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ORIGINAL ARTICLE

# Outside Geomorphosites

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**Abstract**
This paper addresses the problem of geomorphological conservation outside protected areas and in particular outside geomorphological heritage sites (geomorphosites). It is argued that, especially in ordinary territories, the protection (if any) of interesting geomorphological features is often inadequate and would benefit from specific approaches. One such approach is proposed, based on a more extensive use of methods originally developed for assessing the value of geomorphosites. These methods involve considering a number of relevant characteristics of a site — from its scientific importance to its cultural significance — that are usually evaluated separately and assigned qualitative scores that are then weighted and summed to obtain the site overall value. Geomorphosites are landforms of particular importance, but the assumption underlying this paper is that every landform has a value that should be acknowledged, can be ranked on a qualitative scale using the methods mentioned above and must be taken into account — first of all during the development of land use plans — in order to decide whether and how to protect the geomorphological features of an area. An application of the presented approach to a section of the alluvial plain of the River Po — in the Lombardy region of Northern Italy — is discussed. Finally, the notion of an 'exclusion approach' to geomorphological conservation is put forward.

**Keywords** Geomorphological conservation · Geomorphosites assessment methods · Value of landforms · Exclusion approach to geomorphological conservation

## Introduction

Landforms — including anthropogenic ones — have at least a three-fold importance. First, they influence (and are influenced by) the ecosystem composition, patterns and processes over a wide range of scales and to such an extent that the discipline of biogeomorphology could develop (e.g. Naylor et al. 2002). Second, landforms are structural elements of landscapes, which in turn play a major role in the quality of life for people everywhere: in urban areas and in the countryside, in degraded areas as well as in areas of high quality and in areas recognised as being of outstanding beauty as well as everyday areas (European Landscape Convention 2000, preamble). Finally, landforms may have a scientific, aesthetic, cultural, historical or religious importance on their own. This holds not only for sites of outstanding interest (e.g. evidences of the Earth's history, natural monuments, sacred landforms, historical mounds) but also for geomorphic features — such as boulders, rock shelters or abandoned quarries — that may be significant only to local communities.

The importance of landforms is recognised in areas dedicated to the conservation and promotion of geological heritage such as geosites and geoparks, but outside these and other protected areas, it is often underrated and the protection (if any) of potentially interesting geomorphological features is limited or poorly targeted, being — for instance — a side effect of regulations concerning other elements of the environment or the landscape. As a consequence, these features are often carelessly altered or removed, particularly during land use changes such as urbanization, the building of infrastructures or the expansion of agricultural areas.

The aim of this paper, therefore, is to promote consideration for landforms even outside protected areas and to offer a further contribution to the debate on the conservation of geological diversity and heritage. To these ends this work explores the possibility of a more general use of the methods originally developed for the evaluation of geomorphological heritage sites (or geomorphosites for short).

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Geomorphosites can be broadly defined as natural or anthropogenic landforms to which a value can be attributed, related to their scientific, cultural, ecological, socio-economic and aesthetic importance (Panizza 2001; Reynard et al. 2009). Geomorphosite assessment methods are used to assess this value, generally take into account different characteristics of a site and are devised, basically, for the analysis, comparison and protection of geomorphological heritage. These methods vary from those that rely solely on experts' judgements based on a few guiding criteria to parametric methods where a number of relevant characteristics of a site (the parameters or indicators) are usually evaluated separately and assigned qualitative scores that are then weighted and summed to obtain the site overall value (e.g. Bruschi and Cendrero 2009; Reynard 2009b and, for a comparative review, Mucivuna et al. 2019). Only parametric methods will be considered in this paper, as they are qualitative but formalized, and provide a more detailed and transparent account of how the value of a landform is assessed.

For a comprehensive illustration of the theoretical and practical aspects concerning the identification, assessment, protection and management of geomorphosites, the reader is referred to, e.g. Panizza and Piacente (2003), Reynard et al. (2009), Reynard and Brilha (2017, in particular chap. 5), volume 3/2007 of the Swiss journal of geography *Geographica Helvetica* and the many papers published in the journal *Geoheritage*, including those in the special issue 1/2016 on geomorphosites.

It must be noted that the concept of geomorphosite can be extended to include not only the landforms visible today but also former landforms destroyed or hidden by human activities (Clivaz and Reynard 2017; Pica et al. 2017). What is more, humans have become an important geomorphic agent beside the internal and external natural ones (e.g. Li et al. 2017; Szabó et al. 2010) and many authors have pointed out the importance of the archaeo-historical value of anthropogenic geomorphosites and landforms (e.g. Fouache and Rasse 2009; Fouache et al. 2012; Pica et al. 2016; Brandolini et al. 2019; Pelfini et al. 2020).

Geomorphosites are areas of special interest, but the assumption underlying this paper is that every landform has a value that should be acknowledged, can be ranked on a qualitative scale using the parametric methods mentioned above and must consistently be taken into account — particularly when planning land use changes — in order to decide whether and how to protect the geomorphological features of an area.

The next three sections outline the steps of the proposed approach. 'A Study Area' presents an application example, 'Valuing and Conserving Abiotic Nature?' discusses how this approach may contribute to geomorphological conservation and 'Discussion and Conclusions', finally, is devoted to the conclusions and put forward the notion of an 'exclusion approach' to geomorphological conservation.

## First Step: Draw a Basic Geomorphological Map of the Area of Interest

According to Otto and Smith (2013) and Dramis et al. (2011), geomorphological maps can be categorized as basic (or analytical) and derived (or specialized). Basic maps represent the observed features of a landscape and are produced by the graphic transfer of data collected from field surveys, aerial photograph interpretation, pre-existing maps, etc. These maps may either focus on selected features such as the morphology of active processes or deliver a full view on the landscape composition and evolution. Derived maps are obtained through selection, generalization and reuse of data reported in basic maps with the purposes of zoning the spatial and temporal distribution of significant geomorphological processes. Geomorphological stability maps (Panizza 1973), geomorphological hazard maps (Panizza 1996; Petley 1988) and the landform assessment map considered in the next section are examples of derived maps.

The approach described in this paper provides, as a first step, to draw a basic geomorphological map that (ideally) delivers a detailed and full view on the landscape composition and evolution in the area of interest. The map must not contain blank spaces — i.e. ignored landforms — as this would contradict the assumption that the value of every landform should be acknowledged. On a practical level, of course, the map content and detail will be influenced by the size of the investigated area and the scale of the map itself as well as by time, cost and technical constraints. However, the presence of a landform *L* that is identified, but not mapped, should be taken into account when assessing the mapped landforms that contain *L*.

The basic map may include geomorphological sites of recognized importance, whose features may be surveyed and assessed as elsewhere in the study area. If these features have already been mapped and assessed, it may be possible to represent them on the basic map (perhaps after adjusting its content and symbols) and to express their value on the qualitative scale used in the study. The basic map, otherwise, may refer to other maps (e.g. geomorphosites maps).

The documentation for projects and plans may already include geomorphological maps. The study area described in 'A Study Area', for instance, is located in the Lombardy region of Northern Italy and according to the region's regulations, municipal land use plans must comprise a map, on a scale from 1:2000 to 1:10,000, indicating the landforms and geomorphic processes in the municipal area.

The content and design of these and similar maps can be improved, if necessary, in order to implement the approach proposed in this paper. To this end, the literature on geomorphological site mapping offers useful insights (e.g. Marchetti et al. 2005; Reynard and Coratza 2013 and the bibliography therein). Much of this literature is concerned with the representation of geosites and the problem of communicating geoscience to the general public, but it should be noted that, for instance, even professional planning teams might include experts (such as urbanists) without a specific background in geomorphology. What is more, projects and plans with potential geomorphological impacts (e.g. construction projects and land use plans) are usually examined and approved by individuals with different educational and work backgrounds (e.g. personnel and elected members of public bodies). Therefore, the basic geomorphological map and the landform assessment map (Second Step: Apply a Geomorphosite Assessment Method and Draw a Landform Assessment Map) should be easily comprehensible even to non-experts, or at least a version of these maps for non-experts should be produced.

## Second Step: Apply a Geomorphosite Assessment Method and Draw a Landform Assessment Map

'A Study Area' illustrates an example of the approach proposed in this paper that makes use of the geomorphosite assessment method summarized in Table 1, but any suitable one may be used.

Panizza and Piacente (2003) specify that the indicators and weights in Table 1 should be chosen according to the specific case and not to a universally valid scale.

According to different authors, the scientific importance of a site cannot be negligible; otherwise, the latter cannot be considered a geomorphosite (e.g. Panizza and Piacente 2003; Reynard 2009a). This paper, however, focuses on landforms outside geomorphosites, so it will be acknowledged here that these landforms may be of negligible scientific value, in which case the corresponding parameter (*S* in Table 1) can be set to 0. In this respect, it is interesting to note that several geomorphosite assessment methods already allow indicators to vary from 0 to a maximum, including those related to a site's scientific value (e.g. Bruschi and Cendrero 2009; Pereira et al. 2007; Zouros 2007).

The landforms appearing on the basic geomorphological map may be assessed individually or merged into larger units that are subsequently assessed. These landforms/units and their value (perhaps classified into ordinal categories, e.g. high to low) must be represented on what may be called a landform assessment map. This latter may also show the value of one or more indicators, perhaps only for selected sites.

## Third Step: Devise Appropriate Provisions

Geomorphological forms are modified and removed by natural or human-related processes, a list of which (taken from Gray 2004) is shown in Table 2.

Specific provisions for protecting geomorphological features can be included in regulations, plans and projects. The assumption will usually be that the higher the value of a landform is, the stronger its protection should be. A full range of options can be considered. On the one end of the scale, the alteration or removal of landforms with a very low or negligible value may be permitted provided it complies with other regulations (concerning, say, the environment or the landscape). At the other end of the scale, human activities may be strictly regulated or even prohibited (as it is often the case in geomorphosites or other protected areas). In intermediate situations, the alteration or removal of landforms may be controlled by combining restrictions on the aforesaid activities and provisions for the assessment and mitigation of impacts. For instance, farming may be allowed provided it does not involve filling or grading operations; developments can be sited and designed so as to minimize the alteration of natural landforms, etc. Parametric methods such as that described in Table 1 have a qualitative nature (e.g. Yilmaz, 2013) but nevertheless they allow to (i) evaluate — albeit subjectively and with respect to an ordinal scale — how a project or activity may affect each value indicator and (ii) tailor conservation measures to the value of landforms. When a proper environmental impact assessment is needed, these methods might supplement other approaches specifically developed for the evaluation and mitigation of geomorphological impacts (e.g. Panizza 1996).

In deciding how to protect landforms, it may be useful to distinguish between conservation and preservation. According to Burek and Prosser (2008), conservation can be taken as meaning the 'active management of something to ensure its quality is retained'. This places the emphasis on the management of something to retain a particular quality, rather than on the preservation of the feature, site, process, etc. with no change at all. Preservation, on the other hand, can be taken as 'keeping something in the same state, stopping it from changing' (ibid.). Burek and Prosser consider the natural environment and specify that geoconservation usually involves working with natural change to retain a feature of interest, for example maintaining a clear exposure of a stratigraphical sequence in an eroding cliff, despite the erosion. The distinction between conservation and preservation, however, appears to be relevant in other environments as well.

What is more, the assumption lower value-lower protection, as reasonable as it seems, tends to generate a vicious

**Table 1** A parametric method for assessing the value of geomorphosites (Coratza and Giusti 2003 in Panizza 2003)

| Indicator | Meaning and criteria | Values |
|---|---|---|
| Scientific value $S$ | Actual or potential value for scientific research (number and quality of publications concerning the site, research projects concerning the site, importance for the history of geomorphology, potential value for science, etc.) | 0.25 = low, 0.50 = medium, 0.75 = high, 1 = very high |
| Didactic value $D$ | Actual or potential value for didactic purposes (representativeness of the site, mentions in didactic texts, potential didactic value, etc.) | 0 = none, 0.25 = low, 0.5 = medium, 0.75 = high, 1 = very high |
| Area $A$ | Ratio between the geomorphosite area and the total area occupied by geomorphosites of the same type, in percentage | 0.25 = < 25%, 0.50 = 25–50%, 0.75 = 51–90%, 1 = 91–100% |
| Rarity $R$ | Amount of similar sites in the investigated area (rarity increases if the site is a testimony of past geomorphic conditions) | 0.25 = many similar sites, 0.50 = several similar sites, 0.75 = few similar sites, 1 = unique example |
| Preservation $P$ | Degree of preservation of the site (natural degradation, anthropic alterations, protection interventions, etc.) | 0.25 = poor, 0.50 = fair, 0.75 = good, 1 = excellent |
| Visibility $V$ | Visibility/accessibility of the site (presence or absence of buildings and other constructions that hide the site, accessibility, visibility from distance, etc.) | 0.25 = very poor, 0.50 = low, 0.75 = quite good, 1 = good |
| Added value $Z$ | Additional characteristics that add value to the site (ecological or additional geological features, cultural, historical, touristic and economic relevance, inclusion in a protected area, etc.) | 0 = no added value, 0.25 = limited added value, 0.5 = moderate added value, 0.75 = relevant added value, 1 = the added value is very high, without it the site would lose part of its geomorphological importance |
| Global value | | $Q = sS + dD + aA + rR + pP + vV + zZ$ where $s$, $d$, $a$, $r$, $p$, $v$, $z$ are weights that determine the relative importance of each indicator |
| Normalized value | | $Q/Q_{max}$ where $Q_{max}$ is the maximum possible value of $Q$ |

**Table 2** Human related causes of landforms modification and removal (Gray 2004)

| | |
|---|---|
| 1 | Mineral extraction (includes pits, quarries, dunes and beaches) |
| 2 | Landfills and quarry restoration |
| 3 | Land development and urban expansion |
| 4 | Coastal erosion and protection |
| 5 | River management, hydrology and engineering |
| 6 | Forestry, vegetation growth and removal (afforestation and deforestation) |
| 7 | Agriculture |
| 8 | Other land management changes (e.g. cutting, filling, dumping, spreading or discharging materials) |
| 9 | Recreation/tourism pressures |
| 10 | Removal of geological specimens |
| 11 | Climate and sea-level changes |
| 12 | Fire |
| 13 | Military activity |
| 14 | Lack of information/education |
| 15 | Cumulative impacts |

circle that exacerbates the degradation of already degraded landforms. In order to reduce this possibility, one can, for instance, protect landforms with a limited value but with a restoration and enhancement potential (this may be the case, say, of some unreclaimed borrow pits). Indeed, the assessment method of Table 1 allows for taking into account the potential scientific and didactic value of a site when setting the parameters *S* and *D*.

Finally, the overall value of an area may be increased by acting on specific parameters. This may involve some trade-offs. For example, Zouros (2007) considers among the others the parameters legal protection, vulnerability, accessibility and economical potential. The first two increase, respectively, if the legal protection of a site is strengthened and if the risks to its quality are reduced. On the other hand, the accessibility and economic potential indicators increase, respectively, the easier it is to access the site and the higher is the number of visitors per year. The overall value of a site, therefore, can be improved by introducing regulations and access limitations that increase the legal protection and vulnerability indicators, although the accessibility and economic indicators may decrease somewhat.

## A Study Area

The approach outlined in the preceding sections has been applied in three studies carried out in the Lombardy region of Northern Italy (Cremona province) for the management plans of the Sites of Community Importance (SCI), Special Conservation Areas (SCA) and Special Protection Areas (SPA) Bosco Ronchetti and Lanca di Gerole, and for the management plan of the proposed Golena del Po park, which comprises the two sites mentioned above and an existing smaller park with the same name. These studies were not specifically aimed at identifying geomorphosites and the fact that they were related to protected areas has played no role.

The investigated area, of about 130 km$^2$, is located in the Po River floodplain, mainly along its left bank (Fig. 1) and comprises eight municipalities (Casalmaggiore, Pieve d'Olmi, San Daniele Po, Gussola, Martignana di Po, Motta Baluffi, Stagno Lombardo and Torricella del Pizzo).

The river and its floodplain, marked by abandoned channels, meander scars and some wetlands areas, are the main geomorphological features of the study territory together with the 'bodri', which are bowl-shaped depressions (typically less than 100 m wide and 10 m deep) filled with groundwater and originated from the erosion caused by floodwater that overtops or breach a levee.

The land is intensively cultivated (mainly with corn and wheat), dotted with farms and villages (such as Torricella del Pizzo) and criss-crossed by the Po levees. Despite the intensive farming and the limited variety of crops, the area is still ecologically rich thanks, first of all, to the diversity of habitats offered by the riverine environment. Even the vegetation and fauna of the bodri may be varied and diversified and some of these features have been declared regional natural monuments, one example being the 'Bodrio delle Gerre Ugolani' in the municipality of Stagno Lombardo (Pellegrini et al. 2005). Especially since the beginning of the twentieth century, however, the landscape diversity of the study territory has radically decreased. In particular, the morphological complexity of the Po river and the adjacent areas has drastically reduced (Fig. 2) due also to channelization works that constrain the river itself and narrow its width.

The basic geomorphological map (an excerpt of which is shown in Fig. 3) was obtained by means of aerial photograph interpretation, field checks at selected sites and data from the geographic information system of the Lombardy region and from topographic maps. Given the limited resources, only

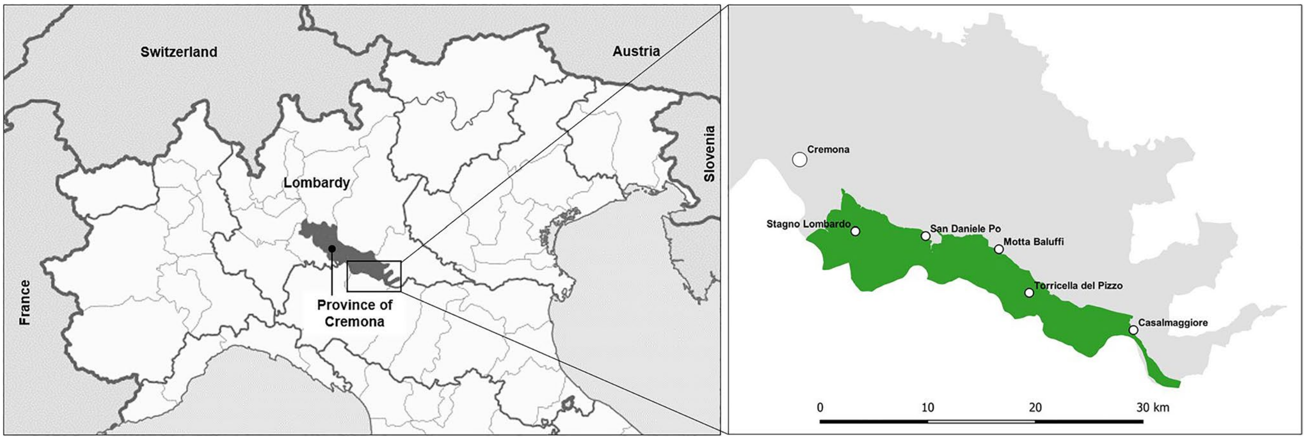



**Fig. 1** The study area within northern Italy (right) and the Lombardy region (left)

the most important features were reported in the basic map. What is more, the map legend and symbols were chosen with the main aim of giving to non-experts a readily comprehensible representation of the diversity of landforms in the investigated area.

Landforms were assessed using the method described in Table 1 (Second Step: Apply a Geomorphosite Assessment Method and Draw a Landform Assessment Map) with the advice of an expert naturalist as to the presence of ecological values that could increase the added value *Z*. The paleochannels, fluvial terraces scarps, fluvial ridges and levees indicated on the basic geomorphological map[1] were not assessed individually but were considered as features of the floodplain contributing to its value. Moreover, visibility and rarity were not regarded as relevant indicators because the study area is basically flat, most sites are easily accessible and the main geomorphological features are fluvial landforms with different evolution stages, degrees of preservation and ecological characteristics, rather than rarity. Even the area ratio did not seem important in this case, so the weights *v*, *r* and *a* of, respectively, the visibility, rarity and area parameters were set to 0. The other indicators were considered equally important and the corresponding weights were set to 1, so that $Q_{max}=4$. Lastly, the class '0 = negligible' was introduced for both the scientific and the preservation parameters and the normalized ratio $Q^*=Q/Q_{max}$ was categorized according to Table 3.

Some examples of assessment and one excerpt of the landform assessment map are shown, respectively, in Figs. 4 and 5.

The assessment results showed that the investigated area comprises:

high value areas (16%): these include the Po, the river banks and the immediately adjacent floodplain, chute channels, abandoned meanders with wetlands and the bodri;
medium value areas (60%): most of these areas are portions of the floodplain that are occasionally flooded and therefore have a scientific, educational and preservation value higher than those sectors, outside the Po embankments, with almost no relationships with the river; medium value areas also include some abandoned meanders, remains of wetlands and even anthropic landforms such as a few flooded borrow pits;
low value areas (24%): these comprises, mainly, the sectors of the floodplain outside the Po embankments, some poorly preserved abandoned channels, meanders and meander scars and built areas.

Most of the territory (76%) has a medium or high value and this provided a further reason for establishing the Golena del Po park. Also, there are no areas with a very low or negligible value.

The studies considered in this section also paid attention to geodiversity, in particular to the diversity of geomorphic, lithologic and pedologic settings and to the diversity of processes, including the hydrologic ones. The final report stressed that geodiversity is an important component of the ecological and landscape diversity in the study area and a topic of scientific, educational and cultural interest on its own. Moreover, it was recommended that the studies for the approval of projects and activities by public authorities should include the following:

an analysis of the geological, geomorphological, pedological and hydrological setting in the area potentially affected by the proposed project or activity;

[1] Fluvial ridges are not present in the area of Fig. 3.

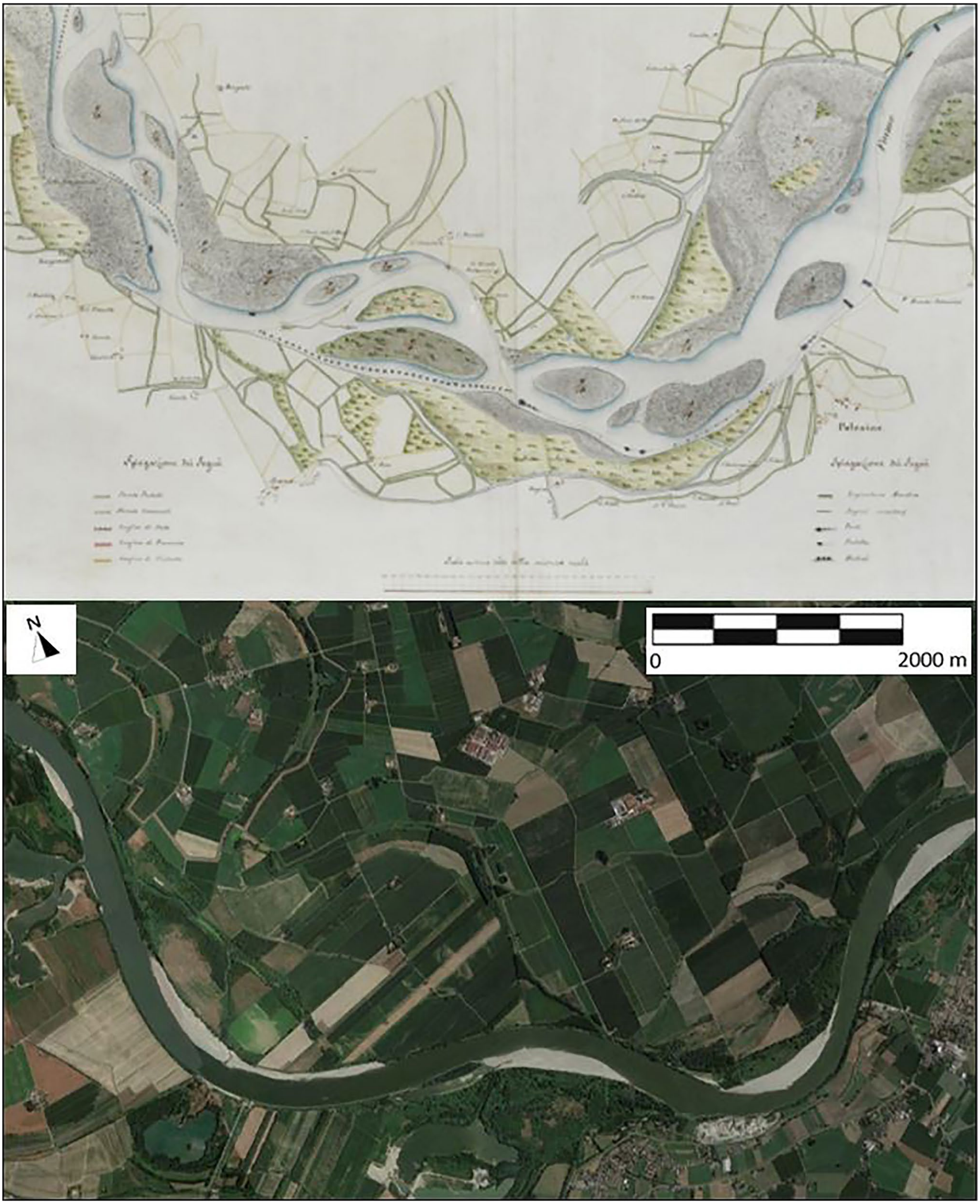



**Fig. 2** Reduction of the channel width and morphological complexity along a stretch of the Po River. The upper part of the figure shows an excerpt of map from 1854 (Agenzia Interregionale del Fiume Po — Fondo Po historical maps collection), the lower part a Google Earth image from July 2021 ( © Google Earth)

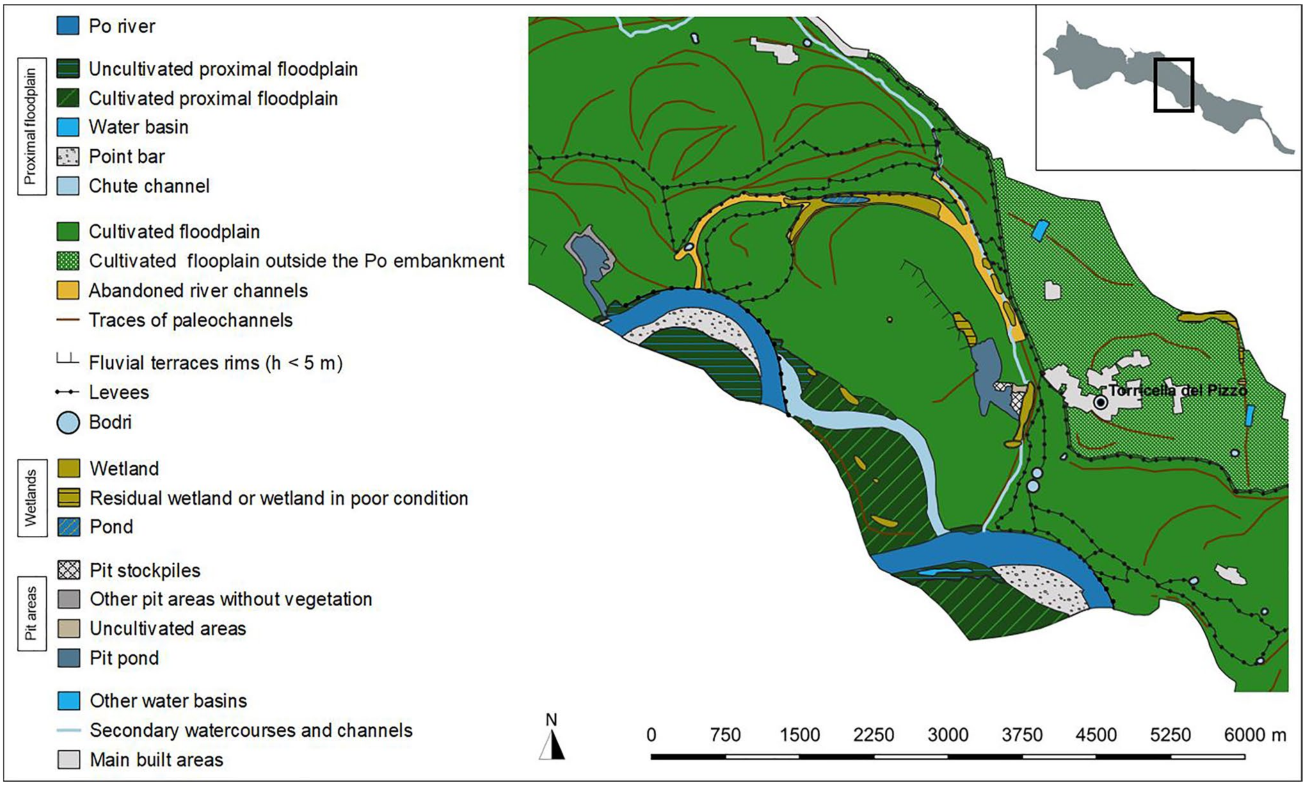



**Fig. 3** Excerpt of the basic geomorphological map

**Table 3** Normalized ratio $Q^*$ and landform value categories

| Normalized ratio $Q^*$ | Landform value |
|---|---|
| $Q^*=0$ | Negligible |
| $0<Q^*\leq 0.125$ | Very low |
| $0.125<Q^*\leq 0.375$ | Low |
| $0.375<Q^*\leq 0.625$ | Medium |
| $0.625<Q^*\leq 0.875$ | High |
| $0.875<Q^*\leq 1$ | Very high |

if necessary, a landform assessment map more detailed than that of Fig. 5;
an evaluation of how indicators such as those in Table 1 and geodiversity may change because of the project or activity under consideration;
a description of the measures for avoiding or mitigating negative impacts.

Finally, the management plans of the Bosco Ronchetti and Lanca di Gerole sites contain, among others, provisions for actions, regulations and monitoring and research programs. The provisions that more directly concern the geomorphology and geodiversity of the sites are summarized in Table 4.

## Valuing and Conserving Abiotic Nature?

Several plans concerning the use of land, the environment and the management of geological and hydrological risks apply to the study area. The most relevant for this paper are as follows:

the municipal territorial plans;
the management plans of the Bosco Ronchetti and Lanca di Gerole sites;
the management plan of the existing Golena del Po park (municipalities of Casalmaggiore, Pieve d'Olmi and San Daniele Po);
the Provincial Territorial Coordination Plan of the Cremona province (PTCP);
the PAI (Piano stralcio per l'Assetto Idrogeologico) of the Po River Basin Authority.

The PTCP directs and coordinates municipal land use decisions and sectoral policies at a provincial level and identifies areas for major infrastructure development. It complies with higher planning instruments such as the Regional Territorial Plan, the Regional Landscape Plan (e.g. OECD 2019) and the PAI.

The PAI is a risk management plan that applies, among others, to the flood-prone areas of the Po plain. It contains


**Abandoned channel with wetlands and pond**

Values and quality: scientific = 1.00, didactical = 0.75, preservation = 0.50, additional = 1.00, total value 3.25, normalized value = 0.81, quality = high


**Cultivated floodplain inside the main Po river levee** (flooded at times)

Values and quality: scientific = 0.50, didactical = 0.50, preservation = 0.50, additional = 0.50, total value = 2.00, normalized value = 0.50, quality = medium


**Pit with excavation pond**

Values and quality: scientific = 0.25 didactical = 0.25, preservation = 0.25, additional = 0.50, total value 1.25, normalized value = 0.31, quality = low


**Bodri**

Values and quality: scientific = 0.75 didactical = 0.75, preservation = 0.50, additional = 0.75, total value = 2.75, normalized value = 0.69, quality = high

**Fig. 4** Examples of landform assessment using the method described in Table 1

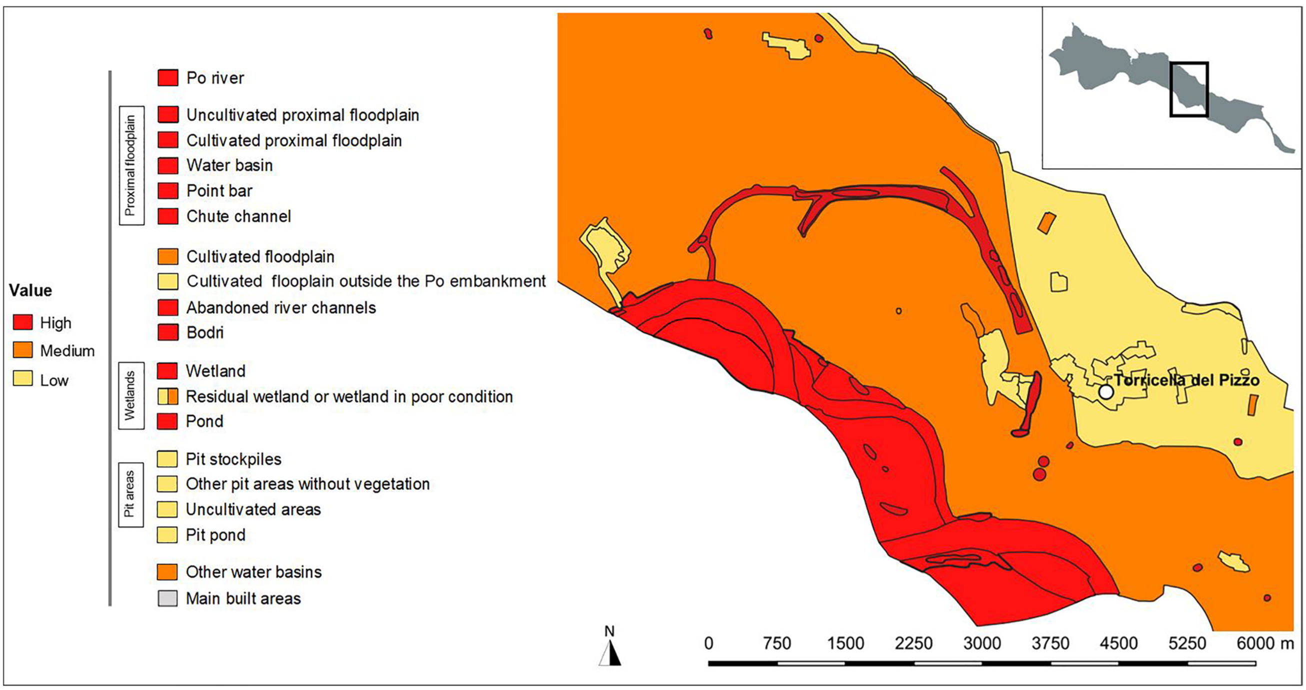



**Fig. 5** Excerpt of the landform assessment map

risk reduction regulations and guidelines regarding land use, activities and projects in areas exposed to flood and mass-movement hazards.

The expanded Golena del Po Park has not yet been established, but there is a proposed park regulation that, despite the studies described in 'A Study Area', presents the same problems discussed below. In addition, the last three provisions of Table 4 — which concern the geological and geomorphological features of Bosco Ronchetti and Lanca di Gerole sites — were not effectively implemented. Does this matter or do the plans listed above still provide an adequate level of geomorphological protection? Can the approach discussed in this paper contribute to geomorphological conservation?

In order to answer these questions, let us note first that collectively, the aforesaid plans directly or indirectly protect several geomorphological features of the study area, among which are as follows:

fluvial ridges and terraces;
scarps;

**Table 4** The provisions in the management plans of the Bosco Ronchetti and Lanca di Gerole sites mentioned in the text

| Type | Goals | Description |
|---|---|---|
| Actions | Restoration and rehabilitation of wetlands | Survey of the wetlands' size and conditions and, where necessary, removal of anthropogenic disturbances |
| Actions | Renaturalization of watercourses | Reshaping of streams and banks at selected sites in order to increase the width of watercourses and restore their morphology; restoration and rehabilitation of vegetation on the banks |
| Regulations | Protection and promotion of the geology, geomorphology and geodiversity of the sites | The studies required for the approval of projects and activities must assess the effects of these latter on the value of geomorphic features and on geodiversity and propose, when necessary, impact mitigation measures |
| Monitoring and research programs | Formulation of guidelines for assessing and managing the geological and geomorphological aspects of the sites | Formulation of guidelines for the studies mentioned above and for protecting the geology and geomorphology of the sites |
| Monitoring and research programs | Assessment of geomorphic features and geodiversity at selected areas | Identification of areas where a detailed assessment of the geomorphological features and geodiversity is critical for scientific reasons or for protecting the quality of the sites; activation of research projects |

rivers, temporary flood channels, other waterbodies and their banks, riparian zones, embankments, primary flood defence levees;

ecologically relevant features of environmentally valuable areas and protected sites (e.g. the SCI/SCA/SPAs, geosites, wetlands and some reclaimed borrow pits);

some abandoned channels and the bodri;

distinctive features of the agricultural landscape such as the 'baulati fields' (Scazzosi 2013; Ferrari et al. 2008a).

Projects and activities that may affect these elements are forbidden or allowed with certain restrictions, perhaps after considering their impacts. The protected landforms, though, are basically only those that represent structural or distinctive components of the landscape, have an important ecological function or are features of geosites and natural monuments. This leaves out a number of other geomorphological forms that, instead, are worthy of more attention.

The study area, for instance, is characterized by fluvial landforms that progressively disappear even without human intervention. Their traces are often visible in the agricultural landscape as curvilinear shallow depressions, field boundaries and ditches, perhaps with patches of vegetation. Often these landforms are protected only as long as they contain water. Even the bodri becomes gradually filled with sediments and drier, until they cannot be classified as bodri anymore (i.e. distinctive features of the landscape and ecologically valuable areas). Land use plans can then be revised with simplified procedures so as to remove conservation restrictions on these areas. As a consequence, the remnants of the bodri are more exposed to human activities (e.g. filling or land grading operations) and may quickly disappear, although they may still have a didactic or an ecological value.

The approach discussed in the preceding sections may improve on this situation because, first, it entails a comprehensive geomorphological survey that — at least at the survey scale — reduces the chances of overlooking the presence of landforms, regardless from their importance or degree of preservation. Second, assessment methods such as that in Table 1 help to raise awareness as to the value of geomorphological forms, thereby justifying some level of protection if needed, and to identify appropriate conservation measures taking into account the levels of different indicators.

Let us consider, for example, the area in Fig. 6. Some elongated depressions (highlighted in the figure) are the traces of old river channels that may be occasionally reactivated during floods (only exceptionally outside the main Po levees). Let us focus on the longest one, bounded to north by a levee. This feature is normally dry, except for a small stream and a patch of wetland in its western part, is not considered to be of particular ecological interest or landscape value and it is not protected as the stream itself, the wetlands spots or the bodri visible in Fig. 6. The plans that apply to this area permit to level the ground for farming. Even if this may cause only small changes to ground levels (less than 1 m), it is very easy to obliterate delicate landforms such as that considered here. Topographic observations, indeed, indicate that the depression has already been partially filled (site no. 3). What is more, centre-pivot irrigation (site no. 1) is increasing the tendency to level the ground surface.

The abandoned channels in Fig. 6 may be reactivated during floods, host areas of significant ecological value, help to reconstruct and illustrate the evolution of the

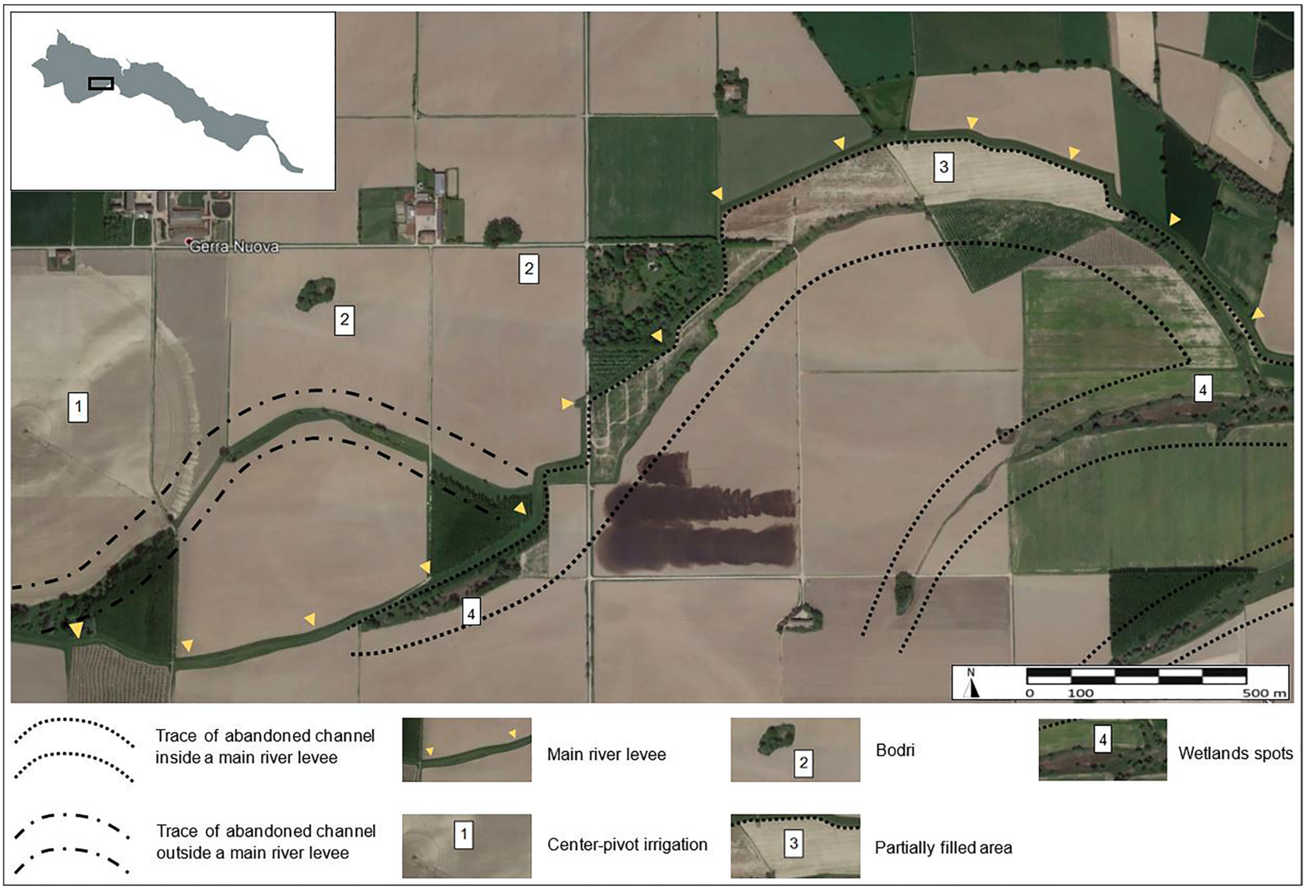



**Fig. 6** The area mentioned in the text (image © Google Earth, acquisition date 25/04/2018)

fluvial environment, in response also to anthropic pressures, and add diversity to the landscape. In the studies described in 'Third Step: Devise Appropriate Provisions', these features were considered in their entirety and given a medium value ($Q^*=0.56$, Table 3). This quality class would not decrease even ignoring the added value $Z$ of Table 1.

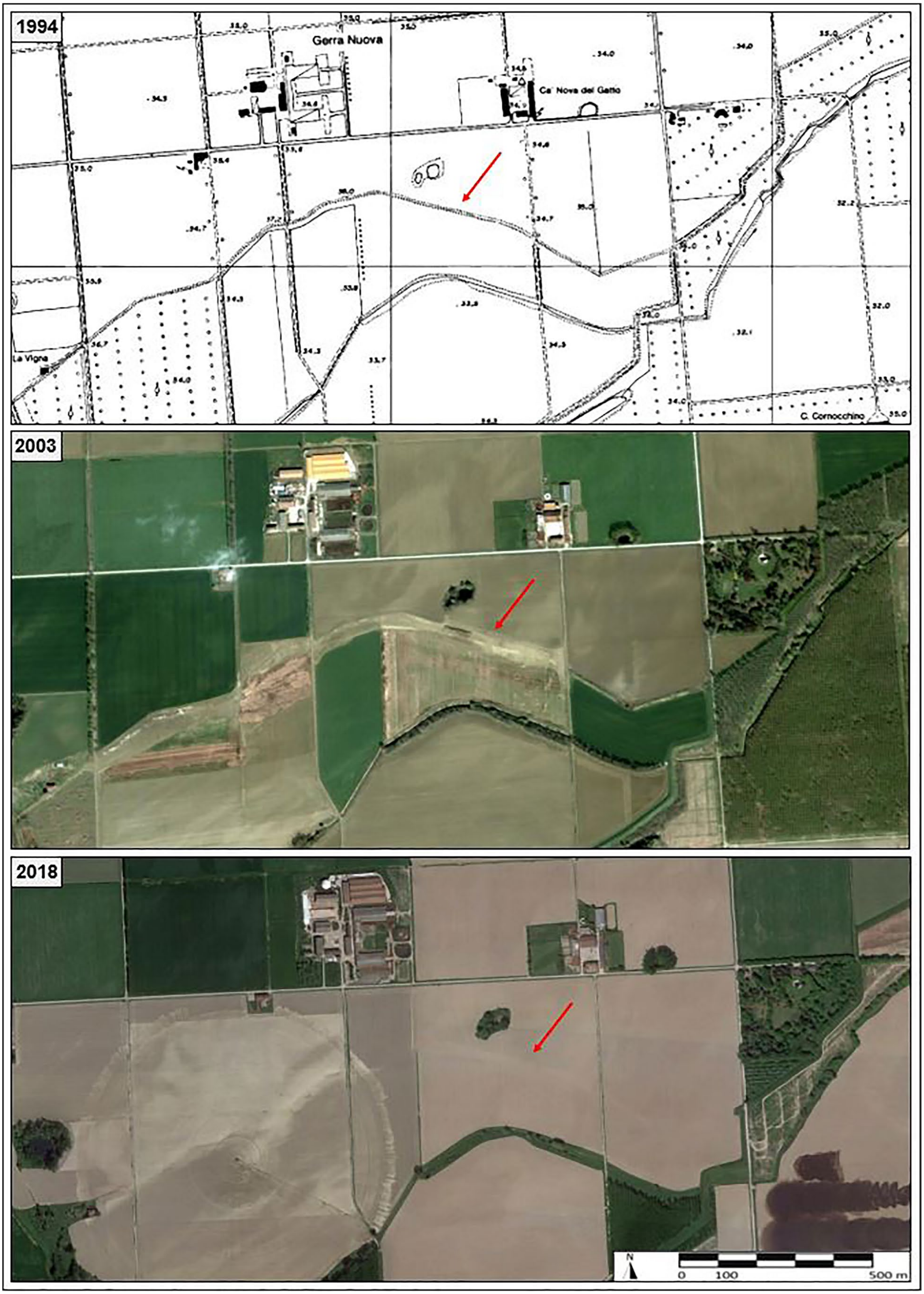
Let us suppose, now, that a regulation limits the activities that may alter landforms, unless these latter have a very low or negligible value $Q^*$ (i.e. $Q^* \leq 0.125$, Table 3). In areas such as that of Fig. 6, this regulation could, for example, allow farming but strictly prohibit to reshape the ground. In the study territory, besides, there are traces of river morphologies (e.g. channels and crevasse splays) that appear, basically, only in satellite and aerial images and can be most easily obliterated.

Let us consider another case. The levees of the Po are the main positive anthropogenic landforms in the investigated area and form a network of man-made reliefs that add complexity to the landscape. The levees not only have an historical value (Ferrari et al. 2008b) but they also represent peculiar and rich habitats with around 350 species of vascular plants and many species of animals, mainly small reptiles and mammals, insects and birds (e.g. Bonali and D'Auria 2007; Ferrari et al. 2010).

The studies described in 'A Study Area' did not assess these features individually (this should be done while carrying out more detailed investigations), but the value of many of them can be expected to be medium or even high in some cases. However, the preservation restrictions on the levees are rather weak (unless they are considered important for flood control) and several stretches have been removed so as to ease agricultural activities (Fig. 7). Again, a regulation such as that mentioned previously could help to conserve these landforms.

The protection of interesting new geomorphic features is also problematic. A notable example is provided by some newly formed bodri that are not recognised as such by land owners (who simply want to fill the depression) on the basis that 'proper' bodri should have a well-developed vegetation and other significant ecological features.

It must be noted that recent studies in the Po Plain point out the values of historical and archaeological human land and water management activities in reshaping the fluvial environment (e.g. Brandolini et al. 2019; Pelfini et al. 2020). Brandolini et al. (2019) propose the term


1994
Gorra Nuova
Ca' Nova del Gatto
La Vigna
C. Cornocchino
2003
2018
N
0
100
500 m

◂**Fig. 7** The disappearance of a Po levee between 1994 and 2008 in the same area of Fig. 6 Images: 1994 – Regional Technical Map of Lombardy (sheet d8b2), 2003 — Google Earth © 2020 Maxar Technologies, 2018 — © Google Earth

geoarchaeomorphosite to indicate a geomorphosite derived by the dynamic interaction between natural and human events and for which archaeo-historical data are crucial to assess its genesis and development during different historical times, and to enhance the geomorphosites' scientific and cultural/historical values. These authors reconstruct the main evolutionary landscape stages due to human activity of an area which is partly similar to (and not far from) that considered in this paper, and propose four geo-educational itineraries (Protohistoric, Roman, Medieval and Post-Medieval) and seventeen potential geoarchaeomorphosites, seven of which are hidden (e.g. three villages of the Bronze Age Terramare Culture and a medieval wetland).

Indeed, it would be desirable to conduct — even in the proposed Golena del Po park area — a research aimed at reconstructing in detail at least some stages of its geomorphological history, including the anthropogenic changes. Such a research could help to promote the value of the area's abiotic nature and to refine the map of Fig. 5. In this respect, among the useful sources of information, one should mention the (freely available) historical maps collections of the Agenzia Interregionale del Fiume Po and the many publications issued by the Province of Cremona concerning the natural and anthropic evolution of the province's territory (e.g. 'I Quaderni dell'Ecomuseo', 'I Quaderni del Centro di Documentazione Ambientale' and the articles published in the journal 'Pianura').

Let us now discuss another issue. Some of the plans mentioned at the beginning of this section require an assessment of the effects, on the environment and the landscape, of projects and plans not subjected to Environmental Impact Assessment (EIA) or Strategic Environmental Assessment (SEA).[2] We consider here, in particular the following:

> the 'Valutazione di Incidenza Ambientale',[3] which aims to assess the impacts of plans or projects on the environment inside the SCI/SCA/SPAs and is required by the European Birds Directive and Habitat Directive[4];
>
> the assessment of the landscape impact of construction projects required by the laws of the Lombardy region.[5]

The Valutazione di Incidenza is, essentially, a simplified EIA for the evaluation and mitigation of the adverse effects of projects and plans on the habitats, fauna and flora of the protected areas belonging to the European Natura 2000 network (e.g. Bosco Ronchetti and Lanca di Gerole). Alterations to the geomorphology of a site are relevant, basically, only if they have appreciable ecological consequences. However, the focus on ecology is not a reason to overlook the presence and value of landforms inside these areas. Even more importantly, a specific focus on geomorphology and geodiversity (particularly at the small scale) may improve the understanding of the relationships between the biotic and abiotic elements of a site and, hence, of the implications of the project or plan under consideration.

The assessment of the landscape impact of construction projects is required, in the Lombardy Region, when applying for building permits. The impact is expressed with a number from 1 to 25 that results from multiplying two indices ranging from 1 to 5 that indicate, respectively, how much the landscape around the project area is vulnerable to changes and how large are the project's effects on this landscape. In the assessment guidelines, landforms are important only in that they are features of the natural landscape, of natural monuments, of symbolic sites or, possibly, of environmentally valuable areas (significantly, these guidelines contain only the term 'geo-morphological' with the dash). However, geomorphosite assessment methods such as that in Table 1 highlight the multiple value of landforms, contribute to the understanding of landscapes and question the above approach (e.g. do invisible landform matter?).

Finally, even EIA and SEA studies may not pay much attention to the value of landforms outside geosites and other protected areas. This is the case, for instance, of the aggregate extraction plan of the Province of Cremona, subjected to SEA. The plan, however, provides for the ecological rehabilitation of borrow pits, which are the main negative anthropogenic landforms in the investigated zone.

## Discussion and Conclusions

Whether, to what extent and how to protect an area's landforms are decisions that should be based on a comprehensive survey and an appropriate assessment of such landforms. As argued in 'A Study Area', plans that do not value geomorphological forms per se or lack a specific approach to

[2] For the EIA and SEA procedures see e.g. European Commission 2019 and 2020.

[3] Contemplated in the Decree of the President of the Italian Republic No. 357 of 8 September 1997.

[4] Directive 2009/147/EC of the European Parliament and of the Council of 30 November 2009 on the conservation of wild birds and Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora.

[5] Regional Law No. 12 of 11 March 2005 and Regional Government Decree VII/11045 of 8 November 2002.

geomorphological conservation may fail to ensure adequate protection to potentially interesting features. This is especially valid for ordinary territories, where the presence and relevance of geomorphic features are often overlooked.

Geomorphosite assessment methods are well suited for the analysis, comparison and protection of geomorphological sites, which embraces features and processes that, first of all, play a key role in the understanding of the history of the Earth (Coratza and Hobléa 2017). It was suggested here, however, that these methods (perhaps with a few modifications) could be applied more generally, particularly for informing land use and management decisions and rising awareness regarding the value of landforms. The proposed approach is probably best applied during the development of land use plans, when thematic maps such as the basic geomorphological map and the landform assessment map are usually produced. The investigated zones, however, cannot be very large because it is usually unfeasible, due to resources limitations, to carry out detailed geomorphological surveys across wide areas. If necessary, these surveys may be performed while setting up local plans or single projects.

As written in the 'Introduction', the assumption underlying this paper is that every landform has a value that should be acknowledged, can be ranked on a qualitative scale using the parametric methods mentioned in the preceding sections and must consistently be taken into account — particularly when planning land use changes — in order to decide whether and how to protect the geomorphological features of an area.

This work, actually, aims to promote an 'exclusion approach' to geomorphological protection, whereby all landforms deserve some form of conservation except those whose value (potential or actual) is considered too low. How and to what degree the other landforms should be conserved, however, is a problem that must be dealt with case by case. The aim of this approach, clearly, is by no means to prevent anthropogenic geomorphological changes, but rather to promote changes that are based on knowledge (about the presence and relevance of landforms), responsibility (what landforms to conserve, to what degree and how) and caution (in altering and eliminating landforms) in accordance with the principles of geoethics and sustainable development (Di Capua et al. 2017 and 2021; Gill and Smith 2021).

As a final remark, it can be noted that over time, ecology, geography, art and environmentalism, as well as other disciplines and movements, have taught us to pay attention not only to what is extraordinary and rare but also to what seems ordinary and common. For biotic nature, and even more for abiotic nature, this process has still a long way to go.

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## Declarations

**Conflict of Interest** The authors declare no competing interests.

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