right depth, **g)**homogeneous distribution of the rocks properties,**h)** low degradability, **i)**low and stable geodynamics in a long term) **All these factors guarantee the safe waste deposits.** To be combiend with the biotic ones: max amount of chemicals can be absorbed by the ground	**GROUND STORE-**The most basic geological factors are the regional efficacy of the caprock and the geology of the reservoir. The caprock efficacy may vary laterally and can exclude large areas of the reservoir rock from consideration. The geology of the reservoir determines the efficiency of the various trapping mechanisms and thus allow calculation of the theoretical maximum amount of CO2 that can be stored.							Supporting burial and storage activities, it is relevant at all levels to analise both abiotic and biotic factors that are linked with these activities, in order to better organize the planning of those. Right use of storage rocks waste deposits are crucial for safety of population.
		a) Phd team preliminary question b) Gray clarifications											
9)Food and drink-(Food and water)	Buffer zone	**a)** Quantity and quality of abiotic elements influencing drink and food production **b)** Quantity and quality of abiotic elements influencing drink and food production Physical environment provides groundwater, acquifer rivers, galciers, lakes, ice sheet. Calcium carbonate and salt are considered as food	**a)** Quantity and quality of abiotic elements influencing drink and food production **b)** Quantity and quality of abiotic elements influencing drink and food production Physical environment provides groundwater, acquifer rivers, galciers, lakes, ice sheet. Calcium carbonate and salt are considered as food **c)**Presence of edible plants and animals- Total or average stock in kg/ha- Net Productivity (in kcal/ha/year or other unit) - Soil formation and regeneration d)Presence of water reservoirs - Total amount of water (m3/ha)- Max sustainable water extraction (m3/ha/Year) d) Presence of water reservoirs - Total amount of water (m3/ha)- Max sustainable water extraction (m3/ha/Year)	**SOIL- factors: Nutrients (biotic)**- living organisms factors like bacteria, mushroom etc. The percent is influencing the soil quality and the food's provisioning - Biotic factor - **Abiotic factors** have been analysed within the "habitat support" since soil is also a factor influencing the habitat support.see **K29**. SOIL 2 EGV **1)Chemistry** -To be calculated the quantity of chemicals and minerals included into soil maps within the geosite- minerals - depends which kind of mineral- Highest quantity of minerals correnspond to higher score **a)fertility**- There are majorly 12 factors influence Soil fertility: Infiltration of water,Soil structure, Active Soil life,Content of organic matter,Minerals present in the soil, Acidity or Soil pH,Water Retention capacity of soil,Water draining ability of the soil, Nutrient release capability, highest is the fertility higter will be the points given, b)**soil salinization** lowest is the salinization, higher will be the points given (agrigultural activities are influenced by salinization-over salinization can lead to none fertility) , c)**pollutants** (Heavy metals, Polycyclic aromatic hydrocarbons, industrial wate, pesticides)- To be calculated the amount of these main pollutants in the soil sample within the geosite, highest level correspond to lower score ,**2)Physical State** a)Formation/degradation of soils/b)soil erosion (index of erosion of the soils sample within the geosite, see above), highest is the erosion lower is the score. If you have soil samples -soils map- **soil classification in Europe- chemistry and physical factors- Map of Soil use in Europe (Coorine Land) - European soil heavy metals Map. Description of the parameters - thematic strateyg of soils protection** https://ec.europa.eu/commission/presscorner/detail/en/MEMO_06_341	**TEMPERATURE-CLIMATE , See ABOVE (I 4-5)** -Factors influencing the climate: Latitude and altitude,presence of mountain chain, slope's exposure (North/South), water proximity, wind expousure- Same calculation can be applied here. **Altitude+Latitude+mountain presence+water proximity+wind exposure+ Slope exposure -higher is the score higher is the influence on climate Altitude: Score= 100; Latitude=25, Mountain presence=10; Slope exposure= 80; Water influence=100; No protection against the wind =10**								Food and drink - elements influencing drink and food production at local, regional and national level are: **soil, climate and habitat**. Institution and communities must develop specific legislation and actions regarding the soil protection, like the European Soil thematic Strategy. (https://ec.europa.eu/environment/soil/three_en.htm) , the specific Farm to Fork Strategy (https://ec.europa.eu/food/farm2fork_en) is also going in this direction ("use of chemical pesticides,excess of nutrients, restoring soil health,improve soil management). EU Commission proposed a Directive concerning soil protection and regeneration (Thematic Strategy for Soil Protection -Summary of the impact assessment (https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52006SC1165) . The italian region have adopted different legislation concerning the soil protection and use. (https://www.teknoring.com/news/tutela-del-territorio/consumo-di-suolo-la-normativa-aggiornata-regione-per-regione/) Soil protection can also be connected with the preseration of habitats, since geodiversity, geological heritage and the use of the soil are also connected with the food and drink provision. Climate has a key role in provisioning of food and drink.
		a) Phd team preliminary question b) Gray clarifications - We consider food as food that soil can provide to community expanding the Gray definition which focuses on calcium and salt as "food" coming from abiotic nature.		**WATER REGULATION A)** Properties of the rocks on surface b) Permeability and porosity of the soil (higher is the porosity, higher is the permeability)**A)ROCKS PROPERTIES** -a)Is the geosite characterized by limestone, dolomite or gypsum? (the geosites' s rock is highly influencing the mineral in the water and the quality- see the definition of mineral water)Yes =100 No= 1 b) Is the geosites characterized by gypsum, iron sulfated? yes=100 No=1 **B)PERMEABILITY** High (100)= gravel (the rock is highly influencing the water quality beacuse its material leave a lot of empty space within the particles),. Medium (50) = sand, Low (20)=fine sand, Unpearmeability 1=clay , in case of rocks high fractured rocks-n. of fractures par cubic meter- High Medium Law.	**PRESENCE OF FRESH WATER** [illegible] between 3-5= 70 Between 1-3 [illegible]								**NOTES ABOUT TERRROIRE E WINE TO BE CONNECTED WITH GRAY DEFINITION , PRIMA DI ESPANDERLA CON LA MIA Water a) water reservoirs (**See water quality regulation criteria)- b)**terroir** (interactive cultivated ecosystem, in a given place, including climate, soil and the vine)factors influencing terroire for providing wine**:** geology, geomorphology, soil, climate, biology of the vine (**Seguin, 1986)** (We do not examine the factors which determine good wine quality). c) Fresh water availability in lakes, glaciers, ice sheet- **Vines derive most of their nourishment** from a depth extending down to 0.6 m, but will, most of the time, rely on water from as far down as 2 m for transpiration. Only during periods of drought will they draw significant water from >2 m. At these times high porosity and low permeability (in both the soil and the underlying rock) will be an advantage. Soil thickness is an important factor in wine quality; in general, leaner wines are produced on thin soils and, on deep alluvial soils. Hanson (1995) quoted R. Gadille as saying that slope has a greater influence on the quality of wine than does bedrock. In hot climates, prone to summer drought, soil may be the most important factor after viticulture, while in cooler climates, slope and slope aspect are probably the second most important factors. Slope and slope aspect are controlled by a combination of geomorphological and geological factors. Only rarely, as in the Coonawarra and the Douro, is the bedrock an important factor in wine quality.**Geology and wine: a review Jennifer M. Huggett-2005.** Trace element and Sr isotopic compositions were measured on musts from vineyards in the Sesia Val Grande UNESCO Global Geopark in the northern Piedmont Region (Italy). The obtained data indicate that musts preserve the peculiar geochemical and isotopic signature of the rhyolitic bedrocks from which soils developed. In particular, some trace elements correlate with each otherfollowing the expected geochemical patterns occurring during magmatic evolution (L.Ghezzi 2018)
10)Nutrients and minerals for healthy growth	Buffer zone	a) Is the geosite directly involved into provisioning of nutrients and minerals for human activities, like agriculture?Are the nutrients useful for healthy growth available within the geosites?	Factors are: **rocks type, erosion-deposition and transport phenomena**, The rocks that produce soil contain mineral elements that, for the most part, are locked in a crystalline matrix and unavailable to plants until physical and chemical weathering loosen the chemical bonds. The nutrients must be released into the soil water before plant roots can absorb them. Those nutrients that become soluble often are leached out of the root zone before roots or soil organisms can absorb them.										Nutrients and minerals for healthy growth, in this case soil protection policies have a crucial role in preserving the soil's benefits including the amount of nutrients. (See "Soil processes")
		a) Phd team preliminary question b) Gray clarifications											
11)Mineral Fuel -	Buffer zone	a) Is the geosite positioned within an energy producing area? Does the geosite provide energy ? b) Presence of energy resources within the geosite (coal and peat, petroleum, renewable energy)	Abiotic factors influencing the mineral fuel provisioning .Coal formation depends on anaerobic conditions ,type of source of water, presence of organic material, pressure, temperature.Petroleum: organic material (sapropel), sediments deposit on sandstone (mother rock) acting with pressure and temperature, gas, Earth movements lift the hydrocarbons, layer of waterproof rock.Uranium:radioactive decay Renewable energy :Geothermal, hydroelectric (vertical faults) wave and tidal power (coastal condition), wind power (higher in upland and coastal situations)	Abiotic factors are linked with the presence of specific conditions listed on the right	Abiotic factors influencing [illegible] material.**Coal formation** [illegible] pressure, temperature [illegible] with pressure and tem[illegible] decay **Renewable ene**[illegible] (higher in upland and [illegible]								Mineral fuels are the most important source of fuels for all the communities at all levels. Coal and peat, petroleum, renewable energy is constantly monitored by International, National and Regional Institutions and Organizations. Data from the European Mineral Map, reveal low presence of minerals in the Sesia Val Grande geosite, while industrial minerals are present in Eigerøy and Jøssingfjord. (http://www.europe-geology.eu/mineral-resources/mineral-resources-map/)
		a) Phd team preliminary question b) Gray clarifications											
12)Construction minerals	Buffer zone	a)Presence of a quarry or other surces for construction material b) building stones, aggregates, limestone, structural clay, gypsum, sand, volcanic products,bitumen.	**Construction minerals are the following a)Building stones -**factors that make a rock becoming a building stone are : structural strenght, durability, appearance, easy of working, availability. (Sedimentary rocks, ignous rocks- granite,dimension stones, armourstone **b)Aggregates** (collection of rocks particles) **c) Limestone** (cement, volcanic ash,) **d)Structural clay** (clayely sediment), **e) Gypsum** (plaster) **Glass sand, f) Vulcanic products** (volcanic ash provide clay fraction in cement production)	Abiotic factors which influence the provisioning of construction minerals are based on the rock type within the geosite.									Construction Mineral and its extraction are sources of income and could be beneficial in terms of job for local population. Mineral provision is crucial for the modern society; however, the extraction and delivery processes should lead to sustainable practices.
		a) Phd team preliminary question b) Gray clarifications											
13) Industrial minerals	Buffer zone	a) Is the geosite located within a mineral extraction area? b)Presence of a mineral quarry	Industrial minerals are considered:any mineral, rock, or other naturally occurring material of economic interest except gemstones, and metallic ores or minerals. Minerals and rock mined for its non-metallic, value such as salt, sulphur, and stone. (Dictionary of Gems and Gemmology, 2019)	Are any extraction areas within the geosite? Yes =100 No=0									Industrial Mineral and its extraction are sources of income and could be beneficial in terms of job for local population. Mineral provision is crucial for the modern society; however, the extraction and delivery processes should lead to sustainable practices.
		a) Phd team preliminary question b) Gray clarifications											
14)Ornamental products	Buffer zone	a) Are any gemstones extraction area within the Geopark? B)Presence of gemstones	**Gemstones** are natural inorganic minerals that are used as precious stones in jewellery or ornaments. Although coloured gemstones and diamonds can both be considered gemstones, they are often treated differently as their supply chains vary distinctly. **Laurent E. Cartier, 2009.**	Are any extraction areas within the geosite? Yes =100 No=0									The direct benefit coming from the extraction and the selling of the ornamental products.
		a) Phd team preliminary question b) Gray clarifications											
15)fossils	Buffer zone	a)Is the geosite overlapping and extraction area for fossils? b) Presence of fossils	The shape of a bone, a shell, or a plant or animal that has been preserved in rock for a very long period- Definition **Cambridge Dictionary**	Are any extraction areas within the geosite? Yes =100 No=0									are costantly monitored by International, National and Regional levels. It is very clear the connection with abiotic factors which lead to existing mineral fuel deposits, due to the immediate economic benefits linked to it.
		a) Phd team preliminary question b) Gray clarifications											
	Cultural: geosite within the buffer zone		**CULTURAL**										
16) Environmental quality		a) Presence of a natural features which improves our lives in some non material way b) Aesthetic appeal of the landscape, landform which enrich our spirit c)Is the geosite contributing to the aesthetic value of the area by providing diverse landscape morphology?	**Landscapes have aesthetic appeal**, traditional geomorphological features can be defining as characteristic of some countries. Beauty of landscape is underestimated: it is responsible for the visual interest and for the tourist interest.	The CULTURAL AND EDUCATIONAL values are part of the so called "additional values" defined by Reynard 2007- "aesthetic value" - we use the same criteria.**two simple criteria: VP (view points) and STR (structure).** The first one takes into account the visibility of a site. A site covered by a forest or very difficult to access would, in this case, have a lower score than a site visible from several viewpoints. The second criterion takes into account research into landscape perception which indicates that contrasting landscapes, land- scapes with a vertical development or landscapes with individual elements that give that space structure are generally considered the nicest. Consequently, sites with colour contrasts (e.g. contrasts due to lithological changes), with high vertical development (e.g. peaks) or with spatial structures (e.g. morainic arcuate ridge that closes a valley, braided rivers) will receive a higher score than monotone reliefs (e.g. alluvial plain, large plateau). The «aesthetic value» corresponds to the arithmetical mean of the two criteria: AEST = (VP + STR)/2.	Visibility of the site; landscape [illegible]								Benefits linked with cultural and knowledge services are covering the local, regional and national level. The aesthetical values of the landscape are directly coming from the biotic and abiotic services, however they do not give directly benefit to the society but indirectly ones linked with tourism and leisure possibilities which are crucial in UNESCO Global Geoparks.
		a) Biotic indicator b)Gray defintion c)Preliminary Phd question											
17) Geoturism and leisure		a)Presence of leisure activities connected with the geosite's geodiversityb) Tourism based on an area's geological or geomoprhological resources that attempts to minimise the impact	**Abiotic: topographic diversity (sky), diversity of rock types (climbers), landscape diversity(golf, hiking).Geological forms**(landforms-landscapes) **Processe**s (how the landforms are formed) and **what time** (when -how long these processes occured) -	Abiotic factors which influece Geotourism are: topographic diversity (sky), diversity of rock types (climbers), landscape diversity(golf, hiking).Geotourism is a new form of tourism based on the geological environment.It promotes tourism to geo-sites and the conservation of geodiversity and an understan-ding of earth sciences through appreciation and learning. This is achieved through visits to geological features, use of geo-trails and view-points, guided tours, geo-activities and patronage of geosite visitor centres - Geotourism is a form of tourism focused on geology and landscape **This is the essence of geotourism which starts with the understanding of geology interpreted through its components of Form (landforms and landscape), Process (how the landforms originated) and Time (when these processes occurred and how long they lasted). This forms the basis of a more holistic understanding of the environment and its component parts and thus, provides the residents or tourists with a greater connection to the environment in which they live or are visiting (Dowling. R.k.2013)**									Directly consequenses of the above services are the ones related with geoturism and leisure activies.
		a)Phd preliminary question b)Gray Definition		Hargitai H., Kereszturi Á. (eds): Encyclopedia of Planetary Landforms. Springer. https://link.springer.com/referencework/10.1007/978-1-4614-3134-3	**Pereira 2012**,Assessme[illegible] **2005:** A PROPOSAL FOR [illegible] (2013). Global Geotour[illegible] 10.2478/cjot-2013-0004 [illegible] **activities promoting hea**[illegible] livingsystems that ena[illegible] interactions (code 3.1.[illegible]								Recreation and nature-based tourism **are important sources of income and employment in many places around the world.** The total value of international tourism exceeds $444 billion (World Bank 1999). Nature-based tourism (sometimes called environmental tourism or ecotourism, al- though strictly speaking, the latter is a subset of nature-based tourism and includes certain ethical considerations) may comprise 40–60% of this total. The recreational benefit from nature also contributes to the health and social relations dimensions of well-being, as there is a correlation between green areas, good air quality, and human health-Linking Ecosystem Services and Human Well-being (Chapter3)- Anthony McMichael, Robert Scholes-Chapter3 Millennium Assesment.

					"The way in which individuals react and interpret the natural environment is a multi- faceted phenomenon, and the ways in which various individuals derive or attach meaning from various landscapes is equally complex" (Fredrickson & Anderson, 1999, p. 35). Re- cent empirical research confirms a multitude of components that influence the relationship between nature-based recreation and spirituality. Existing models of nature-based recre- ation and spirituality have tended to focus on one or some of the components involved in this relationship - **Paul Heintzman (2009) Nature-Based Recreation and Spirituality: A Complex Relationship, Leisure Sciences, 32:1, 72-89**. Consistent with this conception, **Natural England (2009) provides the following definition of the spiritual in a UK context**: "a deep-seated, harder-to-assess value, often delivered in more solitary moments; could be delivered by iconic wildlife, or a single feature tree, as well as by more traditional features such as burial mounds, standing stones, or churches. Also associated with water (still lakes or slow-moving streams and rivers) and with high places; can be created by the weather, such as a dramatic shaft of light or particular colours " (compare Radford and James, 2013). The 'past received through objects and display, representations and engagements, spectacular locations and events, memories and commemorations, and the preparation of places for cultural purposes and consumption' (**Waterton and Watson, 2015 IN Assessing and quantifying offered cultural ecosystem services of German river landscapes- 2020 (MENDELEY;)**								
18) Cultural- spiritual and historic-		a)abiotic provisional indicators-Gray and Phd team	Abiotic: number of mith, historical facts, archaeological features connected with the geosite.		**For environmental aesthetics, instead, Carlson claims that the most legitimate and 'objective' source will be the natural sciences, such as geology and biology. Such knowledge, the argument goes, will ensure aesthetic judgments accord with their objects, enabling a grasp of relevant aesthetic qualities.In this approach, with scientific knowledge in tow, we are able to appreciate aesthetic qualities that are otherwise unnoticed or misapprehended.** Such knowledge can also enable us to appreciate ecological processes and find value where previously we did not. Most relevant to our discussion here is that objectivity can be difficult to achieve in practice, not least because of the variety and diversity of experience, background and values that people bring to aesthetic appreciation of nature (Brady, 2003, Moore, 2008, Parsons, 2008). Approaches that allow for more diversity and, specifically, jettison the requirement of knowledge of the sciences, include those which emphasise intersubjectivity of aesthetic values (Brady, 2003, Brady, 2016). This idea, which originates in Hume and has been widely discussed in aesthetics, suggests that works of art which have been admired for generations come to belong to a canon of great art. Similarly, we find something like a set of natural places, species, etc., which have become deeply valued over time and across communities, as evidenced by forms of legal protection and designations such as national parks and World Heritage sites. These legal protections may be seen as the practical application of the duty of care derived at least in part from the shared objectivity, or intersubjectivity, of aesthetic value. Any working definition should be specific to the culture of the people whose valuations are being sought- **Esthetic and spiritual values of ecosystems: Recognising the ontological and axiological plurality of cultural ecosystem 'services' (2016)**								Benefits for the society related with cultural, historical values of the biotic and abiotic services are strictly connected with their interpretation and valorization at National , Regional and Local level, of curse higher is the effort for interpretation, higher is the possibility to increase the awarness and the economic benefits for a territory.
		a)Presence of myths, historical facts, archaeological features and spiritual heritage connected with the geosite- How many spiritual factors are linked within the geosite ?	Number- of **historical facts** within the geosite: from 1-5 >50 more than 5 >100; Number of **archaeological** features, from 1-5 >50 more than 5>100; **number of storytelling-miths** directly connecte with the geosite (linked to its geomorphological features, the landform processes, its shape, the connection with the environment and nature), **spiritual cannot be measured (see notes)**										
19) Artistic inspiration , both biotic and abiotic.		a)Presence of art related with the geosite b) I: Number-area of landscape features or species with inspirational value, actual number of books, paintings using ecosystem as inspiration	Number of known paintings, art installation within the Geopark, using the geological landscape as source of inspiration.		**see "Assessing and quantifying offered cultural ecosystem services of German river landscapes (2020)"**								
		a)abiotic provisional indicators-Gray and Phd team b)biotic												
20) Social development		a)Presence of local activities promoting communities and personal development based on the geosite's contents- Local geological related activities, voluntary groups (Gray)	Number of specific activities linked with the geosite like folklore, fairs, art performances, local voluntary association											The development of activities related with the geosite and geological heritage could support the strenghten of "sense of belonging" to the citizens whihc is crucial for successfull development strategies and geoparks.
		a)abiotic provisional indicators-Gray and Phd team												
21)Earth history *		a) Geological record as research value b)Presence of geological elements which are international value following the IUGS criteria (peer reviewed and published researches)	Number of international publications concerning the geosite, (eventhough I consider the criteria very dependign on research funds by universities, research insitutions or Governements.)	Scientific experts who make a globally comparative assessment based on the peer-reviewed, published research conducted on geological sites within the area (see STATUTES OF THE INTERNATIONAL GEOSCIENCE AND GEOPARKS PROGRAMME)										
		a) Gray definition b) Phd team definition												
22) History of research *		a) Geological record as research value b)Presence of geological elements which are international value following the IUGS criteria (peer reviewed and published researches)	Number of international publications concerning the the history of the research connected with the geosite which contribute the History of research development, (eventhough I consider the criteria very dependign on research funds by universities, research institutions or Governements.)	Scientific experts who make a globally comparative assessment based on the peer-reviewed, published research conducted on geological sites within the area (see STATUTES OF THE INTERNATIONAL GEOSCIENCE AND GEOPARKS PROGRAMME)										
		a) Gray definition b) Phd team definition												
23) Environmental monitoring and forecasting		a) Record of sediments in lakes, bogs and ice cores, monitoring impact on human activities b) Presence of monitoring station for sampling purposes or for meteorological purposes	Number of monitoring stations for sampling or metereological purposes-											The benefits are linked with the possibility of monitoring geohazards phenomena, human activities. As consequence at all level , proper monitoring is landing into protection of local populaton and appropriate urban planning.
		a) Gray definition b) Phd team definition												
24) Geoforensis		a) Linking suspects to crime scenes b) Presence of evidences linked with a possible solution of a crime investigation	Number of evidence linked with a possible solution of a crime investigation ,											
		a) Gray definition b) Phd team definition												
25) Education and employment *		Gray definition: Presence of geological record with a role in education and training Phd team: Presence of educational activities based on educational geosite contents; Biotic I: presence of features with special educational and scientific values or interest, number of classes visiting, number of scientific studies.	Number of educational activities related with the geosite within the school of the territories from kindergarden to university,											The benefits are linked with the awarness of people concerning their heritage which can lead in establishment of local associations, groups or volunteers for its valorization and protection. Educated citizens disemiante good practices concering the environamental and geological heritage protection.
		a) Gray definition b) Phd team definition												
		* Earth history, History of Research , education and eployement are connected in matter of benefits for the society, all three services are linked with the capacity of developing educational services, materials, and agreed identity of the Institutions in charge for the development of the territory.												

ABIOTIC SERVICE	**VARIABLES FOR ASSESSMENT**	**Geosites**	**Comments on results**	**Results**		
Regulating	**BUFFER ZONE IN USE FOR ALL THE GEOSITES**					
		Eigeroy				
1) Atmospheric and oceanic processes. The combination of oceanic and atmospheric circulation drives global climate by redistributing the heat	**SIX FACTORS**: **Altitude,Climate,Mountain presence, Slope exposure,Sea water proximity,wind exposure.**	Altitude: Score= 100; Climate Zone=50, Mountain presence=10; Slope exposure= 50 ; Water influence=100; No protection against the wind =10	With respect to the atmospheric and ocean processeEigerøy is less protected than others. Higher score=more protection - The Geosite is offering less protection compared to the atmosferic processes, the geosite low mitigates the negative effect in the area.	53,00%		
		Prato Sesia				
	ALTITUDE Below 500 m a.s.l. = 100 From 500 to 1000 m a.s.l. = 80 From 1000 to 1500 m a.s.l. = 50 From 1500 to 2500 m a.s.l.= 30 From 2500 to 3500 m a.s.l. = 10	Altitude= 100; Climate =50; Mountain Presence =100; Slope exposure=50; Water influence=10; Wind = 50	With respect to the atmospheric and ocean processes,Prato Sesia is more protected than Eigeroy. Higher score=more protection - The Geosite is offering more protection compared to the atmosferic processes, the geosite mitigates the negative effect in the area.	60,00%		
		Jøssingfjord				
	CLIMATE ZONE Arid = 100 Temperate= 80 Continental = 50 Tropical = 30 Polar = 10	Altitude= 100;Climate= 50; Mountain Presence = 10; Slope exposure=100 ; Water influence=100; Wind =50	Jossingfjord is more protected than Eigeroy	68,3%		
		Crevola				
	MOUNTAIN CHAIN No mountain = 10 mountain presence between 100 km to 70 km = 30 mountain presence between 70 km to 50 km = 50 mountain presence between 50 km to 30 km = 80 mountain presence closer than 30 km = 100	Altitude=100;Climate= 50; Mountain Presence=100; Slope exposure= 50; Water Influence=10; Wind=50	Same as Prato Sesia	60,00%		
	Slope EXPOSURE NOTHERN HEMISPHER: South=100; Flat area =50; W-E=20 N=10					
	Slope EXPOSURE SOUTHERN HEMISPHER: North=100, Flat area =50; W-E=20; N=10					
	SEA WATER PROXIMITY From and < to 10 Km=100 (warmer), From 10 km to 30 km= 80, From 30 km to 50 Km = 50 From 50 km to 100 km = 30 and abov 100= 10(colder)					
	WIND EXSPOSURE PROTECTION: Very open=10; Partly =20; Well protected =50; Protected =100					
2)Terrestrial processes	**4 FACTORS and 7 SUBFACTORS: Crustal mobility,erosion, transportation,deposition**	**Eigeroy**				
	CRUSTAL MOBILITY a)rate of crustal mobility: Peak of Ground Acceleration High=over 0,90 = 100; Between 0,90 to 0,20= Medium=50 ; 0,05-0,20 Low=-30; 0,02= No mobility=10	Crustal mobility=10 Erosion=50+10+50+10+10+100+10; Transp.=10 ;Dep= 10	Eigeroy geosite is not affected by relevant terrestrial processes due to the absence of soil and the majority of magmatic rocks, so it offers the lowest contribute to the abiotic ecosystem service N.2.	27,00%		
		Prato Sesia				
	EROSION a)Is the geosites located in a river band or in the proximity of glacier or on a shore?a)Yes (one of the three)= 100 Partially =50 No=10 **b)Which are the minerals and structural properties of the most common rock within the geosite?** Sedimentary rocks (calcite)= 100 Clay (pyroxene,feldspar, clastic metamorphized sediments)= 80 Magmatic rocks (quartz)=10 **c) Is the geosite covered by soil?**Yes= 10 , Partly =50 No=100 **d) Is the geosite subject to drop of temperature and permeable rocks?** Yes, with high exposure=100 Medium Exposure= 50 No=10 **e) Is the geosite subject to high precipitation or washout?** e)Yes with high exsposure=100, Medium Exposure= 50 No=10 f**)Is the geosite subject to wind exposure?** Yes with high exposure= 100, Medium exposure= 50 No=10 **g)Average slope gradient** h) Above 37% =100 Middle (average)=50 Under 37%= 10	Crustal Mobility=10 Erosion=(100+80+50+10+100+50+10) Trasp.=100 Dep.= 100	Prato Sesia Is the geosite most influenced by terrestrial processes due to the overlapping of the geosite to the Sesia river bend which maximize the washout and the transportation-deposition phenomena. Rock here are clastic sediments metamorphized, so easier to be eroded compared to the magmatic rocks characterizing the others geosites.	61,00%		
	TRANSPORTATION a) Yes there is high rate of transportation = 100 Medium=50 Low=30 No transportation=10	**Jossingfjord**				
	DEPOSITION a) Yes there is high rate of deposition = 100 Medium=50 Low=30 No deposition=10	10+(50+10+50+10+50+50+50)+30+30	Highest deposition and transportation than Eigeroy because of the presence of morain deposits which originated soil.	34,00%		
		Crevola				
		10+(100+10+50+50+50+50+10)+50+50	There is a dam which regulate washout, deposition and transportation which are than lower than Prato Sesia but higher than in Jossingfjørd due to the geosite location inside a river bend. Different rocks than Prato Sesia	42,00%		
3) Flood control Abiotic processes to be integrated with the biotic services: 3-4-6-7	**Presence of Landform, Amount of precipitation, Flood return period,Maximum Water discarge,Sea tide and Average wind speed = 5 FACTORS**	**Eigeroy**				
	N. LANDFORMS: Zero=10; 1-2=20;3-4= 50; more than 4=100	20 +10+100+ 100+90= 320		64,00%		
		Prato Sesia				
	AMOUNT OF PRECIPITATION 3 Mt/year =100, from 1-3 Mt/year =50, from 1 Mt/year to 0,5 Mt=20, less than 0,5 Mt or no river-lake= 10	10+ 50(1000mm/year average)+ 50+20(70.4 average-mq/sec)+100= 230		46,00%		
		Jossingfjord				
	FLOOD RETURN PERIOD No river or lakes= 100. More than 50 years flood return period = 90. From 25 to 50 years flood return period= 50. From 3 to 5 years flood return period=10.	20 + 10+100+100+90= 320		64,00%		
		Crevola				
	MAXIMUM WATER DISCARGE No river= 100 Less than 10 qmt3/sec/ average par month =90 points. from 10-50 qmt3/sec/ average par month =60. From 50-500 qmt3/sec/ average par month =20. Above 500 mt3/sec/ average par month= 10.	20 + 50+50 +20+100= 240		48,00%		
	SEA TIDE and AVERAGE WIND SPEED No sea= 100 From 0 to 1 Mt and less then 10 Mt/S wind =90 From 1-3 Mt and above 10 Mt/s wind= 60 From 3-8 Mt and above 15 Mt/s wind=20 Above 8 Mt and above 25 Mt/s wind= 10					

4) Water quality regulation: role of soils, sediment and rocks	**Minerealogic properties+ permeability= 2 FACTORS**	**Eigeroy**				
	MINEREALOGIC A)Is the geosite characterized by limestone, dolomite or gypsum? Yes =100 No= 10 B) Is the geosites characterized by gypsum, iron sulfated? yes=100 No=10 C) Is the geosite characterized by magmatic rocks Yes=10 No= 100	Min(10+10+10)+ Perm (10+10+10)=60		10%		
	PERMEABILITY b)Is the geosite characterized by gravel? Yes =100 Medium=50 No=10 Characterized mostly by sand? Yes=100 Medium=50 No=10 Characterized by Clay- Yes=100 Medium=50 No=10	**Prato Sesia**				
		(10+10+10) + (50+50+10)=140		23,3%		
		Jossingfjord				
		Min(10+10+10) +Perm (10+10+10)=60		10%		
		Crevola				
		(10+10+10)+ (50+50+10)=140		23,3%		
Supporting	**BUFFER ZONE IN USE FOR ALL THE GEOSITES**					
5)Soil processes.	**Erosion+ Transportation+Depostion +Agricultural activities+forest= 5 FACTORS**	**Eigeroy**				
a) **EROSION** b) **TRANSPORTATION** Yes there is high rate of transportation = 100 Medium=50 Low=30 No transportation=10 c) **DEPOSITION** a) Yes there is high rate of deposition = 100 Medium=50 Low=30 No deposition=10	**EROSION a)Is the geosites located in a river band or in the proximity of glacier or on a shore?** a)Yes (one of the three)= 100 Partially =50 No=10 **b)Which are the minerals and structural properties of the most common rock within the geosite?** Sedimentary rocks (calcite)= 100 Clay (pyroxene,feldspar, clastic metamorphized sediments)= 80 Magmatic rocks (quartz)=10 **c) Is the geosite covered by soil?** Yes= 10 , Partly =50 No=100 **d) Is the geosite subject to drop of temperature and permeable rocks?** Yes, with high exposure=100 Medium Exposure= 50 No=10 **e) Is the geosite subject to high precipitation or washout?** e)Yes with high exsposure=100, Medium Exposure= 50 No=10 f)**Is the geosite subject to wind exposure?** Yes with high exposure= 100, Medium exposure= 50 No=10 **g)Average slope gradient** h) Above 37% =100 Middle (average)=50 Under 37%= 10	Erosion=50+10+50+10+10+100+10; Transp.=10 ;Dep= 10	No agriculture= 10 Forest= 10	25,45%		
AGRICULTURAL ACTIVITIES within the geosite active agricultural activities (crop cultivation, vineyard, orchard) Yes= 100 in the past =50 No=10	b) **TRANSPORTATION** High rate of transportation = 100 Medium=50 Low=30 No transportation=10					
PRESENCE OF FOREST - Is the geosite hosting a wild -not managed forest? Partially =50 Managed forest (at the moment)=100 No forest= 10	c) **DEPOSITION** high rate of deposition = 100 Medium=50 Low=30 No deposition=10	**Prato Sesia**				
	AGRICULTURAL ACTIVITIES within the geosite active agricultural activities (crop cultivation, vineyard, orchard) Yes= 100 in the past =50 No=10	Erosion=(100+80+50+10+100+50+10) Trasp.=100 Dep.= 100	No agriculture=10 Forest = 50	60%		
	PRESENCE OF FOREST - Is the geosite hosting an unmanaged forest ? Fully covered by a forest=100 Partially covered by forest =50 No forest= 10					
		Jossingfjord				
		(50+10+50+10+50+50+50)+30+30				
			No agriculture=10 Forest = 50			
		Crevola		35,45%		
		(100+10+50+50+50+50+10)+50+50				
			No agriculture=-10 Forest = 10	40%		
6) Habitat provision.	**TYPE OF GEOLOGY+ GEOMORPHOLOGICAL PROCESS+ SOIL DIVERSITY+GEOMORPHOLOGY = 17 factors**	**Eigeroy**				
		T.G. 40(plagioclaste- ortopiroxene-ilmenite)+10+10+G.(Trasp.+Dep.=20)+ SOIL DIV.(10+10+30+10+100+10)+ Geomorphology 30 (lake, pottols,bay)+ (Hidrology) 10+10+10+10+100		38,1%		
TYPE OF GEOLOGY - 3 factors		**Prato Sesia**				
Highest is the geodiversity higher is the biodiversity higher is the habitat provision of the geosite		TG. 100+70+50(eathquakes)+G (Trasp+Dep. (100+100))+ SOIL DIV. (10+50+10+50+50+10)+ Geomorphology 30+ Hidrology 70mt3/sec 10+10+50+50+100		77,2%		
a)Hardrock fossils and mineral distribution (fossils, ornamental stones- natural resources, coal, gas, ore deposit, type fo minerals?) Any source ? 0-1 =10 From 2-4=40 from 5-7= 70 from 8-10 =100						
b)Unconsolidate Deposits (surface distribution of parents materials resulting from geomorphological processes- distribution/scarcity o materials like sand-dynamics of surface materials- sedimentation), 0-1 =10 From 2-4=40 from 5-7= 70 More than 7 =100						
c)Geophysical processes (variability of the intensity of geophisical processes- earthquacke, volcanic eruptions, earth radioactivity, thermal energy, land subsidence;) (number of happenings-antropocene) 0= 10; 1-5= 50 6-10=100						
GEOMORPHOLOGICAL processes - 2 factors		**Jossingfjord**				
a) **TRANSPORTATION** High rate of transportation = 100 Medium=50 Low=30 No transportation=10 ; b) **DEPOSITION** high rate of deposition = 100 Medium=50 Low=30 No deposition=10		T.G 40 (plagioclaste- ortopiroxene-ilmenite)+40+ 10+ G (Transp.+Dep. (30+30)+ SOIL DIV. +(10+50+50+50+50+100)+Geomorph. (bay, fjord, ocean,waterfall)50 +Hidrology 10+10+50+30+50		60%		
SOIL DIVERSITY -6 factors		**Crevola**				
a)Which are the minerals and structural properties of the most common rock within the geosite? Index of erosion? Rocks made of clay = 100 , Limestone= 80 Low metamorphic rocks =30 Magmatic rocks =10 **b) Is the geosite covered by soil?** Yes= 100, Partly =50 No=10 c**) Is the geosite subject to drop of temperature and permeable rocks?** Yes, with high exposure=100 Medium Exposure= 50 low exposure =30 No=10 d**) Is the geosite subject to high precipitation or washout?** Yes, with high intensity=100, Medium intensity = 50 low intensity =30 No=10 **e)Is the geosite subject to wind exposure?** Yes with high exposure= 100, Medium exposure= 50 Little exposure =30 No=10 **f)Steepness of the slope** Above 37% =100 Under 37%= 10		TG.100+70+50(eathquakes) +G (Trasp+Dep.)50+50+ SOIL DIV. (10+10+50+50+50+10)+ Geomorphology 40+ Hidrology 10+10+50+50+ 50 (one damn)		64,5%		
GEO-MORPHOLOGY - 1 factor						

How many landforms can we eventually detect in a geosite? (Aeolian Landforms, Coastal-Oceanic, Erosion, Volcanic- mountains, plain,hills, plateau buttles, canyon, valleys, caves,deserts, and basins) list at: http://worldlandforms.com/landforms/list-of-all-landforms/ One=10; 2-3= 30 4-5=50 6-8= 80 From 9-= 100. Lower is the erosion index, lower is the quantity of soil eventually produced.						
HYDROLOGY - 5 factors						
ROCKS PROPERTIES a)Is the geosite mainly characterized by limestone, dolomite or gypsum?Yes =100 No= 10 **b) Is the geosites mainly characterized by gypsum, iron sulfated?** yes=100 No=10 , **c)PRESENCE OF FRESH WATER (lakes, springs,rivers, glaciars)** More than 5= 100, between 3-5= 70 Between 1-3= 50 No =10 **d)RIVER DYNAMIC** No river within the geosite=10 Small river, less than 10 mt3/sec =30 Small to medium river mt3/sec =10-100 =50 Medium river mt3/sec =100-500=80 large rivers ,above 500 mt3/sec = 100 **e)DAM (dam is interferring ewith the natural hidrology of the geosites-** Zero= 100; One- Three= 50 More than 4=10						
a)b)The presence of certain type of rocks is connected with the permeability of the rocks and consequentely with the presence and quality of aquifers and undeground drinking water.						
7) Land as a platform for human activities	**AGRICULTURAL ACTIVITIES + BREEDING+ LAND AND FORESTRY+ BULDING = 4 FACTORS**					
Agricultural activities		**Eigeroy**				
Is within the geosite any active agricultural activities (crop cultivation, vineyard, orchard) More than 80% of the geosite is occupied by cultivation= 100 Between 60-80% is occupied by cultivation=60 Between 10-60%= 40 No cultivation=10		10+100+10+40= 160		40%		
Animal husbandry and cattle farming activities		**Prato Sesia**				
Is in the geosite any active animal husbandry and cattle farming activities? Yes, more than half of the hectares are used as husbandry-farming=100 Partly, less than 30% of the hectares are used =50 No surface used for this purpose= 10		10+10+50+10 =80		20%		
Activities related with forestry management		**Jossingfjord**				
Is any activities related with managing of forest in the geosite ? Yes, more than half of the hectares=100 Partly, less than 30% of the hectares =50 No forest =10		10+50+50+40=150		37,5%		
Presence of artificial contructions		**Crevola**				
Is any artificial building in the geosite? Town presence =100; presence of a village=60; Presence of several separate houses or artificial contructions= 40 No= 10		10+10+10+40= 70		17,5%		
8) Burial and storage.	**a) human burial b) radioactive waste deposits c) ground store for water,oil, gas, carbon and carbon dioxide = 3 FACTORS**	**Eigeroy**				
Is within the geosite any human burial which adopted gravestones? Yes=100 , Partially= 50 No= 10		10+10+10=30		10%		
Is within the geosite any waste deposit? Yes=100 , Partially =50 No=10		**Prato Sesia**				
Is within the geosite any ground store for water,oil, gas, carbon and carbon dioxide, Yes=100; Partially =50 No= 10		10+10+10=30		10%		
		Jossingfjord				
		10+100+10=120/3		40%		
		Crevola				
		10+10+10=30		10%		
Provisioning	**Buffer Zone**					
9)Food and drink- (Food from agiculture and water)	**SOIL FERTILTY+WATER REGULATION+PRESENCE OF FRESH WATER+ TEMPERATURE CLIMATE=4 FACTORS**					
SOIL FERTILITY: Is the geosite affected directly by agricultural activities- or/and classified as cultural landscape? Yes=100 Partially =50 No= 10 Is the geosite directly affected by soil pollution Yes= 10 Partially =50 No=100 Is the geosite indirectly (nearby) affected by soil pollution? Yes= 10 Partially =50 No= 100		**Eigeroy**				
WATER REGULATION A)MINEREALOGIC PROPERTIES 1)Is the geosite characterized by limestone, dolomite or gypsum? Yes =100 No= 10 2)Is the geosites characterized by gypsum, iron sulphated? yes=100 No=10 **PERMEABILITY** 3)Is the geosite characterized by gravel? Yes =100 Partially =50 No=10 4)Characterized mostly by sand? Yes=100 Medium=60 No=10 5)Characterized by Clay- Yes=100 Partially=50 No=10 **SEE ABIOTIC SERVICE 4**		**Soil fertility** 10+ 100 **Water R**: 10+10+10+10+10 **P.Fresh water**: 10 **Temperature-climate**: 100; 50, 10; 50 ; 100; 10		24%		
PRESENCE OF FRESH WATER-Presence of lakes, ice sheets or rivers in the vicinity Is any lakes, ice sheets or rivers in the vicinity? Yes at least one of the three features =100 No of lakes, ice sheets or rivers=10		**Prato Sesia**				
TEMPERATURE-CLIMATE , Altitude+Latitude+mountain presence+water proximity+wind exposure+ Slope exposure -higher is the score higher is the influence on climate- **ECOSYSTEM SERVICE N1**		**Soil fertility** 10+ 100 **Water R:** 10+10+50+10+10 **P.Fresh water:** 100 **Temperature-climate:** 100+ 50+ 100+ 50+10+ 50		46,4%		
		Jøssingfjord				
		Soil fertility: 10+ 50 **Water R**: 10+10+10+10+10 **P.Fresh water**: 100 (river) **Temperature-climate**: 100+50+10+100+100+50		44,2%		
		Crevola				
		10+10+50+10+10 **Fresh water:** 100 **Temperature-climate**:100+ 50+ 100+ 50+ 10+50		47,1%		
	On geosite					
10)Nutrients and minerals for healthy growth	**1 FACTOR**					
		Eigeroy				
		10+10		10%		
		Prato Sesia				
		30+10		20%		
MINEREALOGIC a) Is the geosite characterized by limestone, dolomite or gypsum? Yes, all three =100 two of them =50 One of them= 30 None= 10 **b)** Is the geosites characterized by gypsum, iron sulfated? Yes, all =100 One of them= 50 None= 10		**Jossingfjord**				
		10+10		10%		
		Crevola				
		30+10		20%		
	Buffer zone					
11)Mineral Fuel -Abiotic factors to be considered together with biotic indicators	**1 FACTOR**	**Eigeroy**				

Is the geosite characterized by (coal and peat, petroleum, renewable energy) plants ? Yes, all three =100 two of them =60 One of them= 30 None= 10		30% (wind power)		10%		
		Prato Sesia				
		10%		10%		
		Jossingfjord				
		60% (wind and hydro power instalations)		60%		
		Crevola				
		30% - hydro powerstation		30%		
	Buffer zone					
12)Construction minerals	**1 FACTOR**	**Eigeroy**				
Is the geosite characterized by extraction activities of construction minerals-number of listed rocks ? Three or more=100; Between one to three=60; one=30; none=10		10		10%		
		Prato Sesia				
		30 (aggregates)		30%		
		Jossingfjord				
		10		10%		
		Crevola				
		10		10%		
	Buffer zone					
13) Industrial minerals	**1 FACTOR**	**Eigeroy**				
		30 (base metals, iron ferro)		10%		
Is any extraction of minerals and/or rock mined for its no metallic, value such as salt, sulphur, and stone areas within the geosite? Three or more=100; Between one to three=60; one=30; none=10		**Prato Sesia**				
		10		10%		
		Jossingfjord				
		30 (Ilmenite)		30%		
		Crevola				
		10		10%		
	On geosite					
14)Ornamental products	**1 FACTOR**	**Eigeroy**				
Is the geosite characterized by extraction activities of ornamental gemstones-? Three or more=100; Between one to three=60; one=30; none=10		10		10%		
		Prato Sesia				
		10		10%		
		Jossingfjord				
		10		10%		
		Crevola				
		10		10%		
	On geosite					
15)fossils	**1 FACTOR**	**Eigeroy**				
		10		10%		
Is the geosite characterized by extraction activities of fossils-? Three or more extraction points=100; From two to three=60; one=30; none=10		**Prato Seisa**				
		10		10%		
		Jossingfjord				
		10		10%		
		Crevola				
		10		10%		
Knowledge and Cultural service	**Buffer zone**					
16) Environmental quality Aesthetic appeal of the landscape, landform which enrich our spirit c)Is the geosite contributing to the aesthetic value of the area by providing diverse landscape morphology	**2 FACTORS**	**Eigeroy**				
VP: How many view points (free from view obstacle) within the geosite? More than 10=100 ; Between 4-10= 60; Between 1-3= 30 None=10		100 (clean from vegetation)+40 (color contrast between anorthosite and the sea; contrast between pottholles,cracks and the landscape)		70%		
STR: How many elements like colour contrast, mountain peaks or specific spatial structures are within the geosite? More than 10=100 ; Between 4-10= 60; Between 1-3= 30 None=10		**Prato Seisa**				
VS: visibility of a site (is the site "clean" from vegetation?) **STR:** number of individual element which give idea of "space structure"colour contrasts (e.g. contrasts due to lithological changes), high vertical development (e.g. peaks) spatial structures (e.g. morainic arcuate ridge that closes a valley, braided rivers) The «aesthetic value» corresponds to the arithmetical mean of the two criteria: AEST = (VP + STR)/2.		100+river band in contrast with mountain on the background (20)		60%		
		Jossingfjord				
		100(clean from vegetation)+mountain peak, fjord valley, contrast with the shore line 60		75%		
		Crevola				
		30 (geosite doesn´t have many points of good visibility which are easy access)+river band in contras with mountain on the back (30)		30%		
	Buffer zone					
17) Geoturism and leisure-						
		Eigeroy				
Number of landforms-landscapes visibile within the geosite? Higher is the number higher is the final score- 0=10 ,1-3=30 From 4 to 8= 80;9 or more=100 -	**3 FACTORS**	glacial erratics =6 (80); Precambrian, Proterozoic and quaternary= 3 (30); hiking, climbing, swimming, kayaking, coasteering		56,6%		
How many geological Era and Period? More than 10=100 ; Between 4-10= 60; Between 1-3= 30 None=10		**Jossingfjord**				
		Landforms: Kettle, moraine, fjord, islands, glacial erratics, screes, mountain =6 (80); Precambrian, Proterozoic and quaternary= 3 (30); hiking, climbing, kayaking, (50)		53,3%		
Number of leasure activities in the geosite? 10=100 ; 8-9=80; 5-7= 60; 3-4= 50; 1-2= 30 None=10		**Prato Sesia**				
		Landforms: Sesia River Bed (30) Periods: Permian and Quaternary (30) L.A hiking, fishing (30)		30%		
		Crevola				
		Landforms: Sesia riverbed, Varallo Sesia glacial terrace, Crevola Pothole= 3 (30); Periods: Permian, and Quaternary(30); L.A.= hiking, rafting (30)		30%		
	Buffer zone					
18) Cultural- spiritual and historic factors	**2 FACTORS**					

Cultural a)Are historical-archaeological manufacts linked within the geosites? 9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10 **b)Is the geosite linked with specific historical known documented facts?** 9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10		**Eigeroy**				
Spiritual: "Any working definition should be specific to the culture of the people whose valuations are being sought"-**It is therefore very complex to determine an omni comprehensive formula**		a)30 (WWII remains and the lighthouse); b)30 (WW2)		30%		
		Jossingfjord				
		a) 100 (2 Helleren; memorials: canoons,buldings, mines); B) 60 (Altmark episode; prehistorical settlements and living place from the XVIX century)		80%		
		Prato Sesia				
		10		10		
		Crevola				
		10		10		
	Buffer zone					
19) Artistic inspiration	**1 FACTOR**					
9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10		**Eigeroy**				
Number of known paintings, art installation within the Geopark, with the geological landscape as source of inspiration.		30 (installation inside the lighthouse)		30%		
		Jossingfjord				
		30 (wooden sculpture within the fjord-landscape art)		30%		
		Prato Sesia				
		10		10%		
		Crevola				
		10		10%		
	Buffer zone					
20) Social development	**1 FACTOR**					
9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10		**Eigeroy**				
Number of specific activities linked with the geosite that contribute to social development like: folklore, fairs, art performances, local voluntary association		30 fyrfestival		30%		
		Jossingfjord				
		30 (wooden dancing platform on the fjord)		30%		
		Prato Sesia				
		10		10%		
		Crevola				
		10		10%		
	Geosite					
21)Earth history	**1 FACTOR**					
		Eigeroy				
Number of international publications concerning the geosite which contribute to the Earth History development		100		100%		
		Jossingfjord				
		100		100%		
		Prato Sesia				
		100		100%		
		Crevola				
		100		100%		
	Geosite					
22) History of research	**1 FACTOR**					
9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10		**Eigeroy**				
Number of international publications concerning the geosite which contribute the History of research development		80		80%		
		Jossingfjord				
		80		80%		
		Prato Sesia				
		100		100%		
		Crevola				
		100		100%		
	Buffer zone					
23) Environmental monitoring and forecasting	**1 FACTOR**					
9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10		**Eigeroy**				
Number of monitoring stations for sampling of meteorological purposes-		30 (weather station)		30%		
		Jossingfjord				
		30 (pollution in the water)		30%		
		Prato Sesia				
		10		10%		
		Crevola				
		30		30%		
	Buffer zone					
24) Geoforensis	**1 FACTOR**					
9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10		**Eigeroy**				
Number of evidence linked with a possible solution of a crime investigation.		10		10%		
		Jossingfjord				
		10		10%		
		Prato Sesia				
		10		10%		
		Crevola				
		10		10%		
	Geosite					
25) Education and employment	**2 FACTORS**					
9-10=100; 6-8=80; 3-5=60; 1-2=30; none=10		**Eigeroy**				
Number of educational activities related with the geosite, run by the Geopark directly or in cooperation with the schools (from kindergarten to university grades)		Ornithological association activities, TeachOut App, Outdoor Organization Association activities (60); 80		70%		
		Jossingfjord				
		TeachOut App, Outdoor Organization Association activities (30) ;100		65%		
		Prato Sesia				
		Geopark activities with schools=30; 60		45%		
		Crevola				
Accessibility		Geopark activities with schools=30 ; 80		55%		
Accessible by anyone (including disable) by walk = 100; Acccessible by walk but not for disable = 80; Accessible by car with parking = 60; Accessible by car without parking= 30; Not accessible= 0						