“Not seen, not considered”: An evaluation of differential perceptions of environmental risks using Perception-Based Regional Mapping: the case of heavy metal dispersion extent in the Plain of Mornag facing old plumb mine spoil tips of Jebel Ressass (Tunisia).

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ORIGINAL PAPER

"Not seen, not considered": mapping local perception of environmental risks in the Plain of Mornag and Jebel Ressass (Tunisia)

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Abstract
The Mornag plain—which is dominated by a mountain, Jebel Ressass—has been exploited for various uses for millennia. There are still huge slag heaps around the old lead mines at the foot of the mountain. Olive trees are cropped intensively in the plain, although this agriculture is threatened by the expansion of the suburbs of Tunis nearby. The mapping of environmental issues perceived to be important by local stakeholders in the Mornag plain was carried out. This was achieved by using perception-based regional mapping (PBRM) to inexpensively assess the spatial extent of all the perceived threats and risks to the environment as well as its vulnerabilities in this region. All of the resulting PBRM maps were integrated with a GIS and then merged to obtain a spatial database of the environmental risks that affect this territory. Several risks and nuisances were found to be linked to the presence of Pb mine dust as well as dust from the nearby quarry. Household waste and garbage appear to be the main environmental concerns to local stakeholders. The problems are due to the gap between new periurban consumption practices in suburban Tunis and rural municipality budgets. Other agriculture-related nuisances highlight the gap between the vision of a preserved rural area and the agro-industrial reality. PBRM was found to be a useful tool for assessing the effects of the accumulation of multiple environmental risks on a territory rather than focusing on one factor.

Keywords Lead mining · Tunisia · Multisource nuisances and risks · Periurbanization · Perception-based regional mapping

Introduction

Postrevolution Tunisia: reconsidering the multiple purposes and contaminations of periurban areas

Before the Jasmine Revolution in Tunisia in 2010–2011, the previous political regime was the first in the Arab world to prepare in 1990 a national environmental action plan, which was followed by dedicated environmental impact studies that mainly focused on waste management, industrial units, and quarries (MEDD 2009; Halle et al. 2012). Since then, thanks to increased political openness regarding environmental issues, environmental communication, education, and action programs have been proposed by associations, political parties, and regional authorities, although the postrevolution era in Tunisia has also been a period of political uncertainty (ADB 2012).

One may then ask how environmental risks and issues will evolve in Tunisian territories in years to come (Drissi 2008; Meddeb 2009). The evolution of these risks and issues

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is influenced by residents' perception and acknowledgement of them as issues, and how the government addresses them. The most prominent illustration of an intricate combination of risks, nuisances, and environmental challenges in Tunisia is provided by Greater Tunis: its population (2.7 million inhabitants, 23% of the country's population) requires better environmental management. The city is expanding rapidly (Hammami 2010), particularly into the southern and contiguous Mornag plain, which is becoming periurban as much as rural in terms of habitat and landscape (Bouraoui 2003; Weber and Puissant 2003; Davodeau and Toublanc 2010). The population density of the corresponding administrative region (Mornag Delegation) has risen to 132 inhabitants per square kilometer (Weber and Puissant 2003; Urbaconsult 2011), with major sanitation and traffic consequences. This area has historically been a focus for considerable mining activity (Levainville 1924): the Mornag plain is dominated by 700-m-high Jebel Ressass ("Lead Mountain"), which has been exploited since Carthaginian times, as described by Gustave Flaubert in the novel *Salammbô* (Flaubert 1862). This exploitation of the mountain for over two millennia has resulted in many mining sites and remnants in the area, including slag heaps rich in heavy metals (Pb, Cd, and Zn: Sebei 2007; Bousse 2010; Ghorbel et al. 2010; Mezned et al. 2016). Livelihoods in this rural area are based on agriculture, especially oleiculture. Because of the proximity of the Mornag plain to the major market and harbor of Tunis, olives are grown agro-industrially on the plain, implying the extensive use of pesticides, fertilizers, and irrigation water (Hamrita et al. 2017). Indeed, there have been pilot projects to reuse wastewater for irrigation in this area (Bahri and Brissaud 1996; Bahri 2003; Hamrita et al. 2017).

The combination of environmental issues described above leads us to the purpose of and the justification for the present study. Considering all of these issues collectively and objectively is an ambitious interdisciplinary objective, but we consider it to be a fundamental step before investigating each issue further analytically. It involves devising a scheme that can be used to inventory and spatially discriminate environmental issues in a uniform and rapid manner under unavoidable funding and logistical constraints. In the work reported in the present paper, the perception-based regional mapping (PBRM) methodology was used to map the perceptions of the local community and stakeholders spatially (Saqalli et al. 2009; Maestripieri and Saqalli 2016) by considering survey interviewees to be imprecise but locally relevant risk observers. Collecting interviewees' statements on such issues highlights the gap between perception and data; in other words, the capacity of a population to comprehend risks, which is a significant component of resilience and willingness to cope with hazards (Becerra et al. 2015).

Therefore, as long as the information collected using PBRM is not used to confirm anything, such surveys are useful for examining the dynamics that affect a particular territory, especially in areas with a combination of risks and threats, such as the Mornag plain. This article first presents the environmental issues for the Mornag plain and the methodology that was used to assess them. The main results of this methodology are then presented and discussed. The the article concludes by discussing epistemological and environmental issues.

Materials and methods

The Mornag plain: agriculture and mining

PBRM was applied to the Mornag plain surrounding Jebel Ressass (36°42′–36°30′ N; 10°06–10°34′ E; Fig. 1 shows the study area as presented during interviews). This plain has a semiarid climate (Ghanmi et al. 2012) and constitutes the downstream zone of the Miliane river basin (2000 km^2) and its tributary, Oued El Hamma (Tijani 1968). The latter is cut by a hill reservoir, creating a dam lake approximately 70 ha in size. The Mornag Delegation and plain cover 36,812 ha and are dominated by Jebel Ressass (795 m.a.s.l.) and a series of hills, the Rades Hills. This territory includes 20,000 ha of agricultural land (8660 ha of which is irrigated; Hamrita et al. 2017) that is among the most productive and most agro-export-oriented in Tunisia (Perez 1992; Ben Romdhane 2011). Indeed, the Mornag plain is a privileged area of intensive arboriculture (Zeramdini et al. 1996; Aïachi Mezghani et al. 2012) with relatively good soils and unusually shallow groundwater access compared to the rest of the country (Farhat et al. 2010a, b) as well as a comparatively very good transport network (it is less than 30 km south of Greater Tunis, to which it is connected through roads, a railroad, and a highway). Olives have been grown in this region since the time of Carthage (Leveau 2007a, b). The plain was covered by around 321,000 olive trees in 1881, when it was described as "an immense plain planted with vines and olive trees [... which...] contains neither villages, nor hamlets, only some domains very far from each other and in this desert of vines, separated from Tunis by many miles, one should know how to suffice to itself" (De La Forge 1894).

During independence, most of the land in the estates of this region was redistributed among the former workers, but the progressive reacquisition of land by several agro-industrial groups has led to the recreation of large farms, some exceeding 100 ha, especially in the most profitable areas—downstream areas that have better soil but are far enough away from the sea to avoid saline intrusions (Farhat et al. 2010a; Charef et al. 2012). Most of these areas are close to Mornag City. Farms on hills with little access to irrigation water have maintained a village organization that is based on self-reliance; it focuses on

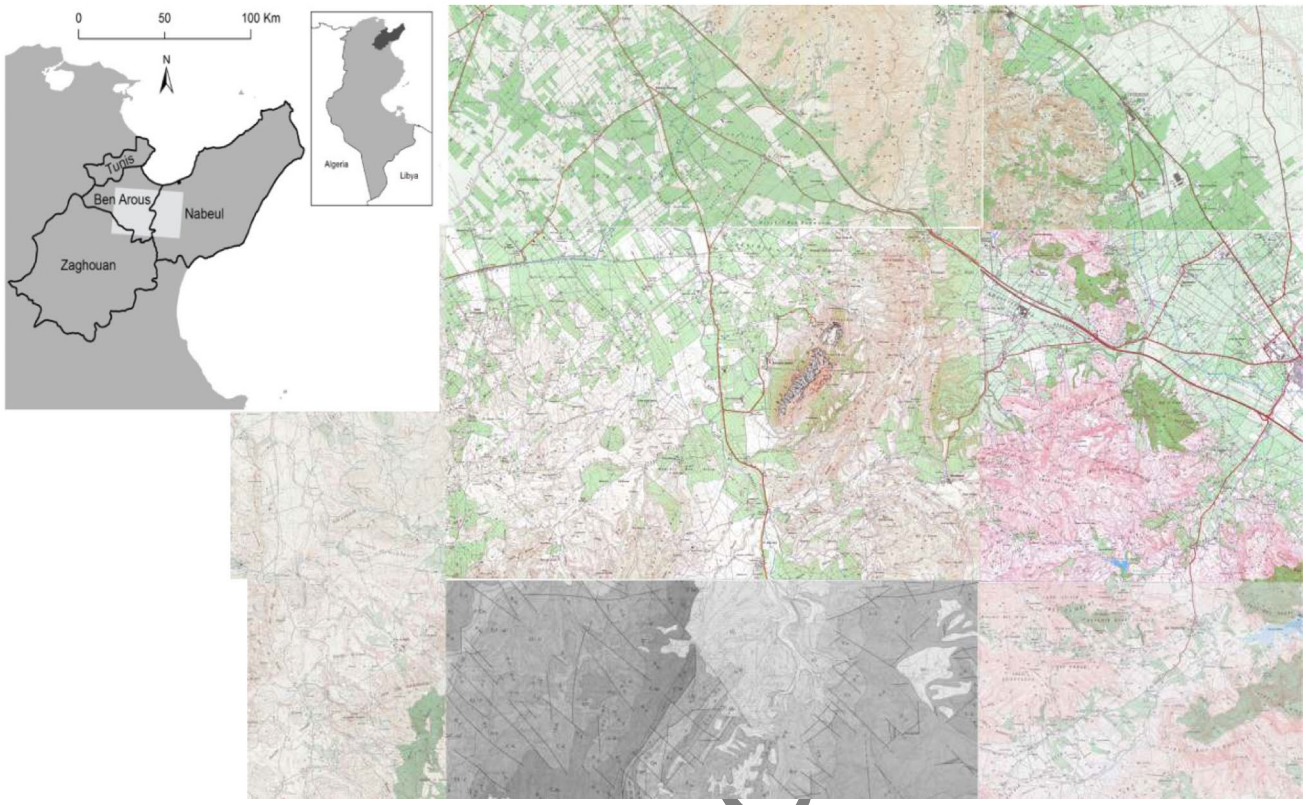

Fig. 1 The study area: Mornag plain, Tunisia

raising livestock without permanent stabling (Boussetta et al. 2012; Maestripieri and Saqalli 2016; 2016 surveys).

The mountain (Jebel Ressass) at the center of this plain is among the most important and most throughly investigated Pb and Zn mining sites in Tunisia. Other sites include the Mejerda catchment area (Ghorbel 2012), the Lakhouat and Jalta sites (Boussen 2010), Jebel Hallouf Sidi Bou Aouane (Mezned et al. 2016), Touiref (Othmani et al. 2006) and its tributaries, and the Mellègue and Tessa streams (Sebei 2007; Nouairi et al. 2019). The Jebel Ressass deposit was exploited during the French protectorate for 70 years until 1957 by the French company Peñarroya, Ltd. (Levainville 1924; Sermet 1964; Troly 2008). Ghorbel et al. (2010) and Ghorbel (2012) have shown that, in this semiarid territory, metallic elements have been dispersed aerially more than via waterways (Chane Kon et al. 2007; Boussen 2010). At the foot of the mountain are mining dumps consisting of approximately 2 million tons of compacted residues of fine dust enriched in Pb and Cd (Courjault-Radé and Destrigneville 2008; Courjault-Radé et al. 2008; Ghorbel et al. 2010). These heaps are close to the village of Jebel Ressass.

Evaluating territories and landscapes based on local perceptions

Investigating residents' perceptions regarding local issues is certainly not a new idea; it has been performed since at least the end of the nineteenth century (Chauveau 1991). Formalizing these perceptions is also not a new concept; for instance, Jackson (1993), Chambers (1994), Deffontaines and Lardon (1994), Loader and Amartiya (1999), and Olivier de Sardan (2003) examined residents' perceptions as part of their "participatory" research and development, and resident's perceptions of public health issues have long been of interest (Herzlich 1984; Olivier de Sardan 1995). This type of risk perception can be interrogated by various methods, such as questionnaires (Remoundou et al. 2015), but it has always been difficult to formalize in a neutral way (Barnaud et al. 2013). So-called mental geography has gained interest since the 1980s, particularly in countries where data are scarce and unreliable (Mettrick 1994) and where adjustment policies have significantly reduced the analytical capacity of the government (Courade 1989). Another more prosaic point is that this method yields attractive illustrations

for donors and fundraisers (Davis 2003). However, interpreting these mental maps geographically is difficult without a geographical reference; the information remains conceptual and qualitative and has a limited scope of action (Killworth and Russell 1982; McNamara 1992; Halfacree 1993; Bailly 2006). Attempts to combine these maps with geographic information systems (GISs) have failed (Campo 2003; d'Aquino et al. 2004; Crosetto et al. 2006; Touré et al. 2009). Integrating qualitative knowledge with a GIS implies to prepare a cartographic background on which participatory maps are to be assessed. Such a background should be both not biased (for instance by enhancing land use or administrative boundaries) and wide enough, to reduce side effects. Full integration of this qualitative geographical information implies the elaboration of a list of parameters that are considered to be crucial, and the construction of a reading grid. For instance, what criteria do we investigate to study the deforestation of an Amazonian territory: economic parameters such as herding and cacao prices, sociological parameters such as family and manpower demographics and dynamics, or anthropological parameters such as values and norms relating to the forest?

Caron (2001) has developed a methodology called actors' zoning (ZADA). This involves collecting perceptions at the regional level based on stakeholders' statements and symbolizing dynamics and territories through choremes (diagrams that reconstitute spatial structures and their historical evolution). PBRM was devised as a formal extension of ZADA that uses the GIS formalism. Applying this open issue-mapping tool to a rather large study territory (McCarthy et al. 2004) produces a hierarchized list of spatially discriminated parameters for the territory, as described below.

The perception-based regional mapping methodology

In practical terms, PBRM involves interviewing 1–3 people using a map as a support in the discussions and for information transcription. The map is covered with tracing paper. Figure 2 describes the different field steps (Bonin et al. 2001; Caron 2001). The innovation of this approach is that the information is processed through the GIS formalism and that all layers of perceived risk are combined into a single final map. A full description of the process and a discussion of the advantages and disadvantages of this method can be found in Saqalli et al. (2009) and Maestripieri and Saqalli (2016).

During each interview, the territory that the interviewee was knowledgeable about was defined first, as this allowed it to be outlined on the map. Then an open question ("Are the environmental problems in the territory you know the same everywhere?") was posed (a questionnaire was not used, as this would have constrained the interviewee's answers). The criteria (i.e., environmental issues raised by the interviewee) of the territory were then noted. A series of maps of criteria created on tracing paper were therefore obtained, with each map corresponding to one interview. All of the maps were scanned, georeferenced, and the attributes of each spatial polygon are filled with the correponding mapped through GIS software (open-source QGIS software). The next step was to combine these different maps into one map. This merger was carried out as a succession of two-by-two mergers. The final map was therefore "multidisciplinary," as it included all of the criteria from all of the interviewees. However, as it was a merged map, it could not show differences in perception between categories (e.g., between genders or professions); such differences can only be probed by performing an equivalent process for each target category (which

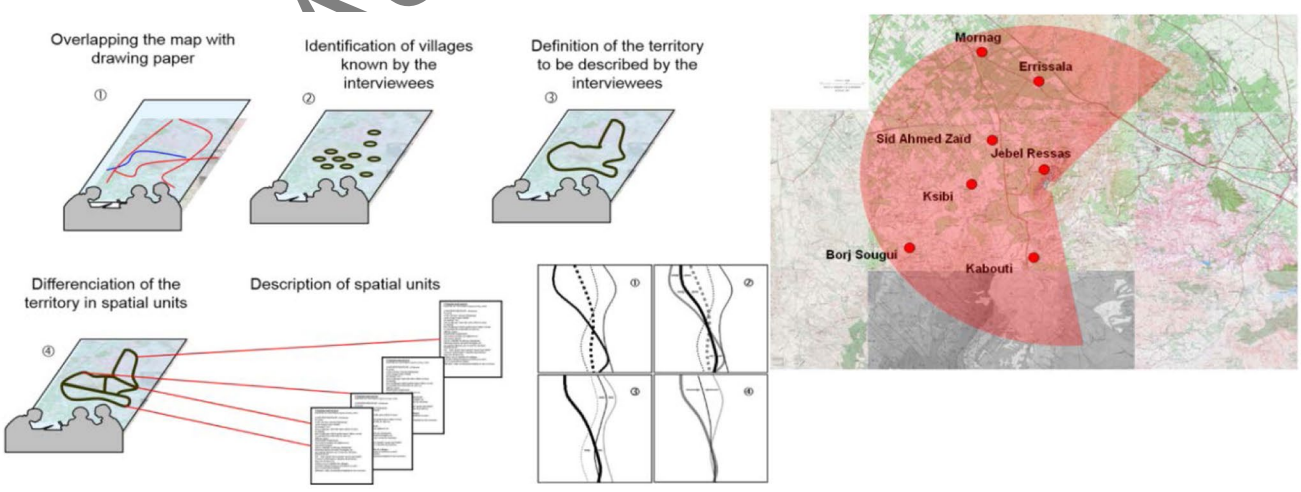

Fig. 2 The steps involved in perception-based regional mapping

may be attempted in subsequent further exploration of our results). Integrating our maps into a GIS allowed them to be stored, manipulated, analyzed, and compared with other geographical sources (Suarez-Vega et al. 2012). As these maps are generated over a previously georeferenced map, they are already positioned, and the georeferencing of the maps is facilitated.

In addition to the centrally positioned Jebel Ressass village at the foothills of the mountain, the following interview locations were utilized to ensure that the whole Mornag plain was covered both geographically and environmentally based on irrigation/agriculture and transportation network density criteria: (i) Borj Sougui and Kabouti (hilly areas without shallow water, perceived as remote); (ii) Ksibi and Sid Ahmed Zaïd (irrigated plain sites located far from urban sites and freeways); (iii) Mornag and Errissala (irrigated plain, semiurban, or urban sites with easy access to freeways).

The sample of interviewees was intended to be as representative as possible (Table 1). In addition, particular attention was paid to the demographics of the people included in the joint interview in order to avoid dominance by one group of people (because of their occupation, for example).

Advantages of the PBRM method

There are several advantages of conducting a survey on perception, particularly perception of multidisciplinary objects such as environmental contamination, the risks presented by those objects, and their impact on a population:

- It enables the identification of risks, issues, and nuisances that may be overlooked by more quantitative tools.
- It allows the dynamics across a large territory to be described qualitatively, which would otherwise be impossible to achieve given the financial and logistical limitations imposed on most current socio-anthropological research projects (Saqalli et al. 2009).
- It permits the parameter hierarchy—the relative weights of all the issues as perceived by the population—to be described. This is achieved by performing a census of the number of times each parameter appears during interviews as well as the spatial extent of each parameter.
- It can provide qualitative information on long-term dynamics when it is only possible to obtain biophysical measurements for a snapshot in time (not an extended period) and for just one spatial point (rather than an area).
- This method has been employed and assessed in several countries with very different territories and environmental and socioeconomic issues and contexts: Brazil in 1996 (Bonin et al. 2001); South Africa in 1998 (Saqalli 1998); France in 2003; Niger in 2005 and 2006 (Saqalli et al. 2009); Tunisia in 2008 (Tounsi et al. 2008); Madagascar in 2011; Laos in 2012 (Saqalli et al. 2015); and Ecuador in 2013 and 2014 (Maestripieri and Saqalli 2016). It has been successfully applied to survey the perceptions of a wide variety of interviewees, including illiterate people.
- This tool challenges the viewpoints of institutional partners, including local governments and even scientific institutions and scholars, all of whom have their own agendas. These agendas may be perfectly legitimate. However, by addressing all of the issues altogether, this tool openly questions the research objectives pursued by partners who are eager to focus on certain themes that could influence the direction of the investigation. Thus, PBRM "automatically" forces the partners to question their research objectives.

However, it is important to note that the purpose of PBRM is to conduct a declaration-based census of the parameters that are believed to be involved in these interactions; citizens cannot be asked to establish a risk (for instance from a contamination), especially if it is not obvious (e.g., a hidden, persistent, low-level, and as-yet unproven risk). There is no reason to look for greater veracity in interviews than in measurements.

Results

Hierarchizing the issues according to local perceptions

Once the perception map was obtained, the issues were hierarchized according to the number of times they were raised and the order in which they appeared during the interviews, which is postulated to be a proxy for criterion (i.e., issue) weight in the interviewees' hierarchy of issues affecting the local environment. The hierarchy presented

Table 1 Representativeness (based on age, professional activity, and gender) of the interviewees questioned during the PBRM in Tunisia

Mean age	Main occupation (%)				Gender (%)	
	Public officer	Trader	Farmer	Retired	Women	Men
49.8	42.3	11.5	19.2	23.1	15.4	84.6

Table 2 Frequency of each order of appearance for each of the main issues raised during PBRM interviews, as well as the calculated ranks of the issues

Criterion	Order 1	Order 2	Order 3	Order 4	Order 5	Total weight	Rank of importance
Garbage and wastes	7	2	2	2	0	9.17	1
Quarry, cement, and all dust	3	2	3	1	1	5.45	2
Water sanitation	3	2	2	2	0	5.17	3
Poultry/pig pollution	0	3	2	0	1	2.37	4
Nitrated irrigation waters	1	1	2	0	0	2.17	5
Lead mining dust	1	1	0	0	1	1.70	6

in Table 2 was constructed using the following empirical formula:

$$\text{Weight of criterion } X = \sum_{i=1}^{5} N_i/i, \quad (1)$$

where N_i is the number of times that criterion X is cited during interviews with order i, with i the order of appearance of criterion X in an interview (i takesvalues between 1 and 5, where 1 indicates that the criterion appeared first in the interview and 5 indicates that the criterion appeared after four othercriteria).

Paradoxically, and contrary to the initial hypothesis that the risk of Pb contamination would be the major concern of the local population, Table 2 indicates that this was perceived to be a relatively minor risk by the population: other issues were clearly perceived to be more important.

Human and nonhuman animal nuisances and associated risks: visible waste and garbage

As seen in the previous section, counterintuitively, the top-ranked issue was waste and garbage. This factor is linked to livestock and strong cultural values of cleanness (Jacob 2006; Abdmouleh 2011). It highlights that this territory, which was once a rural area, is now a periurban area. As previously noted by Bouraoui (2000, 2003), Weber and Puissant (2003), Drissi (2008), and Meddeb (2009), this issue points to the progressive urbanization of the area; even in parts of the Mornag plain that do not have any new buildings, the city is now seen as the main source of jobs, and almost all public and company buses in the area travel to and from Tunis. The Mornag plain region exports not only agricultural products but also humans on a daily basis. One may hypothesize that this issue was not raised in the interviews because the interviewees felt that it was not something that could be controlled, so they did not view it as an environmental issue that could potentially be resolved.

The shift of the majority of the population of Mornag plain towards mostly urban consumption practices implies that food is now bought in markets and supermarkets. The changes in the habits and demography of the population have caused the amount of garbage to grow dramatically in recent times. While public services have been able to keep up with the growing demand for access to tap water in the area (as seen in Fig. 3a; poor water accessibility is now mostly a rural phenomenon), public garbage collection was seen by 63% of the interviewees as being highly inadequate (Fig. 3b). Garbage collection is the legal responsibility of municipalities, which are seriously underfunded considering the growing population and the garbage collection practices in the territory of interest. Therefore, garbage bags pile up for weeks. Three areas of the Mornag plain region can be distinguished in this context; these areas are labeled with different symbols in Fig. 3b:

The area labeled with an *asterisk* surrounds periurban centers, especially Mornag, and faces a growing problem with garbage: municipal collection services are undersized, forcing residents to illegally burn this waste, which in turn causes odor nuisances.

Due to administrative confusion regarding the statute of the village of Jebel Ressass, there is no garbage collection by the Mornag Delegation from the area labeled with an *'X' symbol*. Even worse, Mornag and other more urban municipalities neighboring the village of Jebel Ressass illegally dispose of excess garbage there. There are two unauthorized landfills at the location indicated by the symbol X.

The area labeled with a *cross*, which is still considered to be rural and is characterized by a plateau landscape, is experiencing drastically reduced access to shallow water for irrigation. This rural area includes villages originating from French agricultural domains. There is no garbage collection in this area, but local consumption practices reduce the need for garbage collection, as residents still burn their (mostly organic) waste.

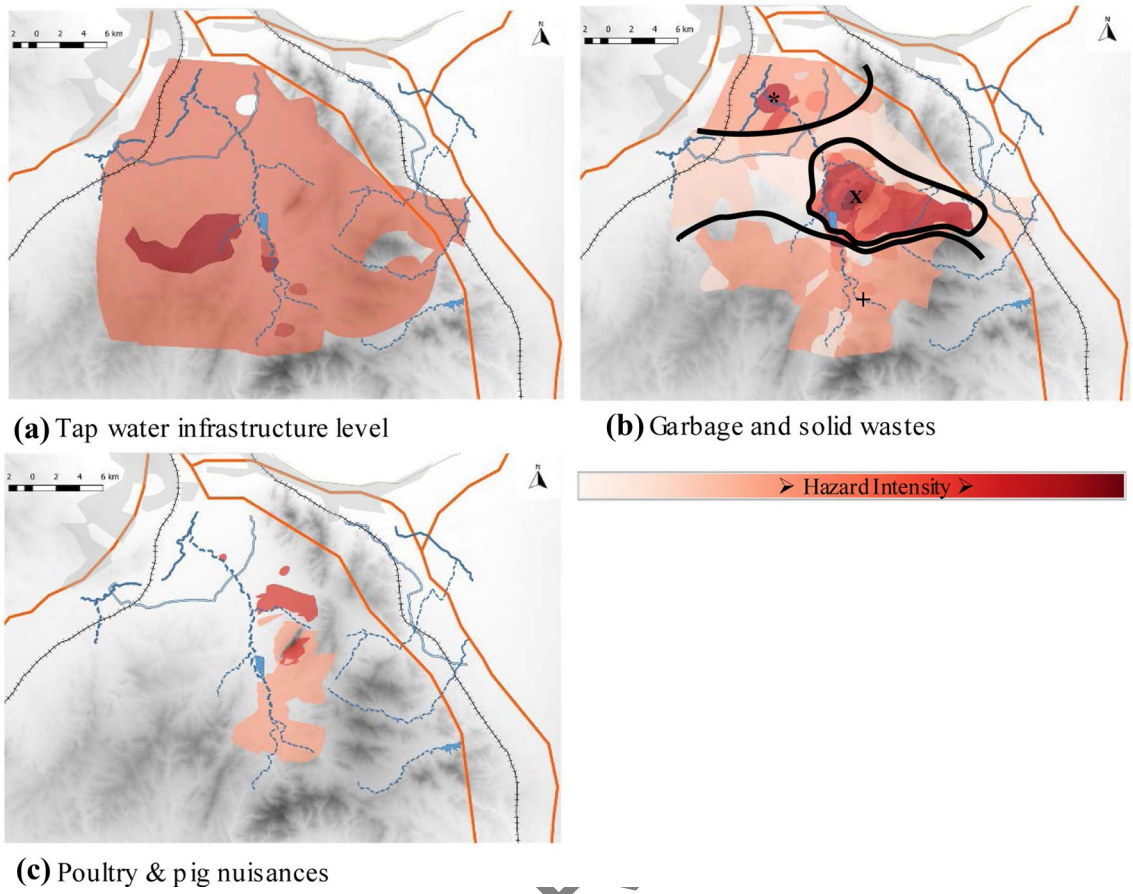

Fig. 3 Human and animal nuisances and associated risks: **a** water availability, **b** garbage and solid wastes, **c** animal nuisances

Finally, Fig. 3c is representative of the perceived failure of the state: eating pig is socially reprehensible according to the precepts of the dominant religion in Tunisia—Islam. The pig farms in the area are viewed with distaste, and their odor, mixed with that of poultry droppings (from farms raising broilers, laying hens, and guinea fowl), is detested. In the interviews, the blame for this nuisance was clearly assigned to the state and a lack of application of the law, which should be viewed in a postrevolution context (i.e., there is a fear that the state will collapse).

Risk of dust: interviewee confusion between dust from quarry/cement works and dust from slag heaps

The dust in this area originates from two sites, as shown in Fig. 4. These sites are located in the center of the plain, at the foot of Jebel Ressass. The first site is located on the western side of the mountain and consists of a series of rectangular slag heaps oriented north–south. This is a large site: almost 500 m long, approximately 50 m wide, and 1–6 m high. This site has evolved into the legally recognized village of Jebel Ressass, with approximately 700 inhabitants, a school, and a dispensary. One of the slag heaps has been leveled for use as a football field. The mixture of soil and Pb mining waste is mobilized by high winds. As shown by Ghorbel et al. (2010), the dust is mainly swept up by gusts of wind. Given the wind direction, the dust moves in several directions ranging from SW-NE to SE-NW, but especially in the S-N direction.

To the south of the first site, on the small southern slope of the mountain, is the aggregate quarry and cement plant owned by Carthage Cement. This company was producing 2.2 million tons of cement per year in 2015 from a quarry extending across 218 ha. Although the cement plant is relatively new (construction started in 2008), the aggregate quarry is more than 30 years old, and it has considerably reduced the volume of the mountain over this period. These two operations—but mostly the quarry—emit much more dust than the slag heaps. However, because the dust is red and dust from both sources is swept up under the same wind conditions, the two dust sources were confused by most of the interviewees.

Either or both of the two dust sources combined were cited in 74% of the interviews (Fig. 4a); of those, 20%

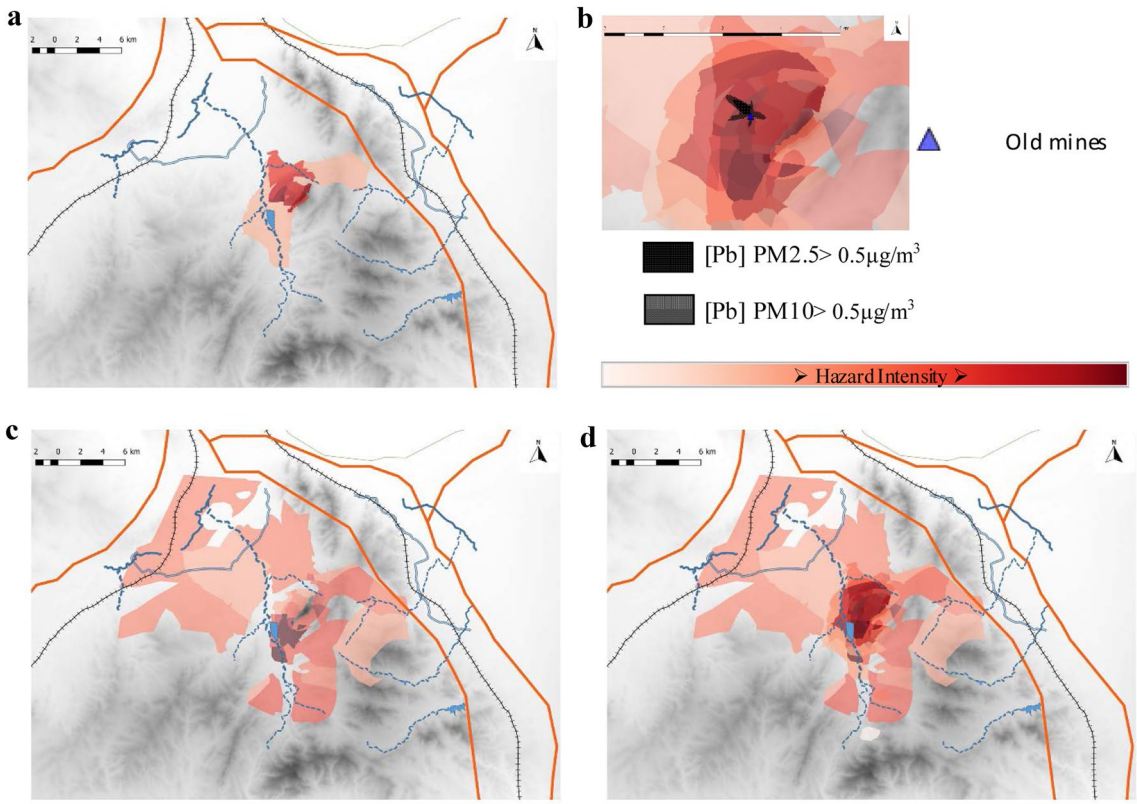

Fig. 4 Perception maps for dust criteria: **a** mine dust, **b** the Pb wind dispersion model from Ghorbel et al. (2010), **c** quarry/cement dust, **d** undifferentiated dusts

mentioned the mine dust (Fig. 4c), 67% mentioned the quarry dust (Fig. 4d), and 13% simply mentioned (undifferentiated) dust. The mine dust halo is localized to the western slope of the mountain (Fig. 4a) but extends over an area at least three times larger than that modeled by Ghorbel et al. (2010) (Fig. 4b), suggesting an even stronger effect of wind gusts than accounted for in the corresponding modeling, or the deposition of mobilized dust across a larger area than expected. Each time the mine dust criterion was cited by interviewees, it was as a counterpoint to the also-cited quarry/cement dust criterion, meaning that the mine dust was viewed by interviewees as being separate from the dust from the quarry.

Water-related risks and constraints: flooding, shortages, and pollution

Intensive agriculture on the Mornag plain has reduced the water table over the past 30 years, leading to saline intrusions in the lowest parts of the plain closest to the sea

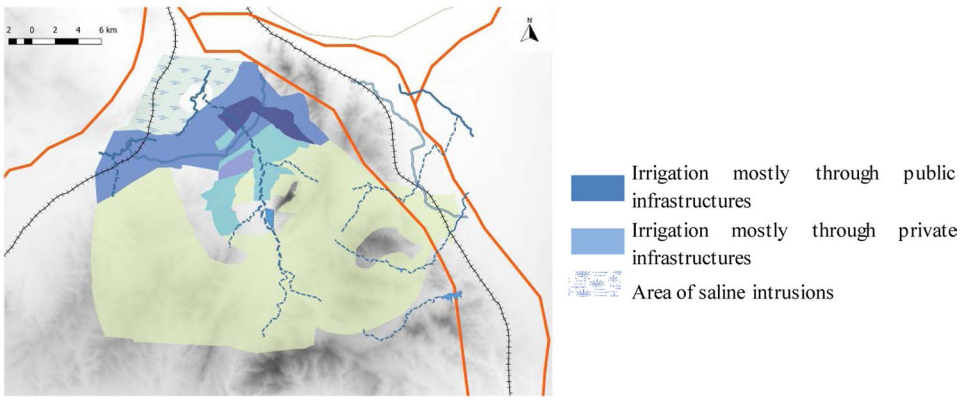

Fig. 5 Territories that are irrigated privately or by so-called public water (aqueducts from the north in particular), and saline intrusions (in areas with entirely public irrigation)

according to the results of two interviews (Fig. 5). Irrigated areas were also described by all of the farmers interviewed (5 people) as being contaminated with pesticides, given the doses used on the irrigated olive groves.

Several farmers interviewed in the area where local groundwater is used (private irrigation) also reported that, following the drawdown of the groundwater table, drippers have become clogged due to an abundance of mineral residues. They also reported that there is now long-term inability of the olive trees grown in certain areas higher up—around Jebel Ressass and the quarries—to access irrigation water (Hamrita et al. 2017). This area is not indicated in Fig. 5, but it is the topmost part of the private irrigated area.

Between these two altitude-related extremes (saline intrusions and inaccessibility to irrigation water, leading to dewatering: Charef et al. 2012), the water management infrastructure in the region of the plain is degrading, leading to an increased flood risk in the lowlands of the plain (Fig. 6a), along with decreased access to the sewer system and siltation of the Oued el Hamma dam. Together, these problems are creating additional health issues (Fig. 6b) and reducing water availability. The Ministry of Agriculture, Water Resources and Fisheries (MAWRF) is considering rehabilitating the irrigation scheme based on public water for Mornag (a coverage of 6812 ha is planned), which has been in operation since 1982. This combination of problems was set to be resolved in 2018, but work to address the problems was then postponed until 2020.

On the other hand, the Mornag plain is also experiencing the consequences of wastewater reuse for fruit tree irrigation, which is the subject of a pilot project on the plain. In 2015, the MAWRF authorized the artificial recharging of the Mornag aquifer with treated wastewater from the Sud Meliane II wastewater treatment plant and the Medjerda Cap Bon Canal (Bahri and Brissaud 1996; Bahri 2003; Charef et al. 2012; Hamrita et al. 2017). These so-called northern waters were considered by 25% of our interviewees to have high levels of nitrates because the waters are not recycled far enough upstream of where they are used for irrigation (Fig. 6c).

Combining the risks and issues to redefine the most threatened areas

Finally, because the local population is exposed (Ghorbel et al. 2010) not only to Pb but also to a series of other nuisances and risks, rather than determining where the risk of Pb exposure (previously assumed to be the main health hazard in the region) was the most intense, it was important to

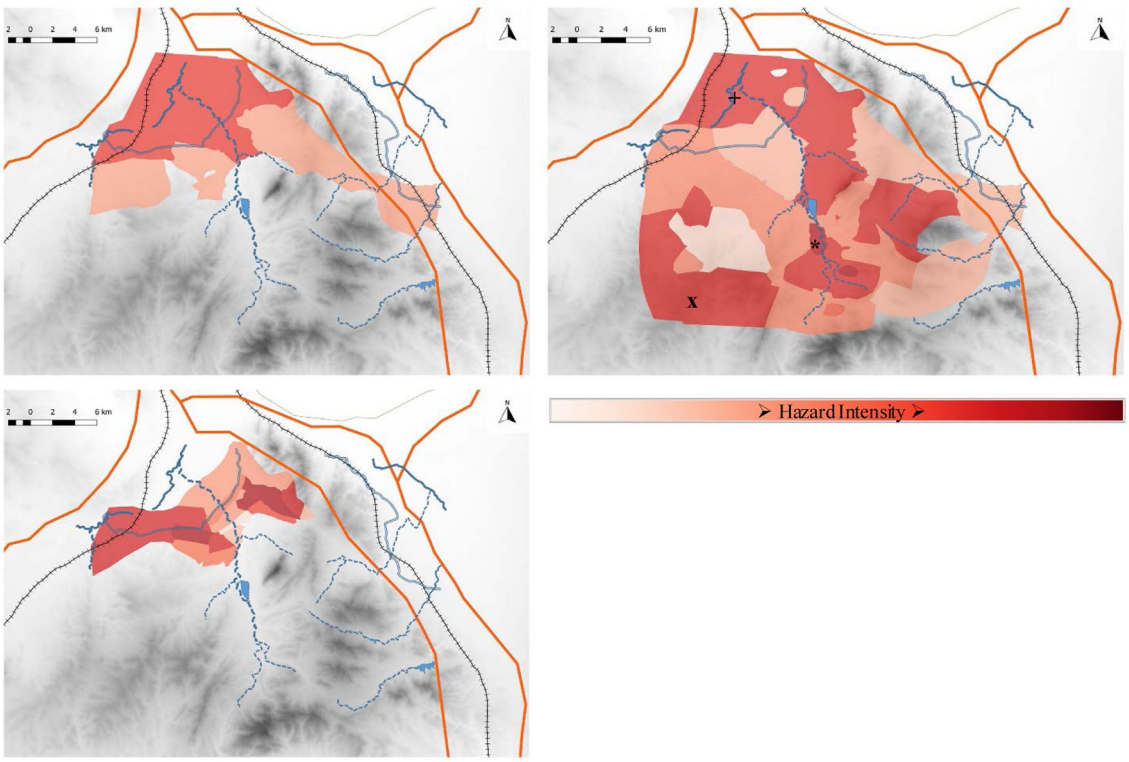

Fig. 6 **a** Territories at risk of flooding. **b** Liquid wastes: sewer and sanitation problems (*asterisk* Oued el Hamma dam lake, *cross* insufficient and dilapidated infrastructure, *x symbol* almost no infrastructure). **c** Areas that are mainly irrigated by northern waters (public farms)

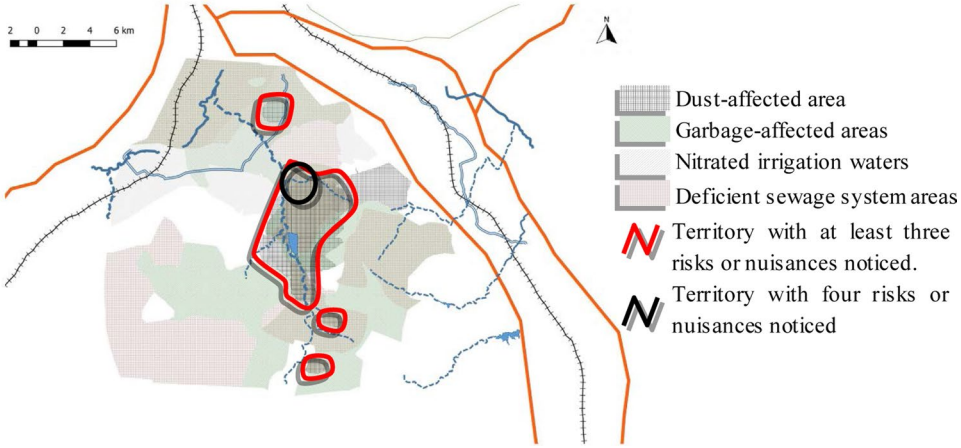

Fig. 7 Spatial distributions of the major risks and nuisances, and the areas in which there are at least three or four of the most commonly cited risks

identify the areas and populations with the highest combined risk resulting from a cocktail of several chronic nuisances.

Figure 7 therefore presents the spatial distribution of each type of risk, but also the spatial distribution of high combined risk. The debate over this difference in approach to viewing risk prioritization—either (i) considering each type of risk individually or (ii) exploring the overall risk—is currently directly influencing public policy (Fig. 4a, c). Approach (i), which considers Pb contamination to be the overriding concern, implies that Jebel Ressass is the area with the highest risk. On the other hand, approach (ii), which considers all of the risks and nuisances in the region together, points to the Ksibi area as being the most risky, as there are four of the most commonly cited risks and nuisances in that area (a lack of sewage systems and the presence of nitrated irrigation waters, dust, and excessive garbage). The Ksibi area is surrounded by a larger area in which there are at least three of the main risks raised by interviewees.

Discussion

Limitations: saturation, representativeness, and biases

Anthropological saturation (Olivier de Sardan 1995, 1996; 2003) is the point at which equivalent concepts or facts begin to reappear in interviews. This point was quickly reached in the Mornag study: there were relatively few main risks and nuisances, meaning they were shared by most of the population. That said, some criteria that may have been expected to be mentioned (such as transportation issues) were not, suggesting the need to check that the saturation point was indeed reached.

From a social perspective, the interviewees were not strongly representative of the whole of northern Tunisia, indicating that the PBRM tool should be tested by applying it to more rural areas with fewer contrasting situations. The people interviewed are those who consented to an interview (Table 1). This approach to interviewee recruitment introduces social biases: those who consented to be interviewed were more likely to be people who were socially allowed and eager to talk to foreigners, which excluded most women as well as busy professionals, such as many farmers, traders, and civil servants. Those who agreed to be interviewed—mostly civil servants, elderly men, and people with assured social positions—were therefore essentially privileged. Self-censorship still occurred among the interviewees, especially when many curious people surrounded the people being interviewed. Although the social representativeness of this survey was not that bad given the theme (57.7% of the interviewees were not public officers), gender representativeness was poor (15.4%), especially since almost all of the women interviewed were civil servants (there was only one housewife). Similarly, the average age was high, mostly because young people (i.e., those under 30 years of age), who make up half of the population of the country (National Institute of Statistics 2016), are perceived as having little right to speak out socially. This, of course, could lead us to question how representative the respondents were and the validity of their answers. However, such bias is found in all qualitative surveys.

The focus on a specific issue is a limitation of this survey. Applying PBRM to a specific issue such as the environment is difficult, as the respondents found it difficult to conceptualize and spatialize information. Nonspecialists viewed the issue in different ways. For example, one interviewee described the reception quality of the over-the-air TV signal as a relevant issue.

Justification: methodology and epistemology

First parameters then data: This survey proposed that a territory can be described by acknowledging its inherent complexity through spatialized testimonies, considering that:

1. It is important to inventory all of the risks, threats, and nuisances; in other words, the first objective for environmental research should be to identify all influential factors and then to hierarchize them according to weight and threat. This approach is important, as few scholars justify the legitimacy of the parameters they study.
2. Inventorying the issues may involve scientific or local legitimization. Apart from a few areas of the world where a range of issues have been assessed, most sites are investigated based on only a few issues. The selection of issues to study is influenced by external factors (e.g., the researcher's background or the prominence of a particular issue in the media). We therefore consider local legitimacy to be particularly important, as only the local population can provide a balanced source of information (even if that information is imprecise), given that they consider multiple issues simultaneously.

Data and parameter collection: Any data collection strategy for a particular territory should follow two principles:

- It should be exhaustive and accurate, i.e., it should include all of the parameters required to understand the dynamics of the territory. PBRM fulfills these requirements.
- It should be precise, i.e., it should describe, qualify, and quantify each parameter to a sufficient level of quality to permit an evaluation of the interrelated dynamics of multiple parameters. Note that while PBRM can identify parameters that are important to interviewees, it cannot replace data collection. The data afforded by PBRM (i.e., the perceived spatial distribution of each parameter) provide a rough first approximation that should be refined by investigating field measures.

Thus, PBRM is a tool that allows subsequent lines of research to be hierachized.

PBRM: identifying risks and nuisances so that vulnerable areas can be prioritized

Mapping local knowledge to improve the organization of subsequent investigations: PBRM rapidly highlights the main issues in a territory, thus opening up new lines of scientific investigation. Based on the present survey, it appears that there is a need for further investigations into previously overlooked issues such as garbage, sewerage, and sanitation in periurban areas of Tunisia. The results of PBRM allow the generation of a risk map, i.e., the spatial distribution of hazards and vulnerabilities, including environmental factors, anthropogenic causes, and prospective projections for future human development. Figure 7 shows the importance of basing policy on scientifically legitimate recommendations to public offices and stakeholders. Prioritizing risks based only on data for a potentially biased selection of variables is a negligent approach in terms of scientific and operational relevancy.

Identifying social values and norms: The importance of an issue is linked to the senses—the stronger the sensory response to an issue, the greater the importance attached to the risk and issue. For example, garbage is visible and piles up; dust from the quarry and cement plant makes people cough and covers the surroundings with easily visible fine brownish dust, depending on the wind direction; broken or blocked sewers and water pipes create overflows and strong smells, as do poultry and pig farms.

The issues identified are mostly those that should be resolved by the state: It is just as revealing to consider the potential issues that were not raised during the interviews. Although the impact of periurbanization was highly apparent during the field phases, as also noted by Bouraoui (2003), Weber and Puissant (2003), Drissi (2008), Meddeb (2009), no issues relating to periurbanization were mentioned during the survey (except construction rubble as a form of human waste during one interview). Problems with garbage collection, which is seen as a fundamental service that the municipality should provide, were mentioned first. On the other hand, and paradoxically, the dust from the gigantic slag heaps that had been in the region for 120 years even before independence was only mentioned after the garbage issue. Transportation issues were not raised at all. One may hypothesize from this that the issues pointed out by the interviewees include a *regalia* component, i.e., they are not only manageable but they are services that are expected to be performed by the local or national government. Problems with these services are indicative of an absence or, at the very least, a weakening of the state's regulatory and protective power. Paradoxically, the previous regime was considered by the interviewees to have been "effective" at maintaining these services. Therefore, given the postrevolutionary context, concern about the effectiveness of the state appears to be a significant influence on the qualitative evaluations performed by the interviewees: the efficacy of the state seems to be more of a concern than the environment in this region.

Conclusion

There are various advantages of PBRM: it provides quick results compared with other socio-anthropological tools, and it highlights a broader range of factors for further investigation compared with biophysical investigations. It represents the first step (the identification of relevant parameters) before investigating any socio-anthropological or biophysical factors in detail. In the study area considered in the present work, it highlighted environmental issues that had not previously been quantified or mapped. This is the main advantage of PBRM: it flags up previously overlooked but nevertheless important issues. It raises questions to be answered rather than answers to be proven.

The results yielded by PBRM cannot be proven unless some of the issues identified by it have already been assessed in other analyses. We did not find any mapped and quantified variables equivalent to those highlighted for Mornag plain in the present survey, further underlining the need to investigate the issues raised by PBRM (acting as a whistleblower) fairly, extensively, and objectively.

Therefore, methodologically speaking, the PBRM performed here can be improved: more interviews should be performed and assessed to achieve better population coverage. Indeed, the same is true of the vast majority of social investigations, which face funding gaps and constraints, especially in developing and middle-developed countries such as Tunisia. Pausing investigations until sufficient funds become available to investigate all risks and issues means that, realistically, nothing will be assessed and those risks will be hidden, intentionally or not. Of course, PBRM is not a panacea, but it reveals interesting parameters for characterizing a territory: The results it provides, even approximate, may encourage a better articulation between biophysical and social investigations, both of which having little justification when conducted alone. Especially for issues such as socio-environmental risks, this approach could have a huge impact. While the population of Mornag plain is concerned about failures of the state to perform its duties efficiently and provide security, "digesting" the complexity of reality by hierarchizing vulnerabilities, risks, and nuisances according to explicit criteria is the task of environmental and social scientists as aides to public stakeholders, not the task of the stakeholders themselves. Pleading for an action-oriented but scientific methodology is a stake not to be thrown in the wind.

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Compliance with ethical standards

Conflict of interest We state that we do not have any known conflicts of interest.

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