



Geoheritage Conservation: Systematic Mapping Study for Conceptual Synthesis

Boglárka Németh¹ · Károly Németh¹ · Jon N. Procter¹ · Trisia Farrelly²

Received: 17 June 2020 / Accepted: 31 March 2021 / Published online: 4 May 2021
© The European Association for Conservation of the Geological Heritage 2021

Abstract

Geological resources are basic elements that have shaped both the course of human history and characteristics of human society. Protection of their imprint on our landscapes underlies the field of nature conservation known as geoconservation. Explicitly from 1991—when the term “geoheritage” was used at the First International Symposium on the Conservation of our Geological Heritage—a large body of literature has been produced with multiple conceptualizations. In response to challenges in finding a common definition of geoconservation, a systematic mapping of the scientific literature was undertaken to define key concepts supported by scientific evidence. The aim of this study was understanding the evolution of the research field between 2000 and 2019 to improve conceptual clarity. Relevant databases such as Google Scholar, Science Direct, and Scopus were searched, resulting in the identification of a total of 2478 studies. A method of systematic mapping with supervised keyword acquisition was used to assess geoheritage conservation documents. The analysis uncovered four recurrent concepts, each one describing a very different scope for geoheritage conservation: i) geoscience focus; ii) aligned conservation methods for geo- and biodiversity; iii) the concept of geomorphosites, as a leading resource for geoparks; iv) emphasis on community involvement for sustainability. For characterization of the concept groups, 70 findings were identified as primary articles following criteria implemented through direct reading. These criteria were derived from the identified keywords of each concept group. The information gained by the process allowed us to characterize and list all the major standpoints present in the scientific literature.

Keywords Geoheritage, · Geoheritage conservation, · Geoconservation, · Geoeducation, · Geosite, · Geomorphosite, · Intrinsic values, · Extrinsic values, · Fundamental values, · Additional values, · Geotourism, · Geodiversity, · Google Scholar, · Scopus, · Science Direct

Introduction

Rapid industrialization in both developing and developed countries has placed extreme pressure on geodiversity, on which geoheritage conservation depends (i.e., Belgium, Duser and Dreesen (2012); China, Wang (2007); Germany, Megerle (2012) UK, Prosser et al. (2018) Italy). Geoheritage conservation is more than a moral responsibility. Evolving technology and preserved geoheritage sites allow scientists to refine our knowledge on geological processes and engage

and educate the community through recreation. The principle of geology (Lyell 1833) “that the present is the key to the past and leads to the understanding of Earth’s future” (Rudwick 1998; Scott 1998) was acknowledged at the time against the background of the industrial revolution. Even so, the conservational value of geo(morpho)logy is a relatively new concept yet to be fully recognized.

Conservation practice in New Zealand faces the challenge of bicultural management. To create an indigenous specific geoheritage framework, a clear understanding of what this means in practice is mandatory. New Zealand is recognised as a country of bicultural governance (Te Papa 2004) based on The Treaty of Waitangi, signed between the indigenous Māori inhabitants of New Zealand and the Crown (Orange 1987). Subsequently, conservation and land management policies are required to consider principles of the treaty when undertaking actions. (Conservation Act 1987; Resource Management Act 1991). Bicultural decisions require meaningful consultation;

✉ Boglárka Németh
b.nemeth@massey.ac.nz

¹ School of Agriculture and Environment, Massey University, Turitea Campus, Palmerston North, New Zealand

² School of People, Environment and Planning, Massey University, Turitea Campus, Palmerston North, New Zealand

power-sharing agreements; and clearly laid out co-management strategies with relevant stakeholders (Rother 2016; Tipa and Welch 2006). Places and resources identified by Māori as having spiritual, ancestral, cultural, customary or historical significance are of high importance in any conservation strategy (NGA MANA WHENUA O TAMAKI MAKAURAU and THE CROWN 2012). Nature conservation can and should be based on indigenous values as presented in The New Zealand Biodiversity Strategy (2000). For example monitoring practices of testing waterways for their cultural health from a Māori world view perspective, interweaves environmental, and socio-cultural aspects (Harmsworth et al. 2016) (Harmsworth et al. 2016). In Māori culture, nature and people create a relationship that flows both ways, reflected in the term *tangata whenua*, which may be translated as “people of the land” (Stafford 2008). Local indigenous knowledge relating to *taonga* (this Māori term is often used to refer to objects, but can also include places, cultural landscapes, stories, and intellectual property (Craig et al. 2012) has a crucial role in conservation practices. The Resource Management Act, the main piece of legislation for the management of our environment requires local government and iwi authorities to participate equally in the policy making processes, (Resource Management Act 1991; Saunders 2017). However, application of this requirement is not clearly defined by further legislation; often remains unacknowledged in planning and legal processes; and may be widely open to interpretation by regional governance bodies and planning agencies (McCrossin 2013).

Systematic mapping is a useful tool to address and synthesize knowledge and conceptual diversity of a given domain by categorizing and visualizing existing literature and indicating directions for further review work (Grant and Booth 2009). The process initially uses a wide reaching search string able to extract the largest volume of studies related to the specific topic or research question (Ahmad et al. 2018; Petersen et al. 2008; Sebastián Rivera et al. 2019). This type of knowledge synthesis allows a narrowing towards subsequent policy and practice, and may give rise to further relevant questions without the need for a formal quality assessment (Lockwood et al. 2019). Systematic mapping was created as a method to compile a type of report that improves conceptual clarity and in turn improves the quality of policy outcomes. The procedure in turn leads to systematic reviews that are able to define the level of reliability of the identified implications (Haddaway et al. 2016). Healthcare has a long history in developing synthesis tools for monitoring the quality of research instruments through systematic reviews and meta-analysis. The value of systematic reviews may be weakened by poor conceptualization; however, basing it on prior systematic mapping will rectify this potential shortcoming (Reeves et al. 2010).

The concept of heritage is deeply entwined and rooted in human perceptions, memories, and sensations that allow

individuals to feel connected to their past. Systematic mapping with supervised keyword acquisition makes use of semantics to understand concepts, theories, conventions, and research within the scientific literature relating to any given field (de Souza Neto et al. 2018; Petersen et al. 2008). Within the discourse of geoheritage, concepts evoked from deeply embedded semantics and related terminology may differ according to socio-economic background, cultural history, and regional history. Supervised acquisition allows for a higher resolution analysis through algorithmic controls and allows filtering of domain specific semantics. Geoheritage has evolved into a major component of the discussion about recovering human and environmental wellbeing. As such, a report on simplified contexts where geoheritage appears is important.

Conceptual ambiguity can be observed in the variety of formula and terms employed to express geoheritage actions soon after the first mention of the term geoheritage at the First International Symposium on the Conservation of our Geological Heritage in 1991. Among the earliest publications outstanding geomorphology was addressed by the term geomorphosites, acknowledging the importance of relevant culture and aesthetics alongside geological research (Grandgirard 1997; Panizza and Piacente 1993). At the same time, geoheritage conservation was given a narrow definition, but still seen as vital to the progression of geological research, education, and training through the protection of geosites and outstanding geological features (Wimbledon 1999). Concerns were raised about prompt actions to take in order to avoid multilateral development of a range of conflicting geoheritage concepts (Wimbledon 1996).

The entwined relationship between promotion and visitation has added to the conceptual diversity. Publicity driven by geotourism can increase foot traffic to geoheritage sites thereby providing economic benefits to locals. Interpretive and service facilities offered by the geotourism industry have potential to facilitate appreciation, learning and research by and for current and future generations (Hose 2012); provide opportunities for conversation and increasing the scope of geoheritage conservation; and reinforce values of local communities and visitors (Bujdosó et al. 2015; Doorne 2000; Dowling 2011; Hose 1996; Newsome and Dowling 2006; Ruban 2015; Štrba 2018). Incorporating geoconservation into the broader field of nature conservation will achieve equal opportunities for geosites alongside sites preserved and promoted on the basis of other values, i.e., cultural, ecological, or aesthetic. Geoconservation includes geoheritage conservation as well as the protection of geodiversity as a contributing factor to biodiversity conservation. Geodiversity on the one hand defines abiotic factors such as geological, geomorphological, and soil environments, which in turn shape biotic factors such as species distribution patterns, climate and social landscapes (Anderson and Ferree 2010; Gray et al. 2013; Pickering 1994).

If providing resources for Earth Science research and increasing awareness is to be the basis of long-term geoheritage conservation plans, simply increasing visitation alone cannot guarantee that all relevant initiatives worldwide will develop satisfactorily in the long run. While literature reviews are abundant, they all address a specific branch within geoheritage (Brown et al. 2018; Cayla 2014; Comănescu et al. 2012; García-Ortiz et al. 2014; Kubalíková 2013; Miljkovic et al. 2018; Mucivuna et al. 2019; Ólafsdóttir and Tverijonaite 2018; Štrba et al. 2015; White and Wakelin-King 2014). A key problem affecting the field is that it rests on multilateral conceptualizations of geoheritage related activities. Robust conceptual boundaries advance the understanding of the most effective strategies to facilitate noncontroversial outcomes, and lead to development of powerful decision-making tools for key stakeholders.

Moreover, the recent history of geoheritage emphasises its fundamental role in sustainability. For example, geoheritage has become an increasingly important UNESCO “product” for local communities in form of administrative areas that are called geoparks. In many jurisdictions, Geoparks are not subject to the same level of strict “non-use” protection that National Parks may be subject to. Meanwhile, academics are highlighting the scope and scale of geoheritage conservation and whether it is in fact resulting in slow recognition and loss of important geological relics (Brilha 2016; Gordon et al. 2018a; Gordon et al. 2012; Grandgirard 1997; Gray 2004; Hayward 2009; Hose 1995; Németh et al. 2017; Panizza 2001; Prosser et al. 2006; Reynard 2008; Sharples 1998; Wimbledon 1999).

Geoheritage does not necessarily require strong measures from governments, it is more reliant on bottom-up initiatives and local expert’s knowledge (Brilha and Reynard 2018; Prosser et al. 2018). However, it has become crucial in our modern world to strengthen this bottom up approach with an evidence-based framework drawing on globally accepted values under the scope of geoheritage. Authorized bodies face hard decisions between the economic and life-supporting needs of society and environmental conservation based on intrinsic values. Generally speaking, geoheritage values can be seen as more robust and part of human history, in contrast to biodiversity values based on delicately balanced biotic systems. Therefore, we argue that geoheritage values can coexist with industrialisation and rapid urban developments within some common parameters. Industrial and economic developments can be seen as part of our geoheritage in the context of quarrying, mineral extraction, metallurgy, and tool-making evolution through human history. However, these parameters need to be set clearly and aligned with globally accepted criteria. Mindful industrial operation within geologically diverse and interesting landscapes can save small geoheritage objects such as outcrops, well-preserved fossils or even crystals paragenesis at a microscopic scale. This approach proves

that geoheritage is more a concept based on traditional touristic values such as aesthetics, and geotourism falls far outside the boundaries of more traditional or mainstream of tourism ventures.

To address the conceptual diversity, the goal of this study is to use systematic mapping to identify the current state of knowledge in the pursuit of geoheritage conservation. In particular, this study aims to define the main fields where geoheritage is applied or explained as an emerging concept.

We extend our study to the entire range of geoheritage conservation related literature to map out the existing perceptions regarding the scope and scale of geoheritage conservation. The study shows the same keywords used in all conceptual schemes, but their use in varying proportions significantly change the more refined focus specifically on geoheritage conservation.

Methods

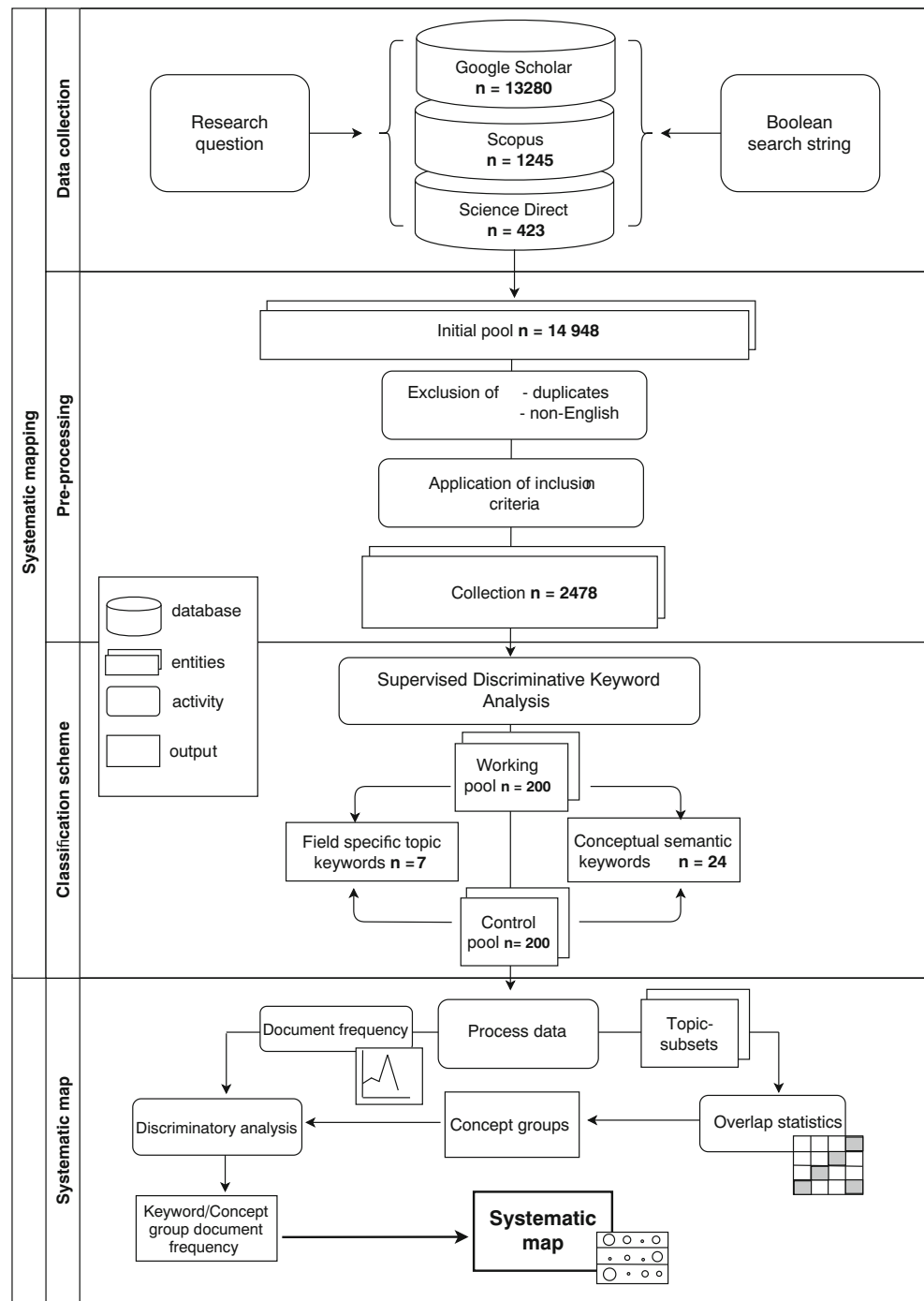
To achieve our goals of mapping the field of geoheritage conservation, identifying shifts in perspectives, and describing research streams, we followed an approach combining systematic mapping with interpretive analysis. Our systematic map procedure followed four steps: data collection and preprocessing; classification by supervised acquisition of geoheritage specific topics and keywords; mapping the result; and conceptual interpretation.

Data Collection

To extract data for mapping the literature, we first defined our primary research questions: (Q1) What are the identified conceptual patterns in geoheritage conservation? To answer that we defined two more sub-questions: (q2) What are the main research fields (topics) concerned with geoheritage conservation? (q3) What are the keywords that best describe the geoheritage discourse?

To build the search query we first used a single word, the central element of our research question. The word “geoheritage” as a single search word was not efficient enough to retrieve the entire range of relevant literature because the literature is characterized by heterogeneity in terminology. To define the most effective search string, we utilized the SciVal web-based analytic platform that enables users to instantly analyse their search results and generates powerful data visualizations (<https://www.elsevier.com/solutions/scival>). We were interested in the most frequent word occurring in the articles retrieved ($n=638$) by the single search word: geoheritage. We queried the top word by relevance of these articles, resulting in the word “geodiversity” (Fig. 1) with the maximum value of 1 over

Fig. 2 Systematic mapping process



as the basis of mapping the literature into concepts. The observed secondary relation between quantification and geotourism was noted and unfolded during the interpretation stage.

For the *discriminatory analysis*, we took the document frequency (df) of each conceptual keyword (C) and the number of documents (d) in each concept group (G). To measure how the proportional makeup of these keywords can change the context, we computed their discriminative weights. These

weights were calculated to measure the keywords ability as concept discriminators.

$$w_{ij} = \frac{\max(dfC)}{dfC_i} \times \frac{\max(dG)}{dG_j}$$

where the weight (w_{ij}) of a given keyword within a given concept group equals to the multiplication of: the fraction of the highest *df* counted for conceptual semantic keywords

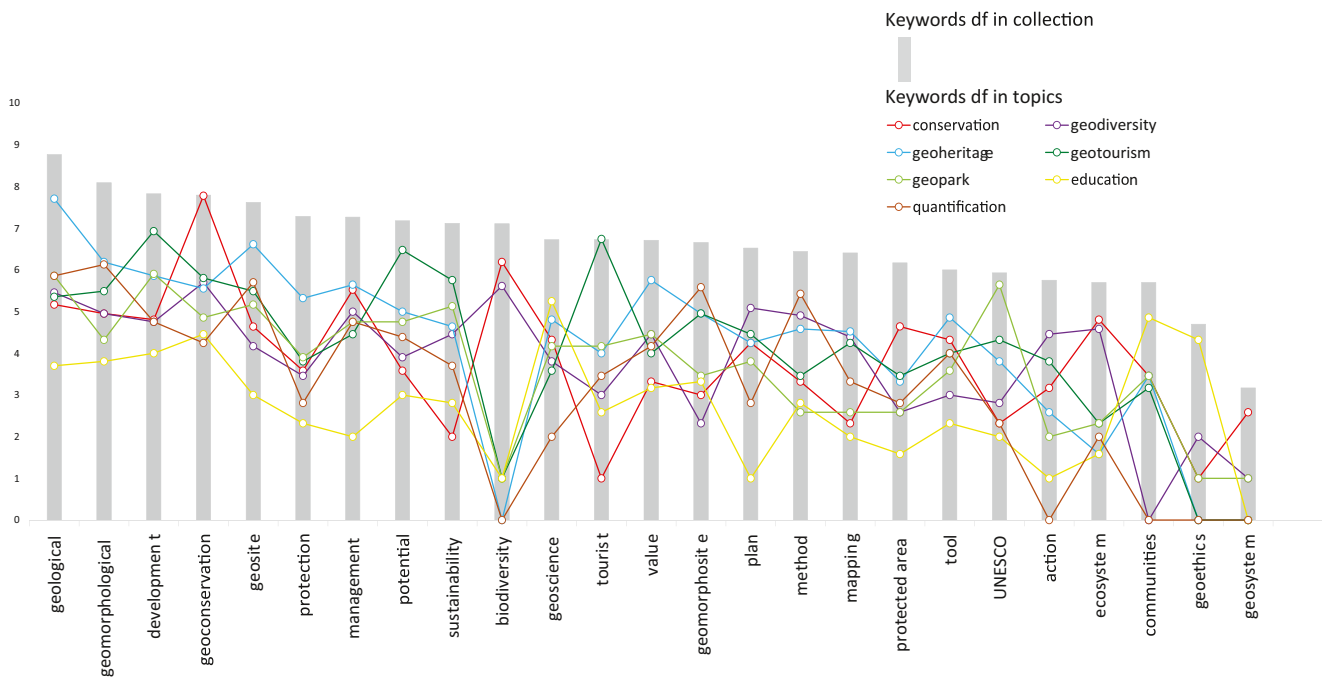


Fig. 3 Results of the frequency analysis

($\max(dfC)$) to the df of given conceptual semantic keyword (dfC_i) and the fraction of the number of documents of the biggest concept group ($\max(dG)$) to the given number of documents in the given concept group (dG_j).

$$DVx_{ij} = w_{ij} \times x_{ij}$$

We named the weighted df values of a given conceptual semantic keyword within a given concept group (x_{ij}) the discriminative value (DVx_{ij}). The DV of x was used for mapping the literature (Fig. 5) into a systematic map.

The systematic mapping process allowed us to answer our research sub-questions: (q2) What are the main research fields (topics) concerned with geoheritage conservation? (q3) What are the keywords that best describe the geoheritage discourse?

The systematic map is an x-y scatterplot with bubbles in concept group and keyword intersections. The size of a bubble is proportional to the weight of keywords within a conceptual group.

Fig. 4 Relationship analysis among topics

	geoheritage	geotourism	geodiversity	geopark	conservation	quantification	education
geoheritage	915	127	84	127	112	136	38
geotourism	127	646	64	129	77	73	40
geodiversity	84	64	594	56	127	80	18
geopark	127	129	56	498	56	63	26
conservation	112	77	127	56	493	30	30
quantification	136	73	80	63	30	363	12
education	38	40	18	26	30	12	168

The interpretation stage resulted in conceptual characterization of the four identified groups (Fig. 6) by analyzing the proportional makeup of keywords. Additionally, a secondary screening was undertaken by searching to identify the most discriminative keywords. With that knowledge, we were able to extract primary studies from each concept group. In total, we identified 70 primary publications contributing the most to our interpretation of the conceptual patterns.

Results

The results of the systematic mapping allowed us to answer our main research question. (Q1) What are the identified conceptual patterns in geoheritage conservation? We identified four concept groups. With an inverse approach we started screening the titles falling in the given concept group and selected the titles corresponding to the word cloud and filtered

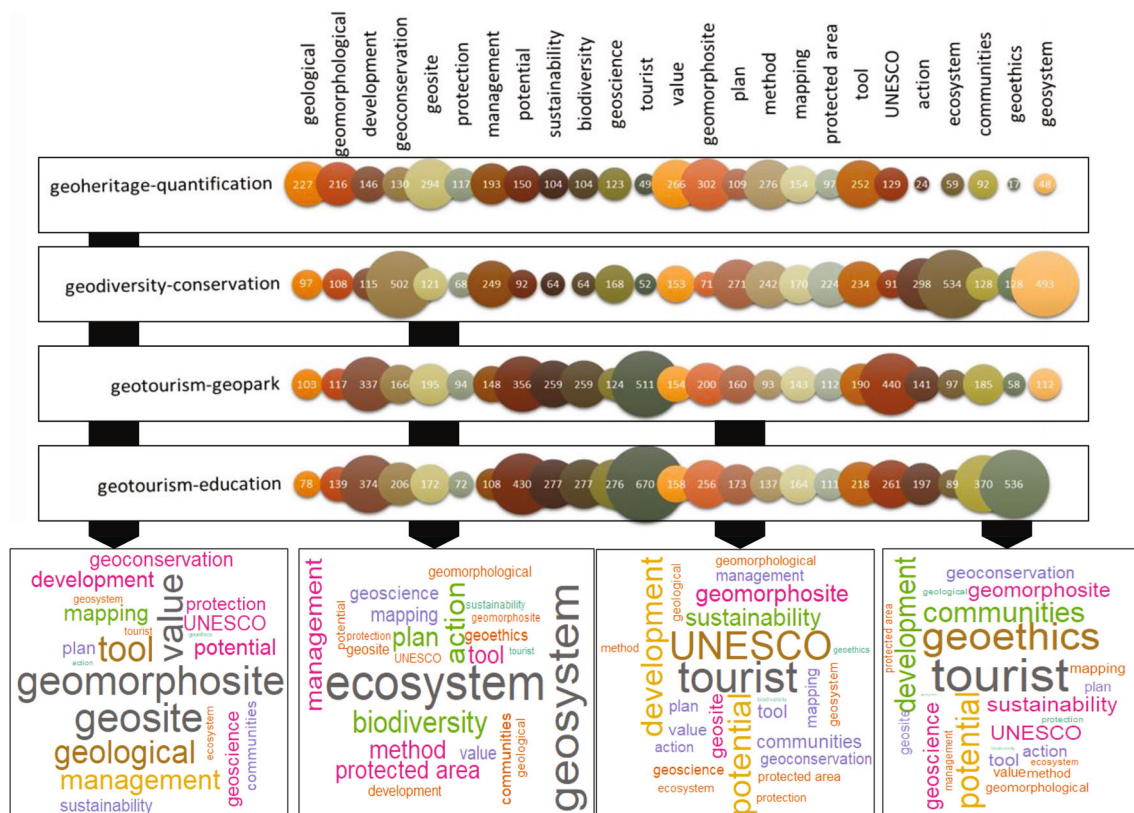


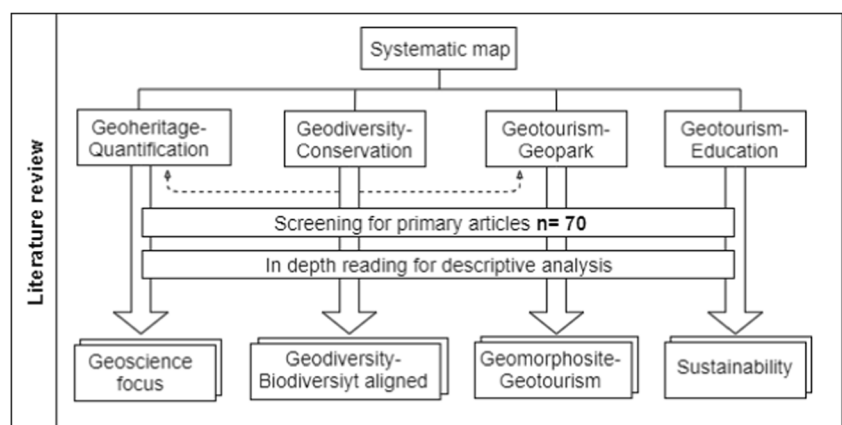
Fig. 5 Visualization of a systematic map with corresponding word-clouds

their relevance to our research question by reading the abstract. They were included in the primary articles if the in-depth reading confirmed their contribution to the conceptual discourse. We chose a paper as primary article if it addressed the lack of conceptual agreement and proposed determination of scope and scale of geoheritage. We were particularly interested in articles including critical acknowledgment of a different combination of rationale for the scope of geoheritage. While the main goal of our study was to map out key concepts, we also aimed to identify the weaknesses of each concept, giving rise to the very different angles and in some cases

demonstrating they could be delaying the formation of universally accepted principles.

During the in-depth analysis, we gave extra attention to investigating the secondary relationship between geotourism and quantification. Primary publications included review papers that were addressing gaps in geoheritage quantification with the primary purpose of geotourism. Review papers have an inherent role in clarifying the state of knowledge and identifying research able to explain the forming new node in literature between quantification and geotourism.

Fig. 6 Process of the literature review for the characterization of the identified concept groups



Earth Science

The most relevant keywords that our study identified from the titles falling in this concept group are *geological*, *geomorphological*, *geosite*, *geomorphosite*, *value*, *method*, and *tool*.

Geosite, as a term, is commonly used to refer to the subject features of geoheritage conservation in general (Brocx and Semeniuk 2007; Fassoulas et al. 2012) whereas the term geomorphosites is used when the observable processes are from the field of geomorphology (Pelfini and Bollati 2014; Reynard 2009; Reynard et al. 2016).

A debated question within the Earth Science community is the weight of aesthetics versus the weight of scientific contribution in evaluation models. One of the most problematic areas from this aspect, are the mining sites. It can be difficult to measure significance of old mines and quarries relating to Earth Sciences, because they more often focus on their importance to human and cultural history. Cultural relevance is still better understood than the importance of informing visitors about geological processes at geosites that may be less favoured for recreational purposes (Marescotti et al. 2018; Ruban et al. 2018). These geosites are valuable educational assets yet it is difficult to protect their accessibility and longevity. A study from López-García et al. (2011) depicts the problem through a case study on protected mining areas. Abundant mines provided insight to otherwise hidden geological processes in the Mazarrón and Cartagena–La Unión district, Spain. Exposed rock formations provide unprecedented materials for earth scientific research and education. While the mining sites are protected, this is to explicitly promote cultural heritage, little recognition is given to their geological heritage value. Important geoheritage sites remain underutilized and at risk of loss (López-García et al. 2011).

Firmly set geographical boundaries placed on geoheritage features can cause confusion. Brocx and Semeniuk (2007) offer a simple solution, stressing the geological aspect as the only way to facilitate sustainable conservation. For education the scale—crystals, outcrops, cliffs, terraces—should not matter as long as the geosite represents any component of Earth Science (Brocx and Semeniuk 2007; Brocx and Semeniuk 2010; Brocx and Semeniuk 2011).

Sovereignty of Earth Science in geoheritage stems from project GEOSITE, a framework to inspire actions to preserve scientifically outstanding elements of geodiversity. Wimbledon (Wimbledon 1996; Wimbledon et al. 1998) The project was linked to the World Heritage System, and later taken over by the International Union of Geological Sciences (IUGS). The aim and principles of this project were to register significant European geosites. Inclusion criteria was extended to aspects such as relevant view of local communities, and regional scientific importance. A centralized working group was formed to ensure scientific rigour for evaluation.

GEOSITE was aiming for a balanced coverage between countries (Joyce 2010).

In the undertaking of geoheritage conservation the IUGS in a joint effort with UNESCO, set up a working group in 1995 (Global Geosites Working Group) to collect not only European but a global list of geoheritage sites. ProGEO was assigned the task, leading to a surge in geoheritage conservation activities in Europe. Erikstad (2008) urged international site status conservation measures to facilitate strong international support for geoconservation. The first unifying project, The Global Geopark Network was formed by UNESCO in 2004, to promote geological, natural and cultural knowledge exclusively through engagement with local communities. Notwithstanding the magnitude of such collaboration, UNESCO labels remain selective and are unlikely to fulfil the need for a systematic international network of geosites at local to regional scales (Erikstad 2008). Following up the aforementioned initiatives, Brilha (2016) proposed a conceptual framework of geodiversity, geoheritage, and geoconservation, reinforcing the principles of the GEOSITES projects (Table 1).

These principles did not achieve consensus. Conservation experts from the environmental sciences prefer an approach that incorporates geoheritage conservation into biodiversity conservation using an aligned evaluation methodology. According to this approach, the success in geoheritage conservation lies in future cooperation among scientists from the wide spectrum of conservation areas (Anderson and Ferree 2010; Erikstad 2013; Hjort et al. 2012; Schrodt et al. 2019). They propose that geology and geomorphology define the patterns and hot spots in biodiversity, therefore geoconservation should put higher emphasis on their interrelatedness.

Call for Aligned Conservation Methods for Geo- and Biodiversity

The most relevant keywords that our study identified from the titles falling in this concept group are *geoconservation*, *management*, *plan*, *method*, *protected area*, *tool*, *action*, *ecosystem*, and *geosystem*.

Kozłowski (2004) describes geodiversity as the perpetual basis for the increasing biological diversity during geological history. The development and survival of life is highly dependent on geophysical conditions. If we want to maintain the balance necessary for resilience, there is a need to implement the two major global programs: 1) conservation of biological diversity and 2) conservation of geodiversity.

Geodiversity in recent conservation planning constitutes the geophysical conditions of inhabitants and connectivity. The outstanding features of geodiversity are not yet recognised as equally important elements of protection as

Table 1 The principles of GEOSITES project

<i>Principle</i>	<i>Essence</i>
i Geoconservation is a fundamental to the prosecution of geological research, education and training	Geoscientists notice that geoconservation is a vital necessity when a key site is damaged or lost
ii Key to conservation as a whole	Geology underpins all landscape and biotic nature. Biodiversity determined by geodiversity.
iii The geological story, time and scale are continuing sources of wonderment to earth scientists and lay public	The conservation of geosites encourages and fosters geologic research
iv Geosites and terrains establish the geologic record.	Understanding the importance of geologic records creates respect and appreciation of the need of conservation.
v Only geologist can compile a global geosite inventory that produce a balanced coverage between countries and regions	To justify the significance of localities for promoting greater knowledge of geology amongst wider public.
vi Global inventory allows a comparative assessment	Without it the designation of global sites is much harder and open to criticism for not being based on an objective examination of the global picture (which is the major drive of the ongoing debate today)
vii Avoid selecting just a few superlative localities ignoring the time matrix.	In putting together a global listing, it is necessary to have representation not only of processes and features, but also to exemplify these through geological time.

the species living on it. This is due to the fact that protection of biotic elements has a longer history, and therefore a better understood status in conservation initiatives (Crofts 2014). Despite the huge body of research about the benefits of implementing geoscience in all environmental policies, practitioners argue that inequity between the biotic and abiotic in conservation measures jeopardizes sustainability (Brilha 2002; Comer et al. 2015; Crofts 2014; Crofts 2018; Crofts and Gordon 2015; Gordon et al. 2018b; Gray 2008b; Gray 2018; Prosser et al. 2011). Sustainability is an overarching scientific discipline dependent on an integrated knowledge of geosciences and other environmental and social sciences. Geodiversity, relatively recently recognized as a branch of conservation, should be put in the context of current conservation policy frameworks and established as a fundamental component of conservation (Gray et al. 2013; Zwoliński et al. 2018). Although biodiversity conservation has an impregnable purpose of protecting life, we acknowledge still unresolved conceptual questions (Groves et al. 2002; Rands et al. 2010; Wilshusen et al. 2002). Arguments questioning the place of geodiversity in biodiversity conservation have their fundamental counterpoints that explain the need for exclusive geoconservation principles as visualised in Table 2. The pivot point is the perceived necessity to decide between ecocentric or anthropocentric perspectives (Kopnina et al. 2018). Geodiversity includes resources for provision that may be in conflict with the principles of biodiversity conservation, but it can coexist with geoheritage conservation. For this reason,

geoheritage conservation should be considered as a standalone branch of the discipline.

The ambiguity in applications of the term geodiversity constrain its present use as a working concept. Discussing geodiversity outside of geoscientific disciplines would result in validating broader applications. For example, geodiversity elements should be quantified according to their relationship with the spatial distribution and abundance of species (Boothroyd and McHenry 2019). Hjort et al. (2015) further elaborated how geodiversity is crucial for sustaining species and ecosystems, thereby encouraging a fully integrated and unified approach to geo- and biodiversity.

In contrast, it is difficult to incorporate small-scale geoheritage objects or processes, such as minor and localised volcanic eruption sequences, because they are perceived to have little relation to biodiversity conservation. Strict linkage of geodiversity to biodiversity risks the loss of geoheritage sites of non-protected domains like active mining areas or urban development areas. (Del Monte et al. 2013; Gravis et al. 2020a; Gravis et al. 2020b; Habibi et al. 2018; Marescotti et al. 2018; Valdez 2018)

Mocior and Kruse (2016) reviewed the educational values of landscapes, mainly through geoheritage evaluation methods, and concluded they are too weighted towards geology specifically and would benefit from addressing ecological values encompassing all elements of nature and their interactions. As an example, “geological age” or “number of interesting geological features” could be transformed by removing

Table 2 Arguments why geodiversity should be assessed along with biodiversity and counterpoints why geodiversity itself deserve undivided attention for conservation through geoheritage

<i>Arguments</i>	<i>Counterpoints</i>
i The usage and conceptualization of geodiversity did not always align with the definition found (Boothroyd and McHenry 2019)	Due to the specific interest of each individual evaluating the geoheritage there are differences in terminology (Erikstad 2013; Kozłowski 2004; Serrano and Gonzalez-Trueba 2005). The GEOSITES project set up a centralized working group and guiding framework to prevent confusion. The GEOSITES principles are still valid and should be reinforced (Díaz-Martínez et al. 2016)
ii There are major knowledge gaps in our and ability to predict how different forms of geodiversity influence biodiversity patterns across spatial and temporal scales (Zametske et al. 2019)	The criteria used by geologists in the mainstream geodiversity studies differ from those used in by the biodiversity and geodiversity communities (Ibáñez et al. 2019)
iii Integrating geodiversity and biodiversity at a landscape scale is applicable to key issues such as habitat and natural system responses and adaptations to climate change (Bruneau et al. 2011)	All biological ecosystems are dependent of geodiversity. At the same time geodiversity merits conservation for its own considerable values (Hjort et al. 2012)
iv Big part of the literature specifically recognizes geodiversity as a supporting stage for the spatial differentiation of biodiversity values and as primary contributor to ecosystem services (Boothroyd and McHenry 2019).	The ecosystem function is dependent on specific geosystems that delivers ecosystem services. This interdisciplinary application is not always referenced in discussions centred on geoheritage and geotourism (Thomas 2016)

the specifying adjective “geological”. On that matter “ecological value” should not be considered as an additional criterion (Kubalíková 2013; Pereira et al. 2007) but one of the fundamentals (Bollati et al. 2015; Bollati et al. 2013). This demonstrates that education is one of the ecosystem services that should be incorporated into the quantification of ecosystem services.

The Concept of Geomorphosites, the Leading Resource for Geoparks

The most relevant keywords that our study identified from the titles falling in this concept group are *development*, *potential*, *tourist*, and *UNESCO*.

There is a strong relationship between the keyword geomorphosite and the concept as relating to geotourism and geoparks. Geotourism is one of the core activities of geoparks that stimulate sustainability (Farsani et al. 2011). To date, geomorphosites are more attractive for geotourism purposes (Pelfini and Bollati 2014). If the socio-economic benefit is the main goal, geomorphosites have anaesthetic advantage over geological sites.

Pervasiveness of this concept is demonstrated by examination of respective review papers. Results show (Tables 3 and 4) an elevated recognition of geoheritage in the context of geotourism. More than half of the review papers narrow geotourism down to a specific factor, the geomorphology. Promoting geoheritage as aesthetically pleasing landforms

serviced by facilities catering to tourist demands and recreational purposes attracts the public (Office of World Geopark 2004). The resultant benefit of preserving geoheritage is its potential positive effect on local economy. Renowned researchers have devoted entire articles and books to clarifying the principles of geotourism (Dowling 2008; Hose 1995; Hose 2000; Hose 2010; Newsome and Dowling 2006).

According to Ollier (2012), geotourism takes place mainly within natural or wilderness areas, which in turn conceptually reduces the vital role of geological exposures in road cuts and quarries that are often considered of no aesthetic value. A conceptual argument is implied in the promotional material of National Geographic, defining geotourism as the tourism that sustains or enhances the distinctive geographical character of the place—its environment, heritage, aesthetics, culture, and well-being of its residents (National Geographic 2020). This approach ignores one of the main objectives of raising scientific awareness. National Geographic magazine is described as the “bellwether” nature publication in the USA, translated to over 40 local-language editions, global circulation of around 6.7 million that has been advertising environmental issues over the past 30 years (Ahern et al. 2012; National Geographic Boilerplates 2015). No doubt the environment, heritage, aesthetic values, culture and well-being of residents are the major winners of any conservation activities. However, by stressing these factors and excluding others, the original quest for protecting extremely informative exposures of past geological processes, or a geosite of spiritual value based on centuries to millennia of community engagement

Table 3 Summary of the review protocols review papers used

Year	Aim	Review strategy	No. studies included	Scope
Comănescu et al. (2012)	To create the most efficient method for quantifying the value of geomorphosites.	Screened worldwide known methods of evaluation and apply them on a group of geomorphosites. Final scores were compared.	no. 8: Pralong 2005; Reynard et al. 2007; Coratza and Giusti 2005; Bruschi and Cendrero 2005; Serrano and Gonzalez-Trueba 2005; Pereira et al. 2007; Zouros 2005; Erhartič 2010	Geomorphosites for geotourism
Kubalíková (2013)	To compile a criteria set best facilitate geotourism.	Screened significant assessment methods used for geotourism purposes and analyse their criteria against the concept of geotourism.	no. 7: Pralong 2005; Reynard et al. 2007; Coratza and Giusti 2005; Bruschi and Cendrero 2005; Serrano and Gonzalez-Trueba 2005; Pereira et al. 2007; Zouros 2007	Geomorphosites for geotourism
Štrba et al. (2015)	To compare selected geosite assessment methods to prove that further research is needed for geotourism planning and management.	Six types of quantitative methods selected. Each method was tested on the same group of geosites. Final scores were compared.	no 6: Băca and Schuster 2011; Bruschi et al., 2011; Fassoulas et al., 2012; Pereira et al. 2007; Reynard et al. 2007; Rybar, 2010	Geosites for geotourism
Ólafsdóttir and Tverijonaite (2018)	To systematically review scientific literature on geotourism and analysing the research trends in geotourism.	Systematic search, selection, and categorization of studies for clear, reproducible results.	256 papers	Geotourism
Mucivuna et al. (2019)	To analyse how the evaluation methods developed and to compare them.	International database search by the keywords of 'geomorphological heritage', 'geomorphological site' or 'geomorphosite'.	71 scientific papers	Geomorphosites

(Gravis et al. 2017), will ultimately lose the battle against human demolition (Del Monte et al. 2013; Gravis et al. 2020b; Ruban 2010).

Kubalíková (2013) found that ethical and social principles of geotourism are often neglected and the motivation is often economic profit. Štrba et al. (2015) highlighted the problem of arbitrary and ad hoc interpretation of geoheritage, resulting in varying assessment methods making it impossible to compare (therefore validate) competing geoheritage nominations. Ólafsdóttir and Tverijonaite (2018) noted that research on the effect of geotourism on geological knowledge and engagement with local communities is scarce and this scarcity makes it difficult to improve educational material and wellbeing of communities. Mucivuna et al. (2019) mainly addressed the technical issues of the evaluation methods, noting they generally lack clarity on objectives, criteria and consistency on weighting and formula applied. Despite differences in problems raised through their findings, proposed solutions always include the reduction of subjectivity, either through elimination of fuzzy criteria such as aesthetics, or the unification of the methods where comparability results in objectivity.

Through this approach, it is widely acknowledged and recognised that UNESCO is a “brand” that strictly protects its integrity for delivering features that are the most unique of their kind, under the designation of World Heritage Sites. As the tentative list increased in parallel with the desire to

protect more and more geosites, a system was instigated to bundle the features into one geographic subdivision for enhancing their significance, and for the purposes of education, management and monitoring.

Community Involvement for Sustainability

The most relevant keywords that our study identified from the titles falling in this concept group are *development*, *potential*, *tourist*, *communities*, and *geoethics*.

Ecosystem services are defined as the benefits nature provides to people (Danley and Widmark 2016). Geoheritage as a constituent of ecosystem services would be established as important to humanity by its inclusion under the umbrella of ecosystem services through recognition of the term geosystem services (Gray 2008a). Ecosystem services play a major role in 41 of 169 targets of the Sustainable Development Goals (Wood et al. 2018). The study of Van Ree et al. (2017) aimed to debunk the place of geosystem services in ecosystem management. They found that geosystem services are significantly underrepresented in contemporary studies on the topic. Conceptualization of ecosystem services has been driven predominantly by biological and ecological scientists, interpreting biodiversity and ecosystems as underpinning all dimensions of human, societal, cultural, and economic wellbeing (Folke et al. 2016; Van Ree et al. 2017).

Table 4 Findings and conclusions of the review papers

Year	Selection criteria	Evaluation criteria	Findings	Proposed solution	Discussion
Comănescu et al. (2012)	Assessment methods known worldwide.	Deviation of obtained scores within one assessment method.	N/A	Equal importance to scientific, ecological, aesthetic, cultural, economic value and management value.	It is not compulsory that geomorphosites with the highest scientific value must also have high values for additional criteria.
Kubalíková (2013)	Numerical assessments of geomorphosites.	Presence of scientific, cultural and economic value.	Methods should follow the principles of geotourism with the values of scientific, educational, economic and added.	Reduce criteria difficult and subjective to measure such as aesthetics.	All the methods cannot be used for the geotourism purposes - some of them are not equilibrated and they are focused unilaterally, so they do not meet the principles of geotourism.
Štrba et al. (2015)	Quantitative assessments of geosites.	Possibility for uniform assessment method	Lack of uniform assessment method with criteria of rarity, representatives, integrity, accessibility, ecological value and economic value.	Reduction of subjectivity of assessing person by uniform assessment (1) establish independent team of specialists and laics (2) establish a web-based online assessment form	Necessary to focus on the research of the most suitable and universally applicable assessment criteria
Ólafsdóttir and Tverijon-aite (2018)	Studies directly related to geotourism.	Summary	(1) Lack of research on visitors to geotourism destinations to facilitate the preparation of geologic information. (2) Actual contributions of geotourism to the wellbeing of local communities is currently very short supply.	Empirical knowledge concerning: (1) visitors' preferences and motivations (2) main management challenges (2) positive and negative impacts of geotourism on geoheritage and local communities.	Sustainability is one of the primary objectives of geotourism, that should be achieved through geoeducation.
Mucivuna et al. (2019)	Studies directly related to geomorphological heritage assessment.	General aspects, quantitative or qualitative evaluation.	(1) ignoring the purpose of the evaluation when adapting them (2) lack of clear procedures questions the reliability and replicability of qualitative evaluations (3) lack of clarity in criteria (4) no consistency in the weighting and formula applied	Applying and discussing strengths and weaknesses of previous methods to improve existing methods rather than creating many new methods.	The different ways of presenting results can lead to misinterpretation because some methods present the values separately, while others present the global value, including use and potential threats.

The Sustainable Development Goals prompt all countries to achieve 17 broad development goals by 2030 (United Nations 2015). Gill (2017) presented a matrix to visualise the role of geologists in helping to achieve the Sustainable Development Goals. The study identified that Earth Materials, Processes and Management support 12 of 17 goals (71%), Earth Science Skills and Practice support 10 of 17 goals (59%) and the synthesis clearly demonstrates geologists have a role in achieving all 17 of the Sustainable Development Goals (Gill 2017).

An emerging view is that sustainability science needs to be integrated into the Earth Sciences (Stewart and Gill 2017). The exact definition and value of geoheritage might be under debate, but its contribution to sustainability from varying perspectives is undeniable as well as the contribution geologists can make to resilient communities (Stewart and Gill 2017). Gray (2011) published his analysis demonstrating the lack of

application of geosciences in the global environmental solution frameworks and introduced the term geosystem services. To highlight the significance of geodiversity he used the classification of the Millennium Ecosystem Assessment (2005) and presented the place of geodiversity in four classes of ecosystem services; i) regulating Earth system cycles, ii) provisioning physical resources, iii) supporting and forming soil and land, iv) cultural and community engagement through platforms such as geotourism, v) knowledge of the Earth Sciences for understanding, monitoring and forecasting.

Discussion

The significant body of geoheritage conservation literature forms conceptual network with four major theme nodes. The

characterization of these four key nodes as concepts revealed (Fig. 7) that geoscientific knowledge governs the course of events in geoheritage conservation.

Below we discuss our findings from the systematic mapping from four main aspects “purposes and principles,” “role of education,” “decision-making challenges,” and “participatory geoconservation.”

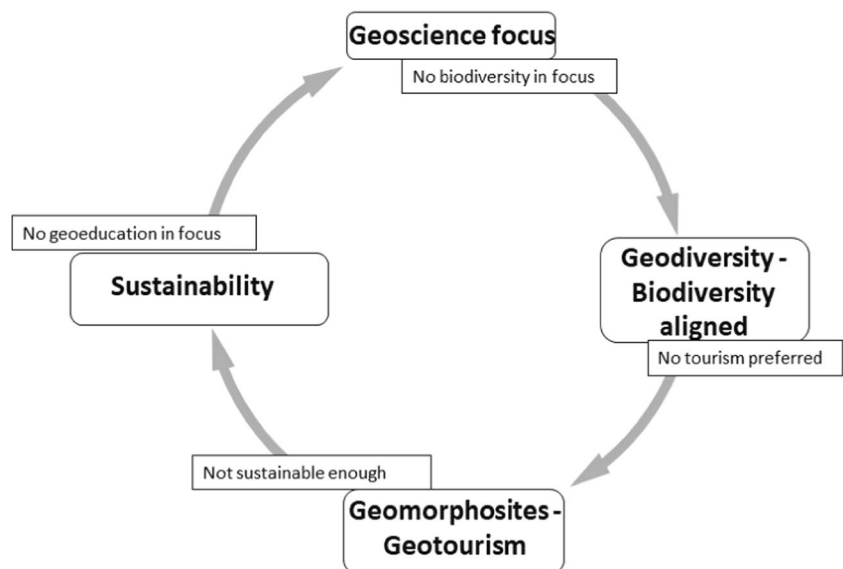
1. The purposes are to promote and to strive for the protection of geoheritage by principles that deliver Earth Science knowledge and generate geotourism. The purposes and principles present an inherent conflict between conservation and tourism. Recognizing the responsibilities embedded in the overarching concept of geoheritage there is an urgent need for uniting them and achieving a balance between protection and promotion. The geodiversity concept based on the biodiversity framework has brought geoheritage closer to the long-practiced guidance of biodiversity conservation.

Within the biodiversity framework, the mere existence of a species is justification for protection, there is no morally acceptable debate over the value of life. This drives the argument back to the conflict between conservation and tourism, in protecting species or sensitive habitats strict measures are applied, for instance severe limitation of visitors. Geoheritage conservation associated with biodiversity conservation gives a false idea about strict regulations and cuts grass root initiatives short. In effect, geoheritage does not require strict protection to be able to offer public access. However, an instrument for organizing geoheritage is necessary. Geoparks are the most effective mediators to promote and protect geoheritage. Geoparks facilitate promotion, access, networking, community engagement, and consequently economic

growth and sustainable development. Geoheritage conservation and geoparks are shown to be a significant gap in Sustainable Development Goals agenda (United Nations 2015).

Awareness about geoheritage is growing through geotourism as an emerging global activity channelled by geoparks (Dowling and Newsome 2010; Dowling 2011; Ruban 2015). The geopark system is coordinated by the dominant international organisation UNESCO, under the name of the Global Geopark Network (<http://www.globalgeopark.org/>). The support of international governing bodies and national governments may give rise to smaller scale geopark networks. For example, China created a hierarchical system of regional, national and international (UNESCO) geopark networks (Xun and Milly 2002). This strategy supports bottom-up initiatives and allows for a graduated growth from a regional practice toward the rigorous UNESCO requirements. Regional geoparks prepare communities for attention and responsibilities the UNESCO label invokes. Geoparks are vastly superior in protecting geological heritage, balancing economic and tourism development, and educating the public. (Bailey and Hill 2010). Declaration of UNESCO (2016) targets the geoparks toward the general public in order to enhance the laypersons awareness of geology. This includes facilitating an understanding of geologic timescales and periods through the global geopark network as they are the best option for informing the public about the entire Earth history. Global geoparks should offer appropriate interpretations about geologic time, but they are often only located in the most accessible locations. Geoparks need to be taken together as well to represent length and significance of each geologic era and eradicate bias towards certain geologic periods (Ruban 2016).

Fig. 7 The circular nature of the four key concepts identified in our systematic mapping



2. This study mapped education as the connection between all environmental disciplines. Education is also the key to knowledge-induced sustainability and resilience to environmental hazards. According to Mata-Perelló et al. (2012), geology is one of the most influential factors in human development, as it determines the evolution of societies and can inform answers to the challenges of urban growth and high quality of life. UNESCO (1998) referred to the birth of socio-geosciences as an unavoidable milestone in human development given the influence of geological resources and geological based risks to society. Socio-geoscience is an emerging discipline addressing sustainable development with respect to the population and environment. Mata-Perelló et al. (2012) proposed a reclassification of geological resources into extractable and non-extractable. Under the non-extractable group, we find the subcategories scientific, cultural, heritage, didactic and recreational. They put scientific knowledge at the top of the hierarchy because it may reduce and mitigate geological risks by increasing policy impact. There is a growth in small volume disasters that could be prevented by more effective local actions that prioritise the principle of mitigation (Puiguirguer 2007).

Societal utilization of resources in an unsustainable manner is causing irreversible changes affecting many fundamental aspects of human life. We do have the knowledge and the potential to make changes to sustain the economy while eradicating global problems through wise management of geological resources, reducing risks, and promoting equitable social development. Geoscientists need to be encouraged to be involved in discussions around sustainable development (Mora 2013; Stewart and Gill 2017). Geoscientists are well equipped to develop more sustainable practices by informing society about the varying manifestations of Earth processes at different spatial and temporal scales (Gosselin et al. 2013).

3. The implementation of geoscientist participation processes into conservation planning and providing space for indigenous co-participation in geoheritage conservation ventures is important for the democratisation of natural values. Geoheritage values are often overlooked in unprotected areas (cities, mines, archaeological sites, infrastructure sites, indigenous sites). With the extent of overlaps in protected area designations, these geoheritage features can be out of sight of policy makers. At a global scale, quarter of the protected terrestrial network, and under a fifth of the global marine network, is protected by two or more designations (Deguignet et al. 2017). The most common overlap is between one or several national designations, with at least one international designation risking conflicting objectives among different governing bodies. Doubled or tripled designations are particular in western

China and need more attention to avoid unclear management objectives, imbalance in regional geopark distribution and inefficient use of funding (Wang 2007).

The literature on geoheritage is very vocal about the hierarchical relationship between bio and geodiversity (Ibáñez et al. 2019). In the case of conflicting objectives, this means geoheritage is inevitably placed at a disadvantage. Moreover, geoheritage carrying very high scientific values outside of protected areas does get overlooked (Gravis et al. 2020a).

The idea of geoparks unites the principles of different conservation goals that gives a fair share of importance to biodiversity. For that reason, very often geoparks share at least part of their territory with areas for conserving nature, wildlife or relics of human history. That can result in a shift of focus from integration of geoscience or the role of geoscience in cultural development and result in unbalanced educational material across disciplines (Megerle and Pietsch 2017).

The operational guidelines of the Global Geopark Network (Office of World Geopark 2004) express the strong statement that no destruction or economic transaction based on the geological value of a global geopark will be tolerated, except for scientific or educational purpose. Geoparks must reflect the principles set by the Sustainable Development Goals. Setting sustainability as an essential practice for economic development and management structure results in a geoheritage evaluation from locals' perspective, presence, and needs. Thus, investing in geoparks contributes to the development of tourism and related actions through the enhancement and promotion of geoheritage. Encouraging active participation in the geopark operation revalidates and revitalizes the values of the territory's heritage. Furthermore, a global geopark must work within a network leading to cross cultural collaboration and new by-products linked with geoheritage and cultural heritage (Patrick et al. 2010). These principles often conflict with the management policies of national parks or protected areas that often require strict protection.

In research presented by Wilshusen et al. (2002), biodiversity protectionists argue that i) biodiversity protection is a moral imperative, ii) conservation linked to development does not protect biodiversity, iii) harmonious, ecologically friendly local communities are myths and iv) that emergency situations require extreme measures. These points are sharply at odds with policies of a geopark that address several issues such as i) people in rural areas suffer from economic decline, ii) the need for educational programs that employ inventive communication techniques, iii) and geological landforms may be either ignored, or appreciated only for their aesthetics. The main conflict arising from establishment of geoparks within already protected areas is that the latter exerts restrictions on land use, while the former encourages locals to engage in more traditional industries and to be an integral part of management promoting sustainable geotourism.

4. Participatory process is an emerging approach in the form of bottom-up consultation and involvement of local communities. It is considered to be beneficial to earn UNESCO Global Geopark status (Bailey and Hill 2010). On the one hand, however, it is not always appealing to locals due to the fear of sudden popularity or the possible effects on indigenous sacred elements. And on the other hand, UNESCO geoparks must deliver international significance (Adie 2017) and no deviation from this rigid quality standard is accepted. Remote rural communities often have no capacity to carry that expected quality. To enable geoconservation at areas of all backgrounds national geopark networks should be encouraged through a process whereby communities would receive attention gradually and take advantage of ample time adapt to geopark goals.

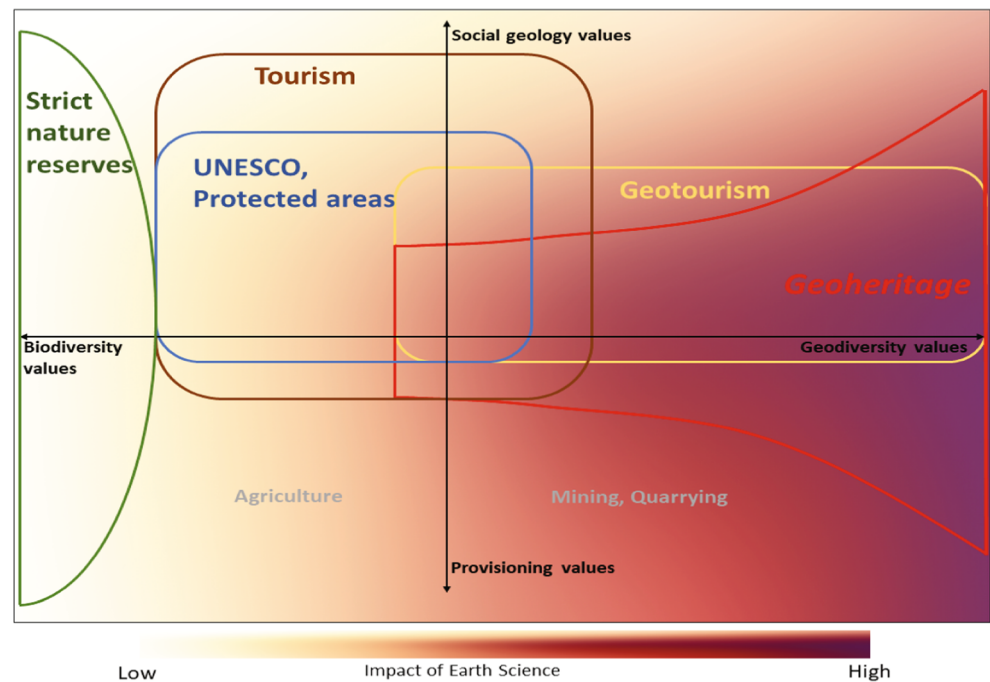
While geoparks safeguard our geoheritage, we question whether that should be the only conservation goal? There will always be areas where a geopark may not be culturally or occupationally suitable, or areas simply lacking the required capacity. Due to the strong geoheritage movement within the geoscientific world, these sites are recognized and inventoried. Additionally, a robust framework for a convention would guide landowners for a geoheritage favouring operation, for example a privately owned quarry in a geologically significant area. Re-establishing the GEOSITES program within the International Geoscience Program could be a suitable starting point for a bottom up community-based framework for the protection of single geosites of local, regional, or national importance.

The GEOSITES project set the objective of compiling an international list of each and every region's representative geological sites. Geoparks or geotrails may not require strict protection status, but they should be subject to a strict process driven by local communities and promoting cultural integrity. This is a would be a significant instrument towards more comprehensive nature conservation in countries where government may already support national geoparks. When the only option is for local initiatives to strive towards the goal of UNESCO Geopark status, they unfortunately need to prove a special local and biotic significance of the area, which may be a significant burden and obstacle to any form of lesser protection. UNESCO was established on principles of culture, flora, fauna, and geodiversity and these are inseparable, as they should be. Communities lacking opportunities or resources (both financial and human resources) for developing and instigating a geopark plan would greatly benefit from the GEOSITES project. As Ryan and Silvanto (2011) noted UNESCO's list of World Heritage Sites as the "coveted brand and seal of approval," it is clear that it will not allow all of a region's representative geological sites to dilute this quality. However, a global list of purely geologically/

geomorphologically significant sites can provide the basis for evolution of a geopark plan or simply to facilitate access to individual sites that may be threatened. To operate a geopark, there is a need for people who identify themselves as related to the area. As the geopark idea was born in the era of growing acknowledgement of the importance of sustainability, we agree that it should facilitate the rise of local communities, with concepts such as biodiversity, cultural significance, geodiversity, inextricably connected. When a geopark is managed by locals and their associated businesses, a sense of pride for the culture and nature in the region will be restored. GEOSITES has the potential to be a "brand" for geoheritage as "UNESCO "has come to be widely recognised for cultural heritage. Unfortunately, as earlier discussed the program stopped despite the serious need for it. Protecting individual outstanding geodiversity features depends on countries conservation strategies, which may be well-developed in certain countries such as New Zealand.

The Auckland Volcanic Field provided topography and fertility for a unique culture to grow and develop into an indigenous culture significantly different from the Pacific Island culture from which it originally evolved (Anderson 2009) (Anderson 2009). This culture is recognised in New Zealand's bicultural governance through the Treaty of Waitangi, though the Western cultural paradigm remains dominant. Māori culture is acknowledged as significant and important, and as a living, dynamic, and evolving culture has adapted many of its elements to remain relevant and important in modern society (Mead and Mead 2016) (Mead, 2016). The Māori worldview reflects the Western concept of sustainability through a holistic approach that sees humankind as part of an inseparable from nature and its ecosystems, rather than existing outside of or above the natural domain (Marsden 2013). Māori values are strongly intertwined with geoscientific values and give significance to outstanding geological/geomorphological features on the basis of self-identity and the unbreakable relationship between people and the land. Geoscientific research in Auckland takes place in a bicultural context and institutions are required to develop a grounding for indigenous knowledge. Māori values also shape the ethics and principles that shape decision making and interactions with the environment at both physical and spiritual levels (Mead and Mead 2016) (Mead, 2016). The Māori world view and its associated ethical principles and values provide a basis for what is valued and define the information required to establish what is significant and how to prioritise values among natural resources (Harmsworth and Awatere 2013). Geoparks were established to promote such holistic, interconnected relationships with nature based on a rich traditional knowledge base developed through centuries of occupation. The Auckland Volcanic Field and its power to shape the social landscape should be understood in more far-reaching terms as it sets an unprecedented example of two

Fig. 8 Relationships among major factors of conservation that influence the establishment of the scope and scale of geo heritage in geosystem services



radically different cultures not only coexisting but attentive and concerned about one another.

We designed a chart (Fig. 8) to break down geoheritage across primary values and variables of conservation and tourism. The chart prompts understanding of the scope of geoheritage in the broad framework of geosystem services. The x axis is the intrinsic conservational value, ranging from high biodiversity value to high geodiversity value, with a moderate value of both in the middle. The y axis is the geosystem services value, ranging from a high provisional value to a high social geology value. Provisional values are the extractable geological resources and social geological values are the associated educational and historical values of the natural elements providing nonmaterial benefits for society (aesthetics, recreational or cultural quality of the landscape). High intrinsic geodiversity values coincide with high Earth Scientific impact, resulting in high geoheritage occurrences. The high intrinsic value correlated with high geoheritage values stretch widely along the spectrum of geosystem services as they get featured within mines, quarries, and cultural landscapes. With the decrease of geodiversity value, biodiversity values appear and multi designated areas occur. Believing in the inherent right for outstanding natural features to exist, geotourism is separated from tourism but not as a true superset of geoheritage. Geotourism as interpreted today is seen as an activity to engage with geoheritage but is slightly shifted toward classic tourism due to the necessary acknowledgment of tourist demands (high social value, aesthetics, tourist facilities).

Protected areas and UNESCO World Heritage Sites focus dominantly on biodiversity and their amenity values. The role

of geodiversity is more acknowledged on the side of provisions of habitat and food to wildlife. Endangered species require extreme measures managed under the category of strict nature reserves defined by the World Commission on Protected Areas. Activities within these areas established exclusively for scientific field work. The curve of strict protection drops when human needs for agricultural land or unique experiences of social landscapes overwrite the highest level of conservation status. Other protection statuses such as UNESCO, or category II-IV Protected Area also generate a large share of tourism.

Conclusion

A systematic mapping study of geoheritage conservation across three decades of practice was considered necessary to address key concepts in the literature that were overlapping and at the same time forming a foundation for conflict between competing interests and ideals. The results of this study provide a structured understanding of the state of geoheritage. The identified keywords of the main body of geoheritage literature were shown to be depicting four major strands of conceptual thinking: i) geoscience focus; ii) call for aligned conservation methods for geo- and biodiversity; iii) the concept of geomorphosites, the leading resource for geoparks; iv) emphasis on community involvement for sustainability.

Assigning value to geoheritage, if left to individuals, will be dependent on their perception. Perception on what we value is a private experience. It is ultimately beyond any measurement technique or tool. Without our capacity to

objectively measure and compare the values assigned by perception, policy makers cannot build them into conservation planning.

Our responsibility is to facilitate the survival of the relics and landscapes telling the story of the Earth's history beyond the limits of human perception of value, which remains prone to instability. Additionally, we have a duty to counteract preventable losses while considering potential benefits for local communities. And that is as well ultimately the concept of sustainability. A unified perception can be achieved if geoscientific facts are taken as the basis for the scope and scale of geoheritage. Science is built on evidence that cannot be changed by individual experiences.

It is a great challenge to find agreement on subjective values, but necessary to open up further opportunities for efficient geoheritage conservation. In order to meet the challenge, we need to understand all the conceptual proposals involved with geoheritage conservation. Understanding the reasoning behind different concepts will lead to better cooperation between practitioners of varying scientific background. This will require concerted effort on the part of policy makers to do more to understand and advance geoheritage conservation. Working with local communities, authorities, planners, and decision makers is crucial for sustainability and long-term adaptation strategies. The geoscientific community therefore must shift its attention toward conservation matters and engage in the geoconservation-geoheritage-sustainability discourse, thus confirming principles and guidelines that will lead to successful local initiatives. In the meantime, it is also important to ensure that those initiatives place prime importance on the outstanding geoscientific value, the principal factor of geoheritage. This paper is a stepping-stone to that consensus as it summarized the full spectrum of geoheritage related standpoints and concerns in addition to illuminating the often-underrated complexity of geoheritage conservation.

Acknowledgements We gratefully acknowledge funding support from DEtermining VOLcanic Risk in Auckland (DEVORA) collaborative research programme and GNS Science contract GNS-EQC00028-DEVORA Sub-Contract—“*GeoHeritage Values in Auckland - Planning and public education.*” We acknowledge the support by the Volcanic Risk Solutions, a multidisciplinary center for applied volcanic hazard and risk management research at Massey University. Our research is aligned with the goals of the UNESCO IGCP 692 “Geoheritage for Geohazard Resilience” project. We thank Ilmars Gravis of The Geoconservation Trust Aotearoa for the suggestions that highly improved this manuscript.

Code Availability Not applicable

Funding This study was supported by a grant from Detecting Volcanic Risk in Auckland research programme, New Zealand that funded by GNS Science contract GNS-EQC00028.

Data Availability The data that support the findings of this study are available from the corresponding author, [BN], upon reasonable request.

Declarations

Conflict of Interest The authors declare no competing interests.

References

- Act C (1987) Conservation Act 1987 No 65 (as at 22 October 2019). Public. Act - New Zealand Legislation New Zealand Government.
- Adie BA (2017) Franchising our heritage: The UNESCO World Heritage brand. *Tour Manag Perspect* 24:48–53
- Ahem L, Bortree DS, Smith AN (2012) Key trends in environmental advertising across 30 years in National Geographic magazine. *Public Underst Sci* 22(4):479–494
- Ahmad MO, Dennehy D, Conboy K, Oivo M (2018) Kanban in software engineering: A systematic mapping study. *J Syst Softw* 137:96–113
- Anderson A (2009) Origins, settlement and society of pre-European South Polynesia. In: Byrnes G (ed) *The new Oxford history of New Zealand*. Oxford University Press, Melbourne, Australia, pp 21–46
- Anderson MG, Ferree CE (2010) Conserving the Stage: Climate Change and the Geophysical Underpinnings of Species Diversity. *PLoS One* 5(7):e11554
- Băca I, Schuster E (2011) Listing, evaluation and touristic utilisation of geosites containing archaeological artefacts case study: Ciceu Ridge (Bistrita-Nasaud County, Romania). *Revista Geografică Academică* 5(1)
- Bailey H, Hill W (2010) The future of North American Geoparks in Geoparks. Think outside the park. In: Bailey H, Hill, W (eds) *The George Wright Forum. The GWS Journal of Parks, Protected Areas & Cultural Sites.*, 27(1)
- Bollati I, Smiraglia C, Pelfini M (2013) Assessment and selection of geomorphosites and trails in the Miage Glacier Area (Western Italian Alps). *Environ Manag* 51(4):951–967
- Bollati I, Coratza P, Giardino M, Laureti L, Leonelli G, Panizza M, Panizza V, Pelfini M, Piacente S, Pica A, Russo F, Zerboni A, 2015 Directions in Geoheritage Studies: Suggestions from the Italian Geomorphological Community 8:213–217
- Boothroyd A, McHenry M (2019) Old Processes, New Movements: The Inclusion of Geodiversity in Biological and Ecological Discourse. *Diversity* 11:216
- Brilha J (2002) Geoconservation and protected areas. *Environ Conserv* 29:273–276
- Brilha J (2016) Inventory and Quantitative Assessment of Geosites and Geodiversity Sites: a Review. *Geoheritage* 8(2):119–134
- Brilha J, Reynard E, (2018) In: Reynard E, Brilha J (eds), *Geoheritage*. Elsevier, pp 433–438
- Brocx M, Semeniuk V (2007) Geoheritage and geoconservation - history, definition, scope and scale. *J R Soc West Aust* 90(2):53–87
- Brocx M, Semeniuk V (2010) The geoheritage significance of crystals. *Geol Today* 26(6):216–225
- Brocx M, Semeniuk V (2011) The global geoheritage significance of the Kimberley Coast, Western Australia. *J R Soc West Aust* 94(2):57–88
- Brown EJ, Evans DH, Larwood JG, Prosser CD, Townley HC (2018) Geoconservation and geoscience in England: a mutually beneficial relationship. *Proc Geol Assoc* 129(3):492–504
- Bruneau PMC, Gordon JE, Rees S (2011) Ecosystem sensitivity and responses to climate change: understanding the links between geodiversity and biodiversity at the landscape scale. In: Report

450. United Kingdom, Joint Nature Conservation Committee, Peterborough
- Bruschi VM, Cendrero A (2005) Geosite Evaluation; Can we measure intangible values? *II Quaternario* 18(1):293–306
- Bujdosó Z, Dávid L, Wéber Z, Tenk A (2015) Utilization of Geoheritage in Tourism Development. *Procedia Soc Behav Sci* 188:316–324
- Cayla N (2014) An overview of new technologies applied to the management of geoheritage. *Geoheritage* 6(2):91–102
- Comănescu L, Nedelea A, Robert D (2012) The Evaluation of Geomorphosites from the Ponoare Protected Area. *Forum geografic* 11:54–61
- Comer PJ, Pressey RL, Hunter MLJ, Schloss CA, Buttrick SC, Heller NE, Tirpak JM, Faith DP, Cross MS, Shaffer ML (2015) Incorporating geodiversity into conservation decisions. *Conserv Biol* 29(3):692–701
- Coratza P, Giusti C (2005) Methodological proposal for the assessment of the scientific quality of geomorphosites. *II Quaternario Italian Journal of Quaternary Sciences* 18(1)
- Craig R, Taonui R, Wild S (2012) The concept of taonga in Māori culture: insights for accounting. *Account Audit Account J* 25(6):1025–1047
- Crofts R (2014) Promoting geodiversity: learning lessons from biodiversity. *Proc Geol Assoc* 125(3):263–266
- Crofts R (2018) Putting Geoheritage Conservation on All Agendas. *Geoheritage* 10(2):231–238
- Crofts R, Gordon JE (2015) Geoconservation in protected areas. *Protected area governance and management*:531–567
- Danley B, Widmark C (2016) Evaluating conceptual definitions of ecosystem services and their implications. *Ecol Econ* 126:132–138
- de Souza Neto JB, Moreira AM, Musicante MA (2018) Semantic Web Services testing: A Systematic Mapping study. *Computer Science Review* 28:140–156
- Deguignet M, Arnell A, Juffe-Bignoli D, Shi Y, Bingham H, MacSharry B, Kingston N (2017) Measuring the extent of overlaps in protected area designations. *PLoS One* 12(11):e0188681
- Del Monte M, Fredi P, Pica A, Vergari F (2013) Geosites within Rome City center (Italy): a mixture of cultural and geomorphological heritage. *Geogr Fis Din Quat* 36(2):241–257
- Díaz-Martínez E, Brilha J, Brocx M, Erikstad L, García-Cortés Á, Wimbledon W (2016) Global Geosites: an active and partially achieved geoheritage inventory initiative, waiting to regain official recognition. In: Cornee, A., Egoroff, G., de Wever, P., Lalanne, A., Duranthon, F. (Eds.), *Actes du Congrès International 'Les Inventaires du Geopatrimoine'* pp 103–108
- Doome S (2000) Caves, Cultures and Crowds: Carrying Capacity Meets Consumer Sovereignty. *J Sustain Tour* 8(2):116–130
- Dowling R (2008) The emergence of geotourism and geoparks. *J Tour IX(2):227–236*
- Dowling RK (2011) Geotourism's Global Growth. *Geoheritage* 3(1):1–13
- Dowling R, Newsome D (2010) Geotourism a global activity. In: Dowling RK, Newsome D (eds) *Global Geotourism Perspectives*. Goodfellow Publishers Limited, Oxford., pp 1–17
- Dusar M, Dreesen R (2012) Challenges to geoheritage conservation and sustainable development in Belgium. *European Geologist* 34:8–11
- Erhartič B (2010) Geomorphosite assessment. *Acta geographica Slovenica* 50(2):296–309
- Erikstad L (2008) History of geoconservation in Europe. *Geol Soc Lond, Spec Publ* 300(1):249–256
- Erikstad L (2013) Geoheritage and geodiversity management – the questions for tomorrow. *Proc Geol Assoc* 124(4):713–719
- Farsani NT, Coelho C, Costa C (2011) Geotourism and geoparks as novel strategies for socio-economic development in rural areas. *Int J Tour Res* 13(1):68–81
- Fassoulas C, Mouriki D, Dimitriou-Nikolakis P, Iliopoulos G (2012) Quantitative Assessment of Geotopes as an Effective Tool for Geoheritage Management. *Geoheritage* 4(3):177–193
- Folke C, Biggs R, Norström AV, Reyers B, Rockström J (2016) Social-ecological resilience and biosphere-based sustainability science. *Ecol Soc* 21(3)
- García-Ortiz E, Fuertes-Gutiérrez I, Fernández-Martínez E (2014) Concepts and terminology for the risk of degradation of geological heritage sites: fragility and natural vulnerability, a case study. *Proc Geol Assoc* 125(4):463–479
- Gill JC (2017) Geology and the sustainable development goals. *Episodes* 40(1):70–76
- Gordon JE, Barron HF, Hansom JD, Thomas MF (2012) Engaging with geodiversity—why it matters. *Proc Geol Assoc* 123(1):1–6
- Gordon J, Crofts R, Díaz-Martínez E (2018a) Geoheritage Conservation and Environmental Policies, pp 213–235
- Gordon JE, Crofts R, Díaz-Martínez E, Woo KS (2018b) Enhancing the role of geoconservation in protected area management and nature conservation. *Geoheritage* 10(2):191–203
- Gosselin D, Manduca C, Bralower T, Mogk D (2013) Transforming the teaching of geoscience and sustainability. *Eos* 94(2013):221–222
- Grandgirard V (1997) *Géomorphologie: protection de la nature et gestion du paysage* : thèse présentée à la Faculté des sciences de l'Université de Fribourg
- Grant MJ, Booth A (2009) A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Inf Libr J* 26(2):91–108
- Gravis I, Németh K, Procter JN (2017) The role of cultural and indigenous values in geosite evaluations on a quaternary monogenetic volcanic landscape at Ihumātao, Auckland Volcanic Field, New Zealand. *Geoheritage* 9(3):373–393
- Gravis I, Németh K, Twemlow C, Németh B (2020a) The Ghosts of Old Volcanoes, a Geoheritage Trail Concept for Eastern Coromandel Peninsula, New Zealand
- Gravis I, Németh K, Twemlow C, Németh B (2020b) The Case for Community-Led Geoheritage and Geoconservation Ventures in Māngere, South Auckland, and Central Otago, New Zealand. *Geoheritage* 12(1):19
- Gray M (2004) *Geodiversity: valuing and conserving abiotic nature*. John Wiley, Chichester
- Gray M (2008a) *Geodiversity: The origin and evolution of a paradigm*, pp. 31–36
- Gray M (2008b) *Geoheritage 1. A New Paradigm for Valuing and Conserving Geoheritage*. Geoscience Canada, Geodiversity, p 35(2)
- Gray M (2011) Other nature: geodiversity and geosystem services. *Environ Conserv* 38(3):271–274
- Gray M (2018) Chapter 1 - Geodiversity: The Backbone of Geoheritage and Geoconservation. In: Reynard E, Brilha J (eds) *Geoheritage*. Elsevier, pp. 13–25.
- Gray M, Gordon JE, Brown EJ (2013) Geodiversity and the ecosystem approach: The contribution of geoscience in delivering integrated environmental management. *Proc Geol Assoc* 124(4):659–673
- Groves CR, Jensen DB, Valutis LL, Redford KH, Shaffer ML, Scott JM, Baumgartner JV, Higgins JV, Beck MW, Anderson MG (2002) Planning for Biodiversity Conservation: Putting Conservation Science into Practice: A seven-step framework for developing regional plans to conserve biological diversity, based upon principles of conservation biology and ecology, is being used extensively by the nature conservancy to identify priority areas for conservation. *BioScience* 52(6):499–512
- Habibi T, Ponedelnik AA, Yashalova NN, Ruban DA (2018) Urban geoheritage complexity: Evidence of a unique natural resource from Shiraz city in Iran. *Res Policy* 59:85–94
- Haddaway NR, Bernes C, Jonsson B-G, Hedlund K (2016) The benefits of systematic mapping to evidence-based environmental management. *Ambio* 45(5):613–620
- Harmsworth G, Awatere S (2013) Indigenous Māori knowledge and perspectives of ecosystems. In: Dymond JR (ed) *Ecosystem services in*

- New Zealand – conditions and trends. Manaaki Whenua Press, Lincoln, New Zealand
- Harmsworth G, Awatere S, Robb M (2016) Indigenous Māori values and perspectives to inform freshwater management in Aotearoa-New Zealand. *Ecol Soc* 21(4)
- Hayward, B.W., 2009. Protecting fossil sites in New Zealand. *PaleoParks - the protection and conservation of fossil sites worldwide* International Palaeontological Association
- Hjort J, Heikkinen RK, Luoto M (2012) Inclusion of explicit measures of geodiversity improve biodiversity models in a boreal landscape. *Biodivers Conserv* 21(13):3487–3506
- Hjort J, Gordon JE, Gray M, Hunter JR, M.L. (2015) Why geodiversity matters in valuing nature's stage. *Conserv Biol* 29(3):630–639
- Hose TA (1995) Selling the story of Britain's stone. *Environ Int* 10(2): 16–17
- Hose TA (1996) *Geotourism, or can tourists become casual rock hounds?* The Geological Society, London
- Hose TA (2000) European geotourism—geological interpretation and geoconservation promotion for tourists. In: Barretino D, Wimbledon WAP, Gallego E (eds) *Geological heritage: its conservation and management*. Instituto Tecnológico GeoMinero de Espana, Madrid, pp 127–146
- Hose TA (2010) Volcanic geotourism in West Coast Scotland. In: Erfurt-Cooper P, Cooper M (eds) *Volcano and geothermal tourism: sustainable geo-resources for leisure and recreation*. Earthscan, London
- Hose TA (2012) 3G's for Modern Geotourism. *Geoheritage* 4(1):7–24
- Ibáñez J-J, Brevik EC, Cerdà A (2019) Geodiversity and geoheritage: Detecting scientific and geographic biases and gaps through a bibliometric study. *Sci Total Environ* 659:1032–1044
- Joyce EB (2010) Australia's Geoheritage: History of Study, A New Inventory of Geosites and Applications to Geotourism and Geoparks. *Geoheritage* 2(1):39–56
- Kopnina H, Washington H, Gray J, Taylor B (2018) The 'future of conservation' debate: Defending ecocentrism and the Nature Needs Half movement. *Biol Conserv* 217:140–148
- Kozłowski S (2004) Geodiversity: The concept and scope of geodiversity. *Prz Geol* 52:833–837
- Kubalíková L (2013) Geomorphosite assessment for geotourism purposes. *Czech Journal of Tourism*, pp 80
- Lockwood C, dos Santos KB, Pap R (2019) Practical Guidance for Knowledge Synthesis: Scoping Review Methods. *Asian Nursing Research* 13(5):287–294
- López-García JA, Oyarzun R, López Andrés S, Manteca Martínez I, J. (2011) Scientific, Educational, and Environmental Considerations Regarding Mine Sites and Geoheritage: A Perspective from SE Spain. *Geoheritage* 3(4):267–275
- Lyell C (1833) *Principles of Geology, Being an Attempt to Explain the Former Changes of the Earth's Surface, by Reference to Causes Now in Operation*. John Murray, Albemarle-Street, London, p 2
- Marescotti P, Branucci G, Sasso G, Solimano M, Marin V, Muzio C, Salmona P (2018) Geoheritage Values and Environmental Issues of Derelict Mines: Examples from the Sulfide Mines of Gromolo and Petronio Valleys (Eastern Liguria, Italy). *Minerals* 8(6):229
- Marsden M (2013) *The woven universe. Selected writings of Rev. Māori Marsden. The Estate of Rev. Māori Marsden, New Zealand*
- Mata-Perelló JM, Mata-Lleonart R, Vintrol-Sánchez C, Restrepo-Martínez C (2012) SOCIAL GEOLOGY: A NEW PERSPECTIVE ON GEOLOGY. *DYNA* 79:158–166
- McCrossin, N., 2013. *Intention and Implementation: Piecing Together Provisions for Māori in the Resource Management Act* (Thesis, Master of Arts). University of Otago. Retrieved <http://hdl.handle.net/10523/4547> Accessed 1. Jan. 2021
- Mead HM, Mead MS (2016) *Tikanga Māori. Living by Māori values, revised edn*. Huia Publishers and Te Whare Wananga o Awanuiarangi, Wellington
- Megerle H (2012) Limited visibility and protection as well as insufficient recognition of geomorphosites: Background and challenges identified in South-West Germany. *Hochschule für Forstwirtschaft Rottenburg Schadenweilerhof* 87(3):157–169
- Megerle H, Pietsch D (2017) Consequences of overlapping territories between large scale protection areas and Geoparks in Germany: Opportunities and risks for geoheritage and geotourism. *Annales de géographie* 717:598
- Miljkovic, D., Bozic, S., Miljković, L., Markovic, S., Lukić, T., Jovanovic, M., Bjelajac, D., Vasiljevic, D., Vujicic, M. and Ristanović, B., 2018. *Geosite Assessment Using Three Different Methods; A Comparative Study of the Krupaja and the Žagubica Springs-Hydrological Heritage of Serbia*.
- Millennium Ecosystem Assessment (2005) *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, DC
- Mocior E, Kruse M (2016) Educational values and services of ecosystems and landscapes – An overview. *Ecol Indic* 60:137–151
- Mora G (2013) The need for geologists in sustainable development. *GSA Today* 23(12):33–37
- Mucivuna VC, Reynard E, Garcia MdGM (2019) *Geomorphosites Assessment Methods: Comparative Analysis and Typology*. *Geoheritage* 11:1799–1815
- National Geographic (2020) *Geotourism*. <https://www.nationalgeographic.com/maps/geotourism/> Accessed 3 January 2020
- National Geographic Boilerplates (2015). National Geographic Press Room. National Geographic Society. <https://web.archive.org/web/20160304110424/http://press.nationalgeographic.com/boilerplates/> Accessed 2 March 2020
- Németh, K., Casadevall, T., Moufti, M.R. and Marti, J., 2017. *Volcanic Geoheritage*. *Geoheritage*, 9(3): 251-254.
- Newsome D, Dowling R (2006) Chapter 1 - The scope and nature of geotourism, *Geotourism*. Butterworth-Heinemann, Oxford, pp 3–25
- NGA MANA WHENUA O TAMAKI MAKAUURAU AND THE CROWN (2012) *NGA MANA WHENUA O TAMAKI MAKAUURAU COLLECTIVE REDRESS DEED*. Government Bill, Hon Christopher Finlayson
- Office of World Geopark, N (2004). *Operational guideline for National Geoparks seeking UNESCO's assistance*. Global UNESCO network of Geoparks
- Ólafsdóttir R, Tverijonaite E (2018) Geotourism: A systematic literature review. *Geosciences* 8(7):234
- Ollier C (2012) Problems of geotourism and geodiversity. *Quaestiones Geographicae* 31:57–61
- Orange C (1987) *The Treaty of Waitangi*. New Zealand. Allen and Unwin, Wellington
- Panizza M (2001) Geomorphosites: Concepts, methods and examples of geomorphological survey. *Chin Sci Bull* 46(1):4–5
- Panizza, M. and Piacente, S., 1993. *Geomorphological assets evaluation*.
- Papa Te (2004) *Bicultural Governance*. Te Papa National Services Te Paerangi, Governance, Management & Planning (22)
- Patrick J, McKeever N, Zouros N, Patzak M (2010) The UNESCO Global Network of Geoparks. in *Geoparks: Think outside the park*. ed. Bailey, H and Hill, W. The George Wright Forum. The GWS Journal of Parks, Protected Areas & Cultural Sites., 27(1)
- Pelfini M, Bollati I (2014) Landforms and geomorphosites ongoing changes: Concepts and implications for geoheritage promotion. *Quaestiones geographicae* 33:131–143
- Pereira P, Pereira D, Caetano Alves MI (2007) Geomorphosite assessment in Montesinho Natural Park (Portugal). *Geographica Helvetica* 62(3):159–168
- Petersen K, Feldt R, Mujtaba S, Mattsson M (2008) Systematic Mapping Studies in Software Engineering. In: *Proceedings of the 12th International Conference on Evaluation and Assessment in Software Engineering*, p 17

- Pickering M (1994) The physical landscape as a social landscape: a Garawa example. *Archaeol Ocean* 29(3):149–161
- Pralong JP (2005) A method for assessing tourist potential and use of geomorphological sites. *Géomorphologie: relief, processus, environnement* 1(3):189–196
- Prosser CD (2018) *Geoconservation, Quarrying and Mining: Opportunities and Challenges Illustrated Through Working in Partnership with the Mineral Extraction Industry in England*. *Geoheritage* 10(2):259–270
- Prosser, C., Murphy, M. and Larwood, J., 2006. *Geological conservation - a guide to good practice*.
- Prosser CD, Bridgland DR, Brown EJ, Larwood JG (2011) Geoconservation for science and society: challenges and opportunities. *Proc Geol Assoc* 122(3):337–342
- Prosser CD, Díaz-Martínez E, Larwood JG (2018) In: Reynard E, Brilha J (eds) *Geoheritage*. Elsevier, pp 193–212
- Puiguiriguer, M., 2007. *Pobres x Desastres*. *Geólogos del Mundo*.
- Rands MRW, Adams WM, Bennun L, Butchart SHM, Clements A, Coomes D, Entwistle A, Hodge I, Kapos V, Scharlemann JPW, Sutherland WJ, Vira B (2010) Biodiversity Conservation: Challenges Beyond 2010. *Science* 329(5997):1298–1303
- Reeves S, Goldman J, Gilbert J, Tepper J, Silver I, Suter E, Zwarenstein M (2010) A scoping review to improve conceptual clarity of inter-professional interventions. *Journal of interprofessional care* 25:167–174
- Resource Management Act (1991) Resource Management Act No 69 (as at 29 October 2019), Public Act - New Zealand Legislation. In: M.f.t. Environment (ed). New Zealand Government, Wellington, New Zealand
- Reynard E (2008) Scientific research and tourist promotion of geomorphological heritage. *Geogr Fis Din Quat* 31(2):225–230
- Reynard E (2009) *Geomorphosites: definition and characteristics*. Dr. Friedrich Pfeil Verlag, Munich
- Reynard E, Fontana G, Kozlik L, Scapozza C (2007) A method for assessing "scientific" and "additional values" of geomorphosites. *Geographica Helvetica* 62(3):148–158
- Reynard E, Perret A, Bussard J, Grangier L, Martin S (2016) Integrated approach for the inventory and management of geomorphological heritage at the regional scale. *Geoheritage* 8(1):43–60
- Rother T (2016) *Shared landscapes: Ownership and governance of Lhiwa Harbour (Aotearoa New Zealand)*. A thesis submitted to Victoria University of Wellington in fulfilment of the requirements for the degree of Doctor of Philosophy in Social Anthropology
- Ruban DA (2010) Quantification of geodiversity and its loss. *Proc Geol Assoc* 121(3):326–333
- Ruban DA (2015) Geotourism - A geographical review of the literature. *Tour Manag Perspect* 15:1–15
- Ruban DA (2016) Representation of geologic time in the global geopark network: A web-page study. *Tour Manag Perspect* 20:204–208
- Ruban DA, Tiess G, Sallam ES, Ponedelnik AA, Yashalova NN (2018) Combined mineral and geoheritage resources related to kaolin, phosphate, and cement production in Egypt: Conceptualization, assessment, and policy implications. *Sustainable Environment Research* 28(6):454–461
- Rudwick MJS (1998) Lyell and the Principles of Geology in Lyell: the past is the key to the present. In: Blundell DJ, Scott A (eds) *Geological Society Special Publication* 143: 3–17
- Ryan J, Silvano S (2011) A brand for all the nations: The development of the World Heritage Brand in emerging markets. *Marketing Intelligence & Planning* 29:305–318
- Rybar P (2010) Assessment of attractiveness (value) of geotouristic objects. *Acta Geoturistica* 1(2):13–21
- Saunders, W., 2017. *Setting the Scene: The Role of Iwi Management Plans in Natural Hazard Management*.
- Schrodt F, Bailey JJ, Kissling WD, Rijdsdijk KF, Seijmonsbergen AC, van Ree D, Hjort J, Lawley RS, Williams CN, Anderson MG, Beier P, van Beukering P, Boyd DS, Brilha J, Carcavilla L, Dahlin KM, Gill JC, Gordon JE, Gray M, Grundy M, Hunter ML, Lawler JJ, Monge-Ganuzas M, Royse KR, Stewart I, Record S, Turner W, Zametske PL, Field R (2019) Opinion: To advance sustainable stewardship, we must document not only biodiversity but geodiversity. *Proc Natl Acad Sci* 116(33):16155–16158
- Scott A (1998) The legacy of Charles Lyell: advances in our knowledge of coal and coal-bearing strata. in: Lyell: the past is the key to the present, (eds) Blundell, D. J. Scott, A. *Geol Soc Spec Publ* 143:243–261
- Sebastián Rivera G, Gallud JA, Tesoriero R (2019) Code Generation Using Model Driven Architecture: A Systematic Mapping Study. *Journal of Computer Languages* 56:100935
- Serrano E, Gonzalez-Trueba JJ (2005) Assessment of geomorphosites in natural protected areas: The Picos de Europa National Park (Spain). *Géomorphologie relief processus environnement* 3:197–208
- Sharples C (1998) *Concepts and principles of geoconservation*, 86 pp
- Stafford D (2008) *Tangata whenua: The world of the Maori*. New Zealand. Raupo, Auckland
- Stewart IS, Gill JC (2017) Social geology — integrating sustainability concepts into Earth sciences. *Proc Geol Assoc* 128(2):165–172
- Štrba Ľ (2018) Analysis of Criteria Affecting Geosite Visits by General Public: a Case of Slovak (Geo)Tourists. *Geoheritage*
- Štrba Ľ, Rybár P, Baláž B, Molokáč M, Hvizdák L, Kršák B, Lukáč M, Muchová L, Tometzová D, Ferenčíková J (2015) Geosite assessments: comparison of methods and results. *Curr Issue Tour* 18(5): 496–510
- The New Zealand Biodiversity Strategy (2000) *New Zealand Biodiversity Strategy 2000-2020*. Department of Conservation & Ministry for the Environment, Wellington
- Thomas M (2016) New keywords in the geosciences - some conceptual and scientific issues. *Revista do Instituto Geológico, São Paulo* 37(1):1–12
- Tipa G, Welch R (2006) *Comanagement of Natural Resources: Issues of Definition From an Indigenous Community Perspective*. *J Appl Behav Sci* 42(3):373–391
- UNESCO (1998) *Environmental and Engineering Geology for sustainable development*. Moscow University of Engineering Ecology, Moscow, p 201
- UNESCO (2016) *UNESCO global geoparks: Celebrating earth heritage, sustaining local communities*. UNESCO, Paris, p 17
- United Nations (2015) *Sustainable Development Goals (Online)*. Available at: <http://www.un.org/sustainabledevelopment/sustainable-development-goals/> Accessed 3 Jan 2020
- Valdez F (2018) *Geoheritage: Obtaining, Explaining and Transmitting Archaeological Knowledge*. *International Journal of Geoheritage and Parks* 6(2):86–102
- Van Ree CCDF, van Beukering PJH, Boekestijn J (2017) Geosystem services: A hidden link in ecosystem management. *Ecosystem Services* 26:58–69
- Wang L (2007) Multi-designated geoparks face challenges in China's heritage conservation. *J Geogr Sci* 17(2):187–196
- White S, Wakelin-King GA (2014) *Earth Sciences Comparative Matrix: A Comparative Method for Geoheritage Assessment*. *Geogr Res* 52(2):168–181
- Wilshusen P, Brechin S, Fortwangler C, West PC (2002) Reinventing a Square Wheel: Critique of a Resurgent "Protection Paradigm" in International Biodiversity Conservation, pp 17–4000
- Wimbledon WAP (1996) *GEOSITES - a new conservation initiative*. Episodes-News magazine of the International Union of Geological Sciences 19:87–88
- Wimbledon W (1999) *GEOSITES - an International Union of Geological Sciences initiative to conserve our geological heritage*. Polish Geological Institute Special Papers 2:5–8
- Wimbledon WAP, Ishchenko N, Gerasimenko N, Alexandrowicz Z, Vinokurov V, Liskak P, Vozár J, Vozarova J, Bezák V, Kohut M,

- Polak M, Mello J, Potfaj M, Gross P, Elecko M, Nagy N, Baráth I, Lapo A, Vdovets M, Bevins R (1998) A First attempt at a Geosites Framework for Europe, an IUGS initiative to support recognition of world heritage and European Geodiversity. *Geologica Balanica* 28: 5–32
- Wood SLR, Jones SK, Johnson JA, Brauman KA, Chaplin-Kramer R, Fremier A, Girvetz E, Gordon LJ, Kappel CV, Mandle L, Mulligan M, O'Farrell P, Smith WK, Willemen L, Zhang W, DeClerck FA (2018) Distilling the role of ecosystem services in the Sustainable Development Goals. *Ecosystem Services* 29:70–82
- Xun Z, Milly W (2002) National Geoparks Initiated in China: Putting Geoscience in The Service of Society. *Episodes*, 25
- Zametske, P.L., Read, Q.D., Record, S., Gaddis, K.D., Pau, S., Hobi, M.L., Malone, S.L., Costanza, J., M. Dahlin, K., Latimer, A.M., Wilson, A.M., Grady, J.M., Ollinger, S.V. and Finley, A.O., 2019. Towards connecting biodiversity and geodiversity across scales with satellite remote sensing. *Glob Ecol Biogeogr*, 28(5): 548-556.
- Zouros N (2005) Assessment, protection, and promotion of geomorphological and geological sites in the Aegean area, Greece. *Géomorphologie: relief, processus, environnement* 3:227–234
- Zouros NC (2007) Geomorphosite assessment and management in protected areas of Greece Case study of the Lesbos island – coastal geomorphosites. *Geographica Helvetica* 62(3):169–180
- Zwoliński Z, Najwer A, Giardino M (2018) Chapter 2 - Methods for Assessing Geodiversity A2 - Reynard, Emmanuel. In: J. Brilha (Editor), *Geoheritage*. Elsevier, pp 27-52