Assessment of geosites in northern Morocco: diversity and richness with potential for socioeconomic development

Adil Salhi[1*], Mohamed Rida Alilou[1], Sara Benabdelouahab[2], Josep Vila Subirós[3], Pere Sala[4], Tarik Benabdelouahab[5], Mahjoub Himi[2], and Albert Casas Ponsati[2]

[1] Geography and Development group, Abdelmalek Essaadi University, Martil, Morocco. asalhi@uae.ac.ma / https://orcid.org/0000-0001-8756-2484 / Phone: +212654601220. [*]**Corresponding author**

[2] Economic and Environmental Geology and Hydrology group, University of Barcelona, Barcelona, Spain. albert.casas@ub.edu / https://orcid.org/0000-0002-4964-1226 / moibenabdelouahab@gmail.com / himi@ub.edu https://orcid.org/0000-0003-1419-6676

[3] Environment and Geographic Information Technologies group, University of Girona, Girona, Spain. josep.vila@udg.edu

[4] Landscape Observatory of Catalonia, Girona, Spain. pere.sala@catpaisatge.net

[5] National Institute of Agronomic Research, Rabat, Morocco. tarik.benabdelouahab@gmail.com / https://orcid.org/0000-0001-8386-934X

Abstract

Despite the importance of geoheritage as an interdisciplinary geo-based topic, it is poorly documented as a tool of harmonious socioeconomic development and territorial strategic planning. The promotion of this natural resource in rural areas of the southern Mediterranean may strengthen social resilience and consolidate management strategies if it is conducted according to a responsible and sustainable approach that takes account of local specificities. Here, an exhaustive, multi-criteria and qualitative assessment of the geomorphological sites of the large Alpine Rif belt was established to assess their scientific and additional values based on a widely adopted score ranking method. Later, it was established a restricted list of the most outstanding sites based on qualitative conditions. This list contains 39 sites which may be linked in three thematic geocircuits to serve as gathering points for initiatives and development projects. We anticipate that this may create an economic diversity to revive a social fabric capable of satisfying its needs and expectations, reducing the gap and inequalities between disadvantaged rural areas upstream and industrialized urban areas downstream, and inspiring a benign and balanced development.

Keywords: Geoheritage, geomorphosites, assessment, socioeconomic development, Morocco.

1. Introduction

The patrimonialisation of geoheritage (landscape and cultural values) is the result of a perception process that makes a territorial element (cultural asset, natural area, tradition and all parts of 'immaterial heritage') be recognized by society as being important to conserve and to be transmitted to future generations (Reynard and Giusti 2018). In this sense, geoheritage acts as a centre of meaning and symbolism, and builds a sense of belonging and a territorial identity that is fundamental in the creation process of a national identity (Nogué and Vicente 2004). Despite this importance, the conservation of geoheritage (or geoconservation) has generally not been well integrated within nature conservation initiatives and policies nor in environmental management and sustaining resources (Gordon et al. 2018). Actually, the conservation of geoheritage is discussed and enhanced only in some parts of the World (e.g. Europe) but not in others like Africa, where geoheritage is mainly appreciated by a scientific minority while it should be promoted and perceived by a much wider audience (Errami et al. 2015). Achieving this may lead to its promotion for their scientific and societal values to ensure their conservation for future use by academics, tourists and casual recreationalists (Melelli et al. 2017; Reynard and Giusti 2018).

The conservation of geoheritage is the practice of conserving, enhancing and promoting awareness of those features and underlying processes of geodiversity that have significant scientific, educational, cultural, aesthetic or ecological value. Its basic aim is to conserve well-developed and well-expressed representative examples of important elements of the geodiversity found in a region (Badang et al. 2017; Ibáñez et al. 2019; Sharples et al. 2018) through a process of recognizing and giving broader meaning to geosites as key elements of a properly managed and sustainable geotourism which may affect local development (Hose 2006; Kubalíková 2013). Geosites, as landforms, represent the particular aspects of relief being determined by the morphogenetic processes and the geographic sublayer. Alone, it can constitute components of the cultural or scientific heritage of a territory, having the same significance as the historical monuments or works of arts, sometimes being the concrete support of an architectural, spiritual or cultural expression (Ilieş and Josan 2009).

Geomorphosites are one of the multiple types of the geosites, and they are defined as landforms that have acquired a value thanks to human perception (Kubalíková 2013). They are important elements of Natural Protected Areas which may be assessed both as structural and functional elements of the natural system and for their social values in relation to their location (Serrano and González-Trueba 2005). Thus, their inventory and assessment as valuable occurrences of geoheritage are essential steps in any geoconservation strategy and in the establishment of priorities in site management (Brilha 2016).

Despite the richness and variety of the Moroccan geodiversity, the concern for geoheritage have only recently begun to come to the front as confirmed by the limited related studies performed in this country (Arrad et al. 2020; Beraaouz et al. 2019; Berred et al. 2019). During the last ten years, Morocco has used actively this richness to promote sustainable development with the aim of reaching 20 million tourists by 2025, based on a strategy which depended on the growing scientific studies output, to valorise the national heritage and to make it well-known overseas (Bouzekraoui et al. 2018a).

The Alpine Rif belt of Morocco (North) is a land of exceptional sites of geological and geomorphological importance. Despite this, geoheritage has never been inventoried and do not yet benefit from any conservation status worthy of its national and international relevance. In this sense, the aim of the paper is to evaluate and catalogue the geoheritage and geodiversity of the Alpine Rif belt combining geomorphosites assessment and field work. All sites with potential for geotourism that can generate social and economic impact are highlighted to encourage the territorial promotion of this mountainous area. This is even crucial in the Mediterranean southern areas (like our case) where the well-being of rural communities is connected to their level of resilience and to their ability to develop and use their own resources to adapt and sustain the productivity and territorial functions despite of their vulnerability and / or the fragility of their environment (Holladay and Powell 2013; Powell et al. 2018; Scarlett and Riede 2019). Thus, investing the geoheritage may enhance social resilience and contain environmental fragility through the development of a cultural and economic motivation that can strengthen human-territorial links to connect the members of rural communities to their counties, which will have beneficial repercussions on vast socioeconomic and ecologic systems at national and cross-border scales.

In fact, the strategic location of the study area makes of it the focal point of the global transition between Africa, Europe, the Mediterranean and the Atlantic Ocean. This crucial role has been reinforced throughout history thanks to its natural richness (water, soil and vegetation) giving it an exceptional character in terms of permeability, stabilization and transmission of human, economic and cultural flows. However, this will be seriously threatened because of the alarming degradation of its natural resources, which will certainly jeopardize the sustainability of its socio-economic development and will have a negative impact on the future of the region; Indeed, soil degradation poses a serious threat to the plant and water heritage already weakened by the lithological fragility, the escarpment of the reliefs, the droughts and the spatiotemporal concentration of the rains (Benabdelouahab and Salhi 2018; Benabdelouahab et al. 2020).

The maintain of social, economic and environmental equilibrium is crucial in this Mediterranean southern frontier where immigration and environmental fragilities should not be underestimated; coupled with socioeconomic congestion (in relation with an illiteracy rate of 31%, an unemployment rate above 8% and an excessive poverty rate (HCP 2018)) it would lead to an irremediable crash (Salhi et al. 2020).

To counter this situation, environmentally responsible tourism may be a factor of openness, enhancement of the local economy and improvement of the living conditions of society (e.g. creation of transport infrastructure, improvement of collective services and living environment, opening up of rural areas). It often leads to changes in lifestyles, which should be implemented gradually so that new practices do not conflict with traditional values but penetrate in harmony according to a strategy of enrichment. If not, this development can lead to withdrawal behaviour which will be harmful to this progressive vision.

Tourism also strengthens the social and geographic mobility of individuals and it can help to fix populations in their homelands, which is vital for conserving water-soil-plant resources. The development of tourist activity and the creation of employment can both constitute a secondary source of income for the locals as it can attract people who are looking for opportunities whether they are qualified and or willing to learn a new trade.

Thus, the creation and strengthening of destinations with confirmed geotourism potential is likely to slow the flow of permanent rural migration, motivated by the quest for better opportunities and well-being. At the same time, this will lead to a decrease pressure on fragile territorial resources and an improvement in awareness of environmental conservation.

Based on this vision, promoting the geoheritage would be the best way to improve social resilience and mitigate environmental fragility. This would only be possible through the enhancement of geomorphosites which must be linked in the form of geocircuits to improve their marketing and attractiveness.

2. Material and methods

2.1. Study area

The Rif belt (northern Morocco) is an Alpine mountain range marked by an exceptional natural wealth that makes its fabulous ecosystem part of the 'Intercontinental Biosphere Reserve of the Mediterranean'. It has a unique landscape, particularly in the extended carbonate ridge ('Dorsale') (**Fig. 1**), which is the main hydrogeological system that feeds the indigenous rural population as well as large cities downstream of the watersheds. Other than its hydrological interest, this ridge has great scientific, ecological and geological values that deserves special and immediate attention. It forms with the Betic Cordilleras an asymmetric arcuate mountain belt (Gibraltar Arc) around the Alboran Sea, at the western tip of the Alpine orogen (Chalouan and Michard 2004). It is known by the abundance of friable lithological formations (i.e. Mudstones, Flysch and Schists) and by the steep and rugged geomorphological aspect. It extends from the Atlantic Ocean (west) to the Nekor river (east) and from the Strait of Gibraltar (north) to the Gharb Plain (south). It corresponds to most of the mountainous Mediterranean area of Morocco. The extensive coastal plains on the Atlantic side (between Tangier and Larache) contrast, on the Mediterranean side, with small low valleys and narrow intramountain plains, the most important of which are Ghis-Nekor, Martil-Alila and Oued Laou. This arcuate mountain belt (convex towards the Mediterranean) reaches up to 2,450 m at Mount Tidirrhine (east), reflects steeper slopes on the Mediterranean side, and is surrounded by a set of low hills with soft contours.

Geologically, it shows three major domains: the 'External Zones' which consist of a fold-thrust belt detached from the attenuated African crust along Upper Triassic evaporitic redbeds, the 'Maghrebian Flysch Nappes' which originate from an oceanic/transitional crust-floored during the Jurassic-Early Miocene times, and The 'Internal Zones' which consist of three nappe complexes of continental origin (Dorsale Calcaire, Ghomaride and Sebtide) (Chalouan et al. 2008). Each of these three domains consists of tectonic complexes of stacked units or nappes with similar lithologies within a given complex but contrasting from one complex to the other (Chalouan et al. 2008; Michard et al. 2008).

The Internal domain extends from Sebta (North) to Jebha (East) and consists of continental units displaced westward over several hundreds of kilometres, thus representing a genuine exotic terrane (Chalouan et al. 2008). It does not exceed 10 km wide northern Tetouan and widens gradually to reach 30 km near the small town of Jebha. It is a thinned block of crystalline continental crust with Palaeozoic to Tertiary sedimentary cover (which are, in places, sheared off to form stack nappes) (Wildi 1983). It constitutes, from bottom to top, three superimposed structural complexes named the 'Sebtide', 'Dorsale Calcaire' and 'Ghomaride' Complexes, respectively (Didon et al. 1973; Suter 1980). The Sebtide Complex is affected by a strong polyphasic Alpine metamorphism which is absent or poorly developed in the Dorsale Calcaire and Ghomaride Nappes (Zaghloul et al. 2010). The lower plate corresponds to the Sebtide dominantly consisting of relatively deep crustal rocks such as mica-schists, migmatites and granulites associated with mantle peridotites ("Beni Bousera" village near Jebha) (Chalouan et al. 2008). The upper plate consists of the Ghomaride, which overlie the Sebtide through a regional detachment. They include Palaeozoic rocks affected by a Variscan metamorphism partly superimposed by weak Alpine recrystallization, and relicts of their Mesozoic-Cenozoic cover (Azzouz 1992; Chalouan 1986). The Dorsale Calcaire is a complex of Mesozoic-Cenozoic thrust sheets dominated by Triassic-Liassic carbonates which appears as discontinuous ranges at the front, and generally below the more internal crustal units (Nold et al. 1981; Wildi 1983).

The Flysch domain is of relatively thin, but extensive thrust-nappes consisting of turbiditic sediments that root beneath the Internal domain and overlie the External one (Durand-Delga 1980; Wildi 1983). This turbidite sequences ('Flysch') are dominant, but clay-dominated sequences occur at the bottom of each nappe ("pre-flysch" sequences). Part of the Flysch nappes has been back-thrust over the northern Ghomaride complex (e.g. Jbel Zemzem southern Sebta) (Chalouan et al. 2008). The External domain is divided into three zones, according to structural and stratigraphic criteria, i.e. from NE to SW the Intrarif, Mesorif and Prerif (Suter 1980).

From the administrative point of view, the study area covers more than 12,000 km² mainly distributed between the provinces of Tetouan, Chefchaouen, Al Hoceima, M'diq-Fnideq, Fahs-Anjra and Larache. It has a rich and diverse heritage, including 21 well-distributed Sites of Biological and Ecological Interest which include maritime, coastal, continental and wetland areas such as the 'Talassemtane' and 'Al Hoceima' National Parks, the 'Bouhachem' Regional Park and six sites of geomorphological, biological and ecological value (Moussa mountain, Smir lagoon, Taifour hill, Ghomara coast, Jebha Circus and Tizirene mountain). It covers almost two-thirds of the Tangier-Tetouan-Al Hoceima administrative region marked by an unbalanced demographic growth and profound changes in the spatial and socioeconomic structure (especially in rural and inland areas); There are nearly 4 million inhabitants (with a growth rate of 1.5%) of which 60% are living in urban areas following the emergence of several small coastal centres (where spreads gradually tourist infrastructure) and the concentration of industrial activities in the major coastal cities (especially in Tangier) (HCP 2018).

Most of the industrial projects are concentrated on the metropolitan area of Tangier (which benefits from a unique location and provides a competitive infrastructure in continuous development) while tourist activities extend mainly along the coastline. In the other provinces (Al Hoceima, Chefchaouen, Fahs-Anjra and Ouezzane), the difficulties of access, the hard mountain conditions and the large migratory flows led to a drop in agricultural profitability (main activity sector) which intensify the disruption between the economy and demography (Salhi and Chikhi 2018). Indeed, the agricultural sector is the locomotive of the regional economy with up to 11% of the country's useful agricultural land and 57% of the total regional area (Salhi et al. 2020).

The rural population is characterized by high rates of illiteracy and poverty and low indices of social development (HCP 2014). Rural economic activities are essentially traditional farming, extensive livestock, and an increase of cannabis crops. Still, there is a seasonal, irregular and unorganized economic income for local population in relation with seaside, geo and spiritual tourisms. These are linked to an extended 235 km of coastline, several attractive mountain parks (e.g. Talasemtane, Bouhachem and Ben Karrich) and the shrine of saints (e.g. ‘Moulay Abdessalam Ben Machich’).

The study area is of the biodiversity hotspots of the Mediterranean which, however, suffers an incessant process of degradation due to overexploitation and non-alignment of management and protection actions threatening several ecosystems and landscapes (Salah et al. 2018; Salhi et al. 2020). Over the past twenty years, it has witnessed an accelerating economic dynamism that has led to the growth of all productive sectors and a rapid increase in the regional gross domestic product (Salhi et al. 2019). This dynamism was accompanied by major structural projects and high demand for investment projects, especially in industry, tourism and construction. However, it involved high pressure on the quality and availability of water and soil, and led to waste production and environmental degradation (Salhi et al. 2020).

The climate of the study area is Mediterranean marked by long dry summers giving rise to several arid months (3 to 5 in average), with high water stress constraints, but potentially favourable to an extended touristic season (Salhi et al. 2019). This potential should be carefully studied and managed within the values of ecological tourism not to break the fragile water balance. Winter and autumn are rainy (45% and 30% per annual rainfall average, respectively), although there is an irregular spatiotemporal variability in the annual rainfall (from 300 mm in average in the East up to 1,100 mm in the central mountain belt), which can locally reach high intensities causing abundant runoff and loss of soil (Salhi et al. 2020). Besides, there is a clear temperature increase in the last decades because of global warming, as well as longer droughts (Benabdelouahab and Salhi 2018; Hadria et al. 2019). The area is known for a very active erosive processes with an average of potential annual soil loss rate of 27.7 t/ha/year which is equivalent to a massive potential gross amount of soil loss of 2.7 kg/m^2/year. This means an average of the potential gross amount of soil loss of 44.3 Mt/year which leads to a rapid decrease of dams' storage capacities and the deterioration of land and vegetation (Salhi et al. 2020).

2.2. Methodological framework

Geomorphosites are geomorphological landforms that have acquired a scientific, cultural/historical, aesthetic and/or social/economic value due to human perception or exploitation (Reynard and Panizza 2005). They can be single geomorphological objects or wider landscapes which may be modified, damaged, and even destroyed under the anthropogenic pressure. Hence, the urgent need to promote their values and to protect them under a legal framework.

During the last decades, several attempts have been made to evaluate the quality of geomorphological heritage in various contexts. Even if many methods of quantitative assessment of geosites are available in the literature, but the criteria and parameters they use are often unclear and ambiguous (Mucivuna et al. 2019). Yet, there are three recurrent assessment criteria that are rarity, representativeness and integrity (Reynard et al. 2007; Reynard and Giusti 2018). In general, the aim of a quantitative assessment is to decrease the subjectivity associated with any evaluation procedure; the result of this numerical assessment is a sorted list of sites (where those with higher value should be given top priority), which is a powerful tool for the establishment of management priorities (Brilha 2016).

Here, the methodology consists of an exhaustive assessment based on the method developed by the University of Lausanne to assess the scientific and additional values of geomorphosites at the regional scale (Reynard et al. 2007; Reynard et al. 2016), which have been widely applied with good results (Bouzekraoui et al. 2018b; Clivaz and Reynard 2018; Comãnescu et al. 2009; Kubalíková and Kirchner 2016; Mauerhofer et al. 2018; Safarabadi and Shahzeidi 2018). It followed simple systematic steps that takes into consideration a set of ecological, cultural, aesthetic and economic criteria qualified by numerical scores that indicate the proportional value attributed to the site (**Table 1**). The assessment included two main stages (inventory and quantification) where the geomorphosites are identified, selected and characterized (inventory) then the importance of sites is determined by numerical assessment of criteria, allowing the comparison of sites (quantification) (Panizza 2001; Pereira and Pereira 2010).

The inventory stage starts with quest for all the possible geomorphosites in which the necessary data is collected in situ after long but fascinating fieldwork. Later, a comprehensive list of existing geomorphosites is established, together with a copious data compilation from specialized literature. The inventory process was completed when the detailed description of each of the selected geomorphosites was finished. The quantification stage succeeds the inventory process and builds on the data which are previously compiled. It makes use of a set of two values (i.e. scientific and additional values) divided into four criteria then to twelve sub-criteria (**Table 1**). The description of each geomorphosite deals mainly with its geomorphological characteristics but also with other features such as archaeological findings, human infrastructures, biotopes, etc.

The assessment of the scientific value of each site was based on the restrictive definition of geomorphosites which include sub-criteria that encourage greater context-sensitivity analysis (i.e. integrity, representativeness, rareness and paleogeographic value). The assessment of the additional value focuses on the ecological, aesthetic, cultural and economic criteria. It is based on simple sub-criteria which aim not to give an exhaustive analysis of the site in each specific discipline (i.e. history, biology, economy, religion) but to highlight potential relationships that may exist between geomorphology and other aspects of culture and nature.

For each site, scores ranging from 0 to 1 (in increments of 0.25) define the importance of the object, according to each sub-criterion. In each value (i.e. scientific and additional), the sub-criteria have the same weight. A score is then calculated for each of the two values which is the average of the scores of the corresponding sub-criteria. Later, the final score is calculated for each site to be equal to the average of the scores for the two values. Consequently, the sites with the highest final scores may be considered to be the most valuable geomorphosites in the study area (Reynard et al. 2007; Reynard et al. 2016). After that, among all the sites, only the most interesting ones were selected taking into account a qualitative assessment based on the geomorphological intrinsic value, the potential use and the need for protection of the site (Pereira and Pereira 2010; Reynard et al. 2007). Finally, it was established a restricted list of the most outstanding sites which have a final score higher than the sum of the average and the standard deviation of the scores. The aim of emphasising rank averages in geomorphosite assessment is to produce a homogeneity criterion of results (Reynard et al. 2016). Thus, geomorphosites that score well over the full spectrum of indicators will also be amongst the best placed in the final ranking (Reynard and Giusti 2018).

The data collected in situ on the qualitative and quantitative characterization of the geomorphosites were compiled in inventory sheets in a simple and easy form to be, later, assimilated by the general public. Each inventory sheet includes the name of the site, its type, shape, photo, specific alphanumeric code, coordinates and administrative situation, dimensions, hydrometry, geomorphological processes and a brief description of the general observations. These data were then integrated into a geographic database under ArcGIS 10.2 which contains the cartographic limits of the selected geomorphosites. The statistical methods adopted to interpret the data included the Pearson correlation coefficient and descriptive statistics analysed based on the Analysis ToolPak Add-in of Microsoft Excel.

3. Results and discussion

The geomorphological value may be assessed according to different material and scientific properties (Coratza and Hobléa 2018; Reynard et al. 2016) and to intangible heritage (Nogué and Wilbrand 2018). In our study, this value (which can be scientific, cultural/historical, aesthetic and / or socioeconomic) is assessed based on ranking scores of the geomorphosites and their statistical analysis. Taking into account the presence of the outstanding attractive and significant landscapes, the Rif belt have a geoheritage wealth that deserves to be emphasized, conserved and interpreted to a wide audience (geotourism).

In the study area, a significant typological diversity is observed regardless the morphogenic form, especially in karstic, coastal, lacustrine and fluvial forms. A total of 185 geomorphosites were identified from which it was selected a final list of 169 most interesting sites, based on a qualitative assessment which takes account of the geomorphological intrinsic value, the potential use and the need for protection of the site (**Table 2**). It is observed a predominance of karstic and coastal forms (36.5% and 24.7%, respectively) in relation with the abundance of limestone in this coastal belt. The aeolian and frost-riven sites are the least numerous in the study area (0.6% and 1.2%, respectively) (**Table 3**).

Out of the 169 interesting sites, it was established a restricted list of the most outstanding ones which have a final score higher than the sum of the average (0.59) and the standard deviation (0.10) of the scores (i.e. the outstanding inferior-limit is 0.69). This list includes 39 outstanding sites again predominated by coastal and karstic landforms (35.9% and 25.6%) while gravity, aeolian and frost-riven sites are absent (**Table 3**).

For the 169 interesting sites, the average final score is 0.59 while the average scientific and additional values are 0.68 and 0.50, respectively. The reason is that most of the sites have more scientific value than cultural, ecological, aesthetic or economic one in relation with the local or regional interests (low scores) of most of the sites; for instance, it is the additional value that really influences the list of the outstanding sites. In fact, it is observed that most of the sites have relatively high scientific values in relation with their good preservation (integrity criteria), the quality of their geomorphological features at the regional level (representativeness criteria) and the unique characteristics they contain (rareness criteria). Contrariwise, the paleogeographic criteria have less influence on scientific value in most cases.

Overall, the highest final scores are calculated for the coastal 'bay of Al Hoceima' (Code C43), the costal 'beach of Lhwad' (C28) and the 'Cirque of Jebha' structural landform (S13). Beside the above-mentioned, the highest scientific values are observed for the fluvio-karstic 'natural bridge and travertine of Assifane' (Fk5) and the karstic 'old cave of Ifahssa' (K28). Likewise, the highest additional values are observed for the karstic 'Spring of Ketama' and the coastal beaches of 'Sebta peninsula', 'Oued Laou', 'Monica', 'Lhwad' and 'Cala Iris'.

In term of coastal landforms, 14 outstanding sites are highlighted out of 42 which are located southern the Strait of Gibraltar then between Oued Laou and Al Hoceima cities (**Fig. 2**). The beaches located between Fnideq and Oued Laou cities have scores that are close to the average but not above the outstanding inferior-limit (0.69), even if they generate high economic products and revenues due to their high national and international seaside attractiveness. The outstanding karstic landforms are 10 out of 62 total karstic sites which are located in the mountains of Al Haouz northern the city of Tetouan and in the extended carbonate ridge ('Dorsale Calcaire') between Tetouan and Bab Berred village (**Fig. 3**). The structural and lacustrine landforms count of 8 outstanding sites out of 33 which are located near Tetouan, between Oued Laou and Chefchaouen cities and in Jebha (**Fig. 4**). Likewise, the fluvial and fluvio-karstic landforms count of 7 outstanding sites out of 21 which are located between Chefchaouen and Oued Laou then in the mountains of Al Haouz (**Fig. 5**).

The outstanding sites could be linked in thematic 'Geocircuits' which may be gathering points for initiatives and projects within four interconnected themes: the exceptional geomorphological sites and landscape, the rich cultural history, the amazing artistic diversity and the local produce and products (Bouzekraoui et al. 2018a; Han et al. 2018). These themes should become the common denominator for the Rif area's collective development which, like in many cases, may stimulate job creation, education, dissemination, environmental protection, sustainability and, above all, identity consolidation which, together, will improve the quality of well-being and lead to the decline of land abandonment and massive immigration (Berred et al. 2019; Bruschi and Coratza 2018; Gordon 2018).

A regional strategical change should be done to enable an inclusive involvement of local communities through the Geocircuits. Still, this change must take into consideration that the rural society of the region includes traditional and devout people which have their own habits and conducts that any new coming should tolerate and adapt. For instance, women are very active within the rural society but it is unusual for them to communicate with strangers. Hence, involving women in the geotouristic activities is a challenge that should be addressed carefully through the preparation of facilities to exhibit their local handmade items (carpets, clothing, food). Local people may also learn simplified and general stories and explanations about the local landscape (in all its natures) to transfer to visitors of the local shops and accommodations.

The competent administrations should firstly recognize, provide necessary equipment and advertise the Geocircuits. After that, once the local communities discover them as a good source for their income, they will start getting involved, learning how to host tourists and give them proper services. Definitively, they will realise their landscape (natural and cultural) as the most valuable wealth they must keep and protect.

Three Geocircuits are proposed for the diversity of their characteristics and richness of their landscape (**Fig. 6**). The first (**Fig. 7**) starts from the Bouanan mountain where it can be contemplated an exceptional landscape comprising the cluse of Tetouan, the mountains of Al Haouz and the coastal area between Sidi Abdessalam (South), Martil and the hill of Taifour (North). The geocircuit continues through the coastal town of Martil to the Taifour hill (located north of it) where it can be contemplated the exceptional panorama of the coastal watersheds and the geomorphological and urbanistic range of the region. The route continues on a coastal road of twenty kilometres crossing several beaches, tourist complexes and cities until arriving at the mountainous 'Moussa' complex located west of the city of Sebta. Since there, it can be admired (in profile from west to east) the contrast of the mountainous geological and biological heritage of the national park of the Strait of Gibraltar, the green hills then the narrow coastal plains linearly urbanized. The following two stops are geographically the last two villages of Africa; the small villages of Belyounesh and Ksar Seghir where the carbonated mountain complex plunges under the Strait of Gibraltar to reappear on the European side offering an extraordinary panorama on the world most famous natural water channel.

The second geocircuit (**Fig. 8**) contrasts with the previous in length and in landscape. More extensive, its path connects Tetouan to the mountainous town of Chefchaouen, in the South, through a first stretch of rocky coasts (except for some small narrow beaches) until reaching the small town of Oued Laou. From this valley, it is gradually immersed in a mountainous fluviokarstic panorama through the canyon of the Laou river. Once in the small village of Akchour, the path can continue by car, mountain bike or on foot through the Talasemtane National Park.

The third geocircuit (**Fig. 9**) is much longer since it connects Chefchaouen and the coastal town of Al Hoceima. The first mountain section contrasts with the second which is mainly coastal. This geocircuit starts from a fluviokarstic landscape rich in springs, waterfalls, cavities and canyons towards a panorama of breathtaking beaches and capes marked by a splendid contrast of colours and rocky, faunistic and floristic diversities which overlaps the crystal-clear waters of the Mediterranean Sea.

These three geocircuits offer a look at the richness of the natural and cultural heritage of the Mediterranean region of Morocco. They exhibit several places where scientific, cultural and educational values can be explored to contribute to knowledge and respect for natural and social heritage. They engender a strong tourist potential but can also attract different levels of educational activities.

4. Conclusions

Natural heritage, and geoheritage as a part of it, plays a positive role for improving resilience thanks to its historic, aesthetic, social, scientific and spiritual values for past, present and future generations. It often represents the only memory of landscape evolution and enrich people’s lives providing a deep and inspirational sense of connection between community and landscape (Icomos 1999). Consequently, its promotion and preservation could result in the positive effect of contributing to preserve natural diversity in all its aspects (Petrosino et al. 2019). Actually, geoheritage is officially recognized as an integral part of UNESCO World heritage which is promoted by many international organizations (e.g. the International Union for Conservation of Nature and the European Geoparks Network). It represents a major resource for sustainable development projects and contributes to social welfare by providing complementarity with biological and cultural heritage (Choi et al. 2010; Suzuki and Takagi 2018).

So far, geoheritage is considered as an interdisciplinary geo-based topic but it should be, henceforward, a source of a harmonious development once integrated into territorial and strategy planning (Poiraud et al. 2016). The promotion and fructification of this little-known natural resource in rural areas of southern Mediterranean may enhance social resilience and consolidate the management strategies especially if it is managed according to a responsible and sustainable approach taking account of the local specificities. Therefore, as suggested in many previous studies, transforming the current simple inventory vision of geoheritage into a territorial planning tool may contribute to maintaining environmental balance and combating depopulation and land abandonment (Poiraud et al. 2016; Stefano and Paolo 2017; Zangmo et al. 2017). This will create economic diversity to revive a social fabric capable of satisfying its needs and expectations, reducing the gap and inequalities between deprived rural upstream and industrialized urban downstream, and inspiring benign and balanced development.

Obviously, this must be brought about by a courageous and bold political decision, which takes account of the fairly tense socioeconomic context, through a gradual change of perception and involvement based on a timeconsuming culture of assimilation and acceptance. Citizen science is called upon to play a primordial role through education, awareness, integration, preparation and innovation to highlight the existing natural and cultural wealth and to voluntarily and gently involve individuals, groups and institutions.

In a Mediterranean (and even global) context marked by a great geopolitical scramble but also by great pandemic, climatic and environmental vulnerabilities, it is time to rethink the style of collaborations between neighboring countries which, while keeping the plural regional character, can become allies and united in the face of climatic extremes, hydro-farming demands, and environmental and biological changes (Benabdelouahab et al. 2020; Salhi et al. 2020). The countries of the North already know that Africa no longer needs aid but rather understanding and strategic support (Glennie 2010; Mangala 2012). Closer multilateral economic relations are the solution to endorse a socio-political context capable of stimulating a level of industrialization and development capable of bringing about a middle class. The latter is vital for ensuring social sustainability and promoting shared cultural and natural heritage.

Declarations

Funding

This research was funded by the National Centre for Scientific and Technical Research (CNRST, Morocco) [contracts number PPR/11/2015 and IK/2018/48].

Author contributions

A.S. and M.R.A. conceived and designed the research. A.S. supervised the field work carried out by M.R.A. Both led the analysis, mapping and wrote the paper with contributions from all the authors. S.B., J.V.S., T.B., P.S., M.H. and A.C.P. provided guidance on mapping, writing the manuscript and interpreting the results.

Competing Interest

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

References

Arrad TY, Errami E, Ennih N, Ouajhain B, Bouaouda MS (2020) From geoheritage inventory to geoeducation and geotourism implications: Insight from Jbel Amsittene (Essaouira province, Morocco) Journal of African Earth Sciences 161:103656

Azzouz O (1992) Lithostratigraphie et tectonique hercynienne des terrains paléozoïques Ghomarides du massif de Bokkoya (Rif interne, Maroc). Thèse de 3° cycle, Fac. Sc. Rabat

Badang D, Ali CA, Komoo I, Leman MS (2017) Sustainable Geological Heritage Development Approach in Sarawak Delta, Sarawak, Malaysia Geoheritage 9:443-462

Benabdelouahab S, Salhi A (2018) Protection et durabilite de l'aquifere cotier de Martil-Alila: Vers une logique de durabilité et protection de l'environnement au Nord du Maroc. Noor Publishing,

Benabdelouahab T, Gadouali F, Boudhar A, Lebrini Y, Hadria R, Salhi A (2020) Analysis and trends of rainfall amounts and extreme events in the Western Mediterranean region Theor Appl Climatol 140

Beraaouz M, Macadam J, Bouchaou L, Ikenne M, Ernst R, Tagma T, Masrour M (2019) An Inventory of Geoheritage Sites in the Draa Valley (Morocco): a Contribution to Promotion of Geotourism and Sustainable Development Geoheritage 11:241-255

Berred S, Fadli D, El Wartiti M, Zahraoui M, Berred K, Sadki R (2019) Geomorphosites of the Semi-arid Tata Region: Valorization of an Unknown Geoheritage for Geotourism Sustainable Development (Anti-Atlas, South Morocco) Geoheritage 11:1989-2004

Bouzekraoui H, Barakat A, Mouaddine A, El Youssi M, Touhami F, Hafid A (2018a) Mapping geoheritage for geotourism management, a case study of Aït Bou Oulli Valley in Central High-Atlas (Morocco) Environmental earth sciences 77:413

Bouzekraoui H, Barakat A, Touhami F, Mouaddine A, El Youssi M (2018b) Inventory and assessment of geomorphosites for geotourism development: A case study of Aït Bou Oulli valley (Central High‐Atlas, Morocco) Area 50:331-343

Brilha J (2016) Inventory and quantitative assessment of geosites and geodiversity sites: a review Geoheritage 8:119-134

Bruschi VM, Coratza P (2018) Geoheritage and environmental impact assessment (EIA). In: Geoheritage. Elsevier, pp 251-264

Chalouan A (1986) Les nappes Ghomarides(Rif septentrional, Maroc), un terrain varisque dans la chaîne alpine.

Chalouan A, Michard A (2004) The Alpine Rif Belt (Morocco): a case of mountain building in a subduction-subduction-transform fault triple junction Pure and applied Geophysics 161:489-519

Chalouan A, Michard A, El Kadiri K, Negro F, de Lamotte DF, Soto J, Saddiqi O (2008) The Rif Belt. In: Continental evolution: the geology of Morocco. Springer, pp 203-302

Choi AS, Ritchie BW, Papandrea F, Bennett J (2010) Economic valuation of cultural heritage sites: A choice modeling approach Tourism management 31:213-220

Clivaz M, Reynard E (2018) How to integrate invisible geomorphosites in an inventory: A case study in the Rhone River valley (Switzerland) Geoheritage 10:527-541

Comãnescu L, Nedelea A, Dobre R INVENTORING AND EVALUATION OF GEOMORPHOSITES IN THE BUCEGI MOUNTAINS. In: Forum geografic, 2009.

Coratza P, Hobléa F (2018) The specificities of geomorphological heritage. In: Geoheritage. Elsevier, pp 87-106

Didon J, Durand-Delga M, Kornprobst J (1973) Homologies géologiques entre les deux rives du détroit de Gibraltar Bulletin de la Societé géologique de France 7:77-105

Durand-Delga M (1980) Considerations sur les flyschs du Cretace inferieur dans les chaines alpines d'Europe Bulletin de la Société Géologique de France 7:15-30

Errami E et al. (2015) Geoheritage and geoparks in Africa and the Middle-East: challenges and perspectives. In: From Geoheritage to Geoparks. Springer, pp 3-23

Glennie J (2010) The trouble with aid: Why less could mean more for Africa. Zed Books Ltd.,

Gordon JE (2018) Geoheritage, geotourism and the cultural landscape: Enhancing the visitor experience and promoting geoconservation Geosciences 8:136

Gordon JE, Crofts R, Díaz-Martínez E (2018) Geoheritage conservation and environmental policies: retrospect and prospect. In: Geoheritage. Elsevier, pp 213-235

Hadria R et al. (2019) Derivation of air temperature of agricultural areas of Morocco from remotely land surface temperature based on the updated Köppen-Geiger climate classification Modeling Earth Systems and Environment 5:1883-1892 doi:10.1007/s40808-019-00645-4

Han J, Wu F, Tian M, Li W (2018) From geopark to sustainable development: Heritage conservation and geotourism promotion in the Huangshan UNESCO Global Geopark (China) Geoheritage 10:79-91

HCP (2014) Caractéristiques démographiques et socioéconomiques de la région de Tanger-Tétouan-Al Hoceima, Haut-Commissariat au Plan edn. Haut-Commissariat au Plan. doi:https://www.hcp.ma/region-tanger/attachment/1605576/

HCP (2018) Monographie de la région Tanger-Tétouan-Al Hoceima. Haut-Commissariat au Plan. doi:https://www.hcp.ma/region-tanger/attachment/1322593/

Holladay PJ, Powell RB (2013) Resident perceptions of social–ecological resilience and the sustainability of community-based tourism development in the Commonwealth of Dominica Journal of Sustainable Tourism 21:1188-1211

Hose TA (2006) Geotourism and interpretation Geotourism 2006:221-241

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 doi:https://doi.org/10.1016/j.scitotenv.2018.12.443

Icomos A (1999) The Burra Charter: The Australia ICOMOS charter for places of cultural significance Burwood: Australia ICOMOS

Ilieş D-C, Josan N (2009) Geosites-geomorphosites and relief GeoJournal of Tourism and Geosites 2

Kubalíková L (2013) Geomorphosite assessment for geotourism purposes Czech Journal of Tourism 2:80-104

Kubalíková L, Kirchner K (2016) Geosite and geomorphosite assessment as a tool for geoconservation and geotourism purposes: a case study from Vizovická vrchovina Highland (eastern part of the Czech Republic) Geoheritage 8:5-14

Mangala J (2012) Africa and the European Union: a strategic partnership. Springer,

Mauerhofer L, Reynard E, Asrat A, Hurni H (2018) Contribution of a geomorphosite inventory to the geoheritage knowledge in developing countries: The case of the Simien Mountains National Park, Ethiopia Geoheritage 10:559-574

Melelli L, Vergari F, Liucci L, Del Monte M (2017) Geomorphodiversity index: Quantifying the diversity of landforms and physical landscape Sci Total Environ 584-585:701-714 doi:https://doi.org/10.1016/j.scitotenv.2017.01.101

Michard A, Hœpffner C, Soulaimani A, Baidder L (2008) The variscan belt. In: Continental evolution: The geology of Morocco. Springer, pp 65-132

Mucivuna VC, Reynard E, Garcia MdGM (2019) Geomorphosites assessment methods: comparative analysis and typology Geoheritage 11:1799-1815

Nogué J, Vicente J (2004) Landscape and national identity in Catalonia Political Geography 23:113-132 doi:https://doi.org/10.1016/j.polgeo.2003.09.005

Nogué J, Wilbrand SM (2018) Landscape identities in Catalonia Landscape research 43:443-454

Nold M, Uttinger J, Wildi W (1981) Géologie de la Dorsale calcaire entre Tétouan et Assifane (Rif interne, Maroc) Notes et Mémoires du Service géologique du Maroc 233:1-233

Panizza M (2001) Geomorphosites: concepts, methods and examples of geomorphological survey Chinese science bulletin 46:4-5

Pereira P, Pereira D (2010) Methodological guidelines for geomorphosite assessment Géomorphologie: relief, processus, environnement 16:215-222

Petrosino P, Iavarone R, Alberico I (2019) Enhancing Social Resilience Through Fruition of Geological Heritage in the Vesuvio National Park Geoheritage 11:2005-2024 doi:10.1007/s12371-019-00404-y

Poiraud A, Chevalier M, Claeyssen B, Biron P-E, Joly B (2016) From geoheritage inventory to territorial planning tool in the Vercors massif (French Alps): Contribution of statistical and expert cross approaches Appl Geogr 71:69-82

Powell R et al. (2018) Examining community resilience to assist in sustainable tourism development planning in Dong Van Karst Plateau Geopark, Vietnam Tourism Planning & Development 15:436-457

Reynard E, Fontana G, Kozlik L, Scapozza C (2007) A method for assessing the scientific and additional values of geomorphosites Geographica Helvetica 62:148-158

Reynard E, Giusti C (2018) The landscape and the cultural value of geoheritage. In: Geoheritage. Elsevier, pp 147-166

Reynard E, Panizza M (2005) Geomorphosites: definition, assessment and mapping. An introduction Géomorphologie: relief, processus, environnement 11:177-180

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 8:43-60

Safarabadi A, Shahzeidi SS (2018) Tourism silence in geomorphosites: a case study of Ali-Sadr Cave (Hamadan, Iran) GeoJ Tour Geosites 21:49-60

Salah HB, Bombín RE, Taïqui L (2018) Natural sacred sites as indicators of social-ecological system change in traditional landscapes of Northern Morocco Landscape and Ecological Engineering 14:121-133 doi:10.1007/s11355-017-0338-6

Salhi A et al. (2020) Bridging the gap of perception is the only way to align soil protection actions Sci Total Environ 718:137421 doi:https://doi.org/10.1016/j.scitotenv.2020.137421

Salhi A, Chikhi N (2018) Recherche géographique et questions du développement durable au Maroc. Al Hamama Imprenta, Morocco, Salhi A, Martin-Vide J, Benhamrouche A, Benabdelouahab S, Himi M, Benabdelouahab T, Casas Ponsati A (2019) Rainfall distribution and trends of the daily precipitation concentration index in northern Morocco: a need for an adaptive environmental policy SN Applied Sciences 1:277 doi:10.1007/s42452-019-0290-1

Scarlett JP, Riede F (2019) The Dark Geocultural Heritage of Volcanoes: Combining Cultural and Geoheritage Perspectives for Mutual Benefit Geoheritage 11:1705-1721 doi:10.1007/s12371-019-00381-2

Serrano E, González-Trueba JJ (2005) Assessment of geomorphosites in natural protected areas: the Picos de Europa National Park (Spain) Géomorphologie: relief, processus, environnement 11:197-208

Sharples C, McIntosh P, Comfort M (2018) Geodiversity and Geoconservation in Land Management in Tasmania–A Top-Down Approach. In: Geoheritage. Elsevier, pp 355-371

Stefano M, Paolo S (2017) Abandoned quarries and geotourism: An opportunity for the Salento quarry district (Apulia, Southern Italy) Geoheritage 9:463-477

Suter G (1980) Carte structurale de la chaîne rifaine au 1/500 000 Notes et Mémoires du Service géologique du Maroc 245

Suzuki DA, Takagi H (2018) Evaluation of geosite for sustainable planning and management in geotourism Geoheritage 10:123-135

Wildi W (1983) La chaîne tello-rifaine (Algérie, Maroc, Tunisie): structure, stratigraphie et évolution du Trias au Miocène Revue de geographie physique et de geologie dynamique 24:201-297

Zaghloul MN et al. (2010) Depositional systems, composition and geochemistry of Triassic rifted - continental margin redbeds of the Internal Rif Chain, Morocco Sedimentology 57:312-350

Zangmo GT, Kagou AD, Nkouathio DG, Gountié MD, Kamgang P (2017) The volcanic geoheritage of the Mount Bamenda calderas (Cameroon line): assessment for geotouristic and geoeducational purposes Geoheritage 9:255-278