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Some like it complex: building a common multidisciplinarity background from local experiences within the South-Mediterranean environmental research communities

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This article addresses the difficulty of introducing and establishing multidisciplinarity in environmental research within and among the South-Mediterranean environmental research national communities. Moreover, this work attends to assess the internal and external structural factors treating such complex issues in rural, urban, and peri-urban contexts as well as the connections and dependencies of these factors. Throughout a series of programs, projects, and actions that involved scientists and scholars from Algeria, France, Lebanon, Morocco, and Tunisia, some common patterns can be observed despite notable differences in environmental and political contexts. Thus, the main common issues involve funding matters (budget reductions and less versatility), administrative and social hierarchy, relatively small connections with public services and community representatives, and finally the reluctance shown by many researchers to make data available for the community. Nevertheless, the fact that national and international (Arabic and French speaking sphere) researcher's communities have progressively built mutual knowledge thanks to different collaborations is a major

achievement, sustaining multidisciplinarity in environmental research. Indeed, this allowed the elaboration of sustainability metrics, demarches, and procedures for assessing environmentally and socioeconomically complex issues.

KEYWORDS

South-Mediterranean shores, multidisciplinary research, national research communities, research program history, rural-urban environmental issues

Introduction

Mediterranean shores are among the most fragile and degraded biomes on Earth, mainly due to (i) the geographical situation, as they are often at the edge of arid areas, and play a major role in the distribution of natural resources, and (ii) the long history of human use of local resources and occupation that has shaped current ecosystems. Indeed, historically Mediterranean areas suffered an early neolithization (east Mediterranean areas) as well as many great phases of landscape anthropization (especially during the Bronze Age and the Roman-Byzantine periods), resulting in the diversification of agricultural activities (mainly deforestation, cultivation, and grazing), which had major environmental consequences. Many of these activities led to soil transformation, impacting the whole land cover and hydro and morphosystems and, therefore, all the biophysical components of socio-ecosystems (SES). Consequently, this approximately 10 millennia of anthropization, especially the last two centuries, has negatively impacted the resilience of the Mediterranean SES, mostly the southern areas currently situated in the arid/semi-arid areas (Massuel and Riaux, 2017; Mekki et al., 2018; Ouin et al., 2022). For this reason, it is essential when studying the Mediterranean environment to acknowledge the following points:

- Because of the impact of long-term anthropogenic factors, every landscape is deeply anthropized, thus there is no "unperturbed/natural" environments present in this area.
- According to the first point and even if the SES concept is initially originated from a mostly biophysical point of view and following Stojanovic et al. (2016) or Saqalli (2020), the study of present-time environmental components and SES implies considering anthropic actions and motives (including demographic and socio-economic) as the most important environmental driver by far;
- Even more, while all preindustrial farming systems included a city where food surplus and cash crops were concentrated and consumed, ancient SES from Middle East and Mediterranean shores are mostly organized around and defined by dominating cities and urban fluxes and drivers, with their hinterlands, although rare (inland Spain, Morocco, or Turkey) avoiding this structural pattern (Grigg, 1974; Mazoyer and Roudart, 1997). Consequently, all shoreline Mediterranean SES are *de facto* also urban in their nature, structure, and dynamics. Research programs working on them should be settled accordingly;
- Finally, applied socio-environmental research does not mean to study each environmental risk, threat, or nuisance separately. One may see that these risks are often prioritized according to the ease of their studies (easy-to-measure data and simple procedures) rather than their local characteristics. It shows the need for a formal methodology to evaluate and compare socio-environmental issues. This means that applied research must include socio-environmental issues in order to deliver effective advice to stakeholders in terms of environmental management and land-use planning regarding sustainable development challenges.

Furthermore, these systems are evolving rapidly: climate change has already greatly impacted Mediterranean shores (Lelieveld et al., 2012; Malek et al., 2018; Lionello and Scarascia, 2020), especially in very urbanized areas where the combination of extreme events, particularly droughts and extreme heat waves, as well as the urban heat island phenomenon, can increase the vulnerability of the concerned populations (Cartalis et al., 2001; Houet et al., 2014; Masson et al., 2014; Bartholy and Pongrácz, 2018; Badaro-Saliba et al., 2021). Coastal areas are indeed exposed to environmental pressures regarding natural resources (water, soil, or biodiversity) and hydro-climate fluctuations, even if some trends indicate that desertification is not the sole future of the considered areas (Malek et al., 2018). As an illustrative example, Lebanon and Algeria coastal areas have undergone over the past decades an uncontrolled positive urban sprawl rate (Faour, 2015; Rabehi et al., 2019), resulting in high environmental pressures threatening valuable natural habitats such as coastal wetlands (Aitali et al., 2022), and the quantity and quality of available natural resources such as coastal water aquifers (Mitri and Gitas, 2011). Altogether, geopolitical instability, demographic growth, and urban expansion are undeniable vulnerability-enhancing factors threatening and pressuring natural resources, creating only a very thin buffer to withstand future shocks and threats. Because of this ancient environmental anthropization and the geographical position of the Mediterranean region (at the margin of various climatic systems; Alpert et al., 2005), the related habitats are extremely vulnerable to both human pressures and hydro-climatic fluctuations. For instance, despite being a natural phenomenon of the Mediterranean dry season, the combination of human pressures and extreme meteorological events such as summer droughts has made the Méditerranée the most impacted region worldwide by forest fire hazards (Mhawej et al., 2016). In France, about 4,040 forest fire episodes were recorded over the Mediterranean coastline between 2017 and 2018 (BDIFF). In Greece, following the 2021 events, most of the burned areas were classified as vulnerable to water runoff (Evelpidou et al., 2021), hence exposing the neighboring urbanized areas to floods and debris flow hazards during winter storms

events. However, one of the main environmental and economic consequences of forest fire is the reduction of the crop potential of impacted areas, which leads to serious societal crises, including diplomatic incidents (Greece and Turkey in 2020 or Algeria and Morocco in 2021).[1] Hence, the direct impact of drought events on natural resources (water and soil mainly) means it is safe to consider a tangible influence on food prices in the future if the frequency and intensity were to increase. Major social instabilities are therefore to be expected as the Arab spring insurgencies in 2010 directly linked to a food price inflation related to a severe drought episode (Maystadt et al., 2014).

This drought/fire example illustrates both the imbrication of dynamics where human and environmental dynamics are intertwined and the legitimate and genuine difficulty to manage such issues as a public institution. Indeed, SES, especially those that are very anthropized such as the Mediterranean, are difficult to characterize because of the systems' complexity involving many components all interacting with one another. To understand and study such complex systems requires taking into consideration both biophysical and social indicators in a well-organized multidisciplinary scientific approach, yet to be built (Rouchier and Requier-Desjardins, 2000; Schmidt-Lainé and Pavé, 2002; Metzger and d'Ercole, 2009; Hamel, 2010; Marignani et al., 2017). There is a tremendous amount of literature regarding the inherent multidisciplinarity to be considered for assessing research programs on such socio-environments. However, formalizing the demarche faces the obstacle of formal definition among the various terms of pluri or multidisciplinarity, interdisciplinarity, or transdisciplinarity until these "endless" typologies, classifications, and hierarchies (Graff, 2015) collapses on themselves, especially regarding the relation to sustainability. Indeed, several attempts to systemize the definitions did face contradictions, as nuances are difficult to estimate estimate (see text footnote 1) (Brewer, 1999; Lélé and Norgaard, 2005; Chettiparamb, 2007; Jacobs and Frickel, 2009; Klein, 2010, 2017; Alvargonzález, 2011; Lam et al., 2014; Nicolescu, 2014; Brown et al., 2015; Frodeman et al., 2017). As a result, we will use as a common minimal ground with the word "multidisciplinarity" as that implies more criteria but on which no consensus has been established yet.

But the challenge is definitively not only epistemological: development stakeholders and public administrations have to establish and defend integrated environmental policies, implying a politically risky prioritization of issues and objectives. These are undoubtedly, especially in these Mediterranean shore environments, singularly challenging. Apart from influences from various economic operators, which do exist and should be acknowledged as having a major influence over public choices, collaborative scientific approaches for untangling the complexity of environmental issues are therefore essential to provide decision makers with advice and data and at least promote virtuous practices and combat *de facto* easy-going policies. However, researchers still avoid proposing such prioritization procedures as they are firstly diagnostic and doubt providers. Environmental public policies need response-providers, orientating them toward the consulting expert communities. Indeed, these lasts provide quick and direct-to-action results since they usually detach themselves with the constraints of a robust scientific approach and propose turnkey policies.

The question is, therefore, is it only an epistemological and conceptual issue opposing different schools of methodology and practice? Is it primarily an institutional and political issue within research communities, even before considering the political aspect of policies? Why is it extremely difficult to build a structured multidisciplinary research community?

In order to answer these questions, we suggest exploring how previously evaluated public research programs on environmental issues have addressed such challenges. Therefore, by reporting an apparent disparate series of research programs (in which the authors have been directly involved), this article aims to characterize the development of the combination of procedures and indicators on socio-ecological issues.

The objective of this article comes from a series of social experiences within the environmental academic and public service communities and, to be precise, the pursuit of several research programs that built communities of research around sustainability in three Arab countries along the Mediterranean shores, namely Lebanon, Morocco, and Tunisia. Assessing these research programs has been promoted as improving environment research, multidisciplinarity, and cooperation between both North and South and between southern countries. We then question whether these de facto social experiments were positive. If not, what were the obstacles and constraints to such objectives? If so, how was it possible and what experience can we gain from them?

This paper focuses therefore on a reflection on practices aiming at a multidisciplinary approach on research, where it can help in setting-up objectives and being accepted by all scientific communities. Moreover, the need to work on inclusive indicators will be assessed from the growing necessity in research projects to link their results with socio-economic and health situations. Consequently, for the study and understanding of SES, the focus will be on the development of new methodologies for establishing environmental indicators rather than simple technical notes provided on each environmental component separately. Discussing these common trends and obstacles and formalizing the sociological- and institutional-encountered barriers during these experiences may then provide some conclusions and implementation suggestions regarding not-so-obvious integrated and multidisciplinary research.

These questions are not only management issues, as they reveal political, socio-economical, and geopolitical issues of these countries, but also epistemological, presenting obstacles one may face in such socioenvironmental issues.

Materials and methods

Several case studies are here explored and results are obtained as *a posteriori* analyses of these cases. Following the participatory observation demarche as formalized by Olivier de Sardan (1995, 2000, 2001) and questioned by Van

1 Even more, we clearly state against the use of "Indisciplinarity", as it is more of a slogan referring to both a rebellious teenage ambiance and the "when-you-want, you-can" corporate start-up verbiage than a real concept.

Asselt and Rijkens-Klomp (2002), one may consider that field qualitative observation methodologies can adapt to special configurations of strategic group dynamics, institutional contexts, and connections. Consequently, the various case studies do have various methodologies:

SICMED multidisciplinary seminar analysis

Context and purposes

MISTRALS was a 10-year multidisciplinary research program supported by the most important French public research institution (CNRS) to sustain an integrative approach for the study of the Mediterranean socio-ecological systems (Voltz et al., 2018). The program included seven research components including SICMED.[2] The scope of the research was on the interactions between environmental components (water, soil, sea, and atmosphere) with societies. The study area concerned four French-speaking Mediterranean countries (Algeria, Lebanon, Morocco, and Tunisia) and thus opened great collaborations between French laboratories and local research centers and universities.

Moreover, thanks to a series of eight-year-funded actions within the MISTRALS program, the SICMED research community was able to develop solid multidisciplinary approaches involving members of every concerned country (50 members, mostly from France, Lebanon, Morocco, Tunisia, and Algeria as a guest country). During this workshop, many exchanges and collaborations including scientific proposals, field missions, student supervisions, and scientific publications has allowed SICMED researchers from different fields to learn how to work with each other and, thereby, SICMED projects were able to benefit from a true and solid base for scientific multidisciplinary collaboration. The scientific background of the 50 workshop participants (41% Tunisian, 22% French, 15% Moroccan, 11% Lebanese, and the rest Algerian, Armenian, Spanish or Italian) were from social, water, agriculture, environment, and geo-sciences.

Following the prospects of the SICMED2 meeting in Marrakech, Morocco (11/2017), the objective of the 11/2018 workshop on "Governance and Indicators" in Hammamet (Tunisia) were to bring out scientific perspectives exploring thematic, disciplinary, spatial, and temporal boundaries in order to emphasize the research toward a multidisciplinary and multiscale scientific approach. Following this perspective, the purpose of the seminar was to assess complex issues about environmental risks and threats on country and local spatial scales. All the researchers were divided into four groups following their disciplines and nationalities in order to emphasize an objective and distanced point of view.

To each of these four working groups (WG), the following were included:

1. One country representative, i.e., an academic qualified enough to be able to describe and collate all environmental issues (risks and benefits) of the country. However, because of some logistic problems, only three countries were represented, namely Lebanon, Morocco, and Tunisia;
2. A "club of Interviewers" composed by all the nationalities at the exception of the concerned country was included in each WG as investigators. Following this perspective, only Moroccan, French, Algerian, and Tunisian scholars were interviewing the Lebanese representative for instance. Furthermore, the investigators were distributed to cover the maximum number of disciplines—including one social scientist for each session;
3. One observer was designated in each session to take notes on the asked questions, the debate, and the provided answers by the country representatives.

The questions to be addressed during these sessions were open and related to scientific or socio-economic issues which require a multidisciplinary approach and/or a change of spatial scale in order to establish scientific approaches which go beyond thematic boundaries. The assessed problem was "could we consider that grouping non-national experts to interview local ones can ease the diagnosis over socio-environmental issues"? The workshop was conducted in two phases:

Working group phase

According to the Hammamet workshop thematic, researchers/workers were asked to think/design/build indicators which had to (1) illustrate aspects of at least two disciplines and to (2) allow researchers, evaluators, and stakeholders to make sense of the representations/models they adopt for analyzing, describing, and evaluating research sites they investigate in their countries. Hence the following recommendations were given to workgroups for creating multidisciplinary indicators:

1. Settling criteria for evaluating the quality of the then-built indicators.

    a. Usefulness: practicality, measurability, coverage, accuracy, synthetic.
    b. Social relevance: understandable, practical, generic, illustrative.
    c. Sensitivity/robustness.
    d. Multiplicity of target groups: public services, associations, foundations, NGOs, agencies specific programs, general public.

2. Targeting the right groups and stakeholders: public services, associations, foundations, NGOs, agencies, programs, general public.

In order to make the indicators' formulation approach generic across different countries, it was recommended to the participants to identify for each investigated site and within each relevant discipline the following components:

- Type of data: surveys, *in situ* data, images, maps, etc.
- Spatial scale & resolution: experimental plots, farm, watershed, etc.

2 Surfaces et Interfaces Continentales en Méditerranée: Continental Surfaces and Interfaces along the Mediterranean Sea.

- Temporal scale & resolution: intra-annual, inter-annual, decades, etc.
- Social scale & resolution: city, village, families, etc.
- Analysis methodologies: type, calibration, validation, etc.

Project SICMED indicators

Following the 2018 Hammamet seminar, a call for funding for small projects concerning the construction of combined qualitative and quantitative, socio-economic, and biophysical indicators has been launched. This was named PSI program (Project SICMED Indicators) with a two-fold objective:

- To pursue the dynamics of constructing an international research community following the above-described 2018 Hammamet conference;
- To develop but also to investigate whether this approach of multidisciplinary combination of parameters into meaningful and efficiency-driven indicators has been imbued and percolated within the community;

This call was settled with several conditions in order to encourage multidisciplinary work and also to reduce structural and recurring biases:

- The total amounts of funding were low, between 2.5 and 3 k €, and the project was restricted to a 1-year action, mostly because of administrative reasons. However, the applicants were helped because it alleviates the administrative costs and management time for such actions;
- The proposed actions may support/accompany ongoing projects or actions in order to facilitate the submission of projects and not to focus on innovative/new/disruptive research actions;
- Partnerships between researchers and public or parapublic operators were encouraged in order to foster empirical and public service-oriented projects;
- All disciplines and actions regarding socio-environmental risks, hazards, threats, and nuisances can be considered, but the more disciplines in the project the better. However, the inclusion of biophysical and social sciences topic research was mandatory.

The Bouregreg River and dam program

Issue

Over the last decade, several research programs in Maghreb have tried to increase the state of knowledge on the relationships between human activities and sediment transport modifications from upstream to downstream, including the sedimentation in the reservoir of dams on several of the larger rivers. This issue is vital and strategic in this region because of the direct links with the reduction of the volume of water stored in dams and therefore of the socio-economic value of these facilities. The large number of dams built in Maghreb (Remini et al., 2009) is linked to the very high stress on potable and irrigated water in this area under the Mediterranean and semiarid climate (Mahé et al., 2013). Understanding and documenting the morphodynamical characteristics of the territories in order to develop mitigation measures to prevent land erosion and sediment accumulation is therefore one of the main environmental challenges in Mediterranean countries. In addition, the accumulation of sediments in dams consistent with the diminution of riverine charges and material deposition downstream may contribute to increasing the vulnerability of coastal areas to erosion and coastline retreat in a climate change and sea level rise context, as the quantity of sediment reaching the coastline is no longer sufficient (Amrouni and Mahé, 2021; Hzami et al., 2021) due to the siltation in dams (Vörösmarty et al., 2003; Syvitski et al., 2005).

However, in most Mediterranean countries, river sediment fluxes are not measured on a regular basis, no dedicated international observatory has been established to conduct regular data collection, and there is a lack of spatial data to support these actions. Rare database establishment attempts are based on individual data collections (Meybeck and Ragu, 2012; Peucker-Ehrenbrink, 2018) with important gaps. How can the real impact of dams on sediment transport from the watershed to coastal areas therefore be assessed?

In 1974, the Sidi Mohammed Ben Abdallah dam was built about 20 km from the coastal area on the Bouregreg River, one of the five largest rivers of Morocco, exclusively for providing potable water for the largest conurbation of the country, extending over approximately 150 km on the Atlantic coastline. In 2005, the facility was upgraded to increase its water capacity to more than 1 billion cubic meters. The river exposes a very modest mean annual discharge of $23 m^3.s^{-1}$ and the important storage capacity of the dam has a direct impact downstream on water flux. The dam has contributed to a significant reduction in the amount of water and sediment delivered downstream for nearly 50 years but to an extent that has not been quantified/measured (El Aoula et al., 2021). Is it therefore possible to understand and foresee the impacts on the amount of sediment reaching the sea at the river mouth of the Bouregreg?

Step-by-step methodology

In Maghreb, several research programs have been dedicated to understanding sediments fluxes (erosion, transport, and deposition) in watersheds since 2010 in a multidisciplinary research framework. All these programs were supported by the same French/Mediterranean 2010–2020 MISTRALS SICMED program funded by the French CNRS Institute of Universe Sciences. The first phase concerned, among other rivers, the Bouregreg River (Mahé et al., 2013).

1. The first step was to raise and better define the focus on which the SICMED 20-person scientific community would gather. This was based on a preliminary assessment to verify whether the level and distribution of required data was sufficient. Every expert, in their specific field, was questioned by other specialists on the requirements (main gaps) of their field, first on the data needs, then on the scientific priorities, and finally even on the vocabulary used, until a final set of databases

was considered mandatory to implement. In practice, this task was achieved through a common meeting and field trip to the basin, breaking the social glass.

2. Multidisciplinary exchanges were an important asset in the second step in the formalization of the scale and resolution of the common study in order to find a compromise between resolution thresholds (the resolution of data coverage) and the variables to be selected as sufficient to characterize a problem (Tra Bi et al., 2013, 2014).
3. In a third and final step, a parallel and more systematic measurement campaign was assessed by the Bouregreg river basin agency and the research project teams on sediment fluxes and surface erosion in the watershed surface.

The Franco-Lebanese multidisciplinary collaborative laboratory: O-*LiFE*

A historical reconstitution demarche: The study here is an a posteriori analysis of the rationalities of the project: firstly, on the choice of the country and the institutional approach. Collective and informal discussions regarding these rationalities were settled during several seminars throughout the project or other collaborative ones, such as the ones described above, from 2018 to 2022. This occurred before and throughout the COVID-19 pandemic and so institutional, diplomatic, practical, logistic, and financial rationalities affected the project construction and purposes. The second and longer step was a reconstruction of the history of the program and its various institutional forms across time, including the different constraints, obstacles, and reorganizations the project had to face and construct for adapting itself to the evolving socio-academic context of Lebanon.

Results of the studied cases

Multi-issues SICMED seminar

WG outcomes were first combined to generate thematic sustainability indicators common to a majority of sites. After this step, in order to evaluate site-specific sustainability, the generated indicators were assimilated to each investigated area. The restitution phase resulted in the obtainment of sustainability indicators common to different sites (Table 1).

The multiplicity of disciplines involved in each site-investigation on previous or ongoing projects pushed the participants to subdivide the indicators into more specific sub-indicators. As these were defined during country-specific sessions, they can be either specific to locations, hence implying different ratios and measurements according to the site, or else be common to several sites. The sub-indicators were then evaluated in agreement with their usefulness, their social relevance, and the multiplicity of target groups for which the sub-indicator would be particularly useful. In the interest of building a common measurement system following Porter et al. (2006) and Hamel (2010), a very basic score assignment was proposed during the sessions in order to evaluate all indicators and sub-indicators according to three sub-criterions (0: indifferent, 1: good, −1: bad). During the restitution phase of the workshop, seminar animators and managers presented an example of a score assignment on one indicator (Table 2).

The example exposed in Table 2 illustrates a simple method to determine an overall score for a given indicator. Participative research as a principle should be positioned at the bottom of the Arnstein (1969) following Van Asselt and Rijkens-Klomp (2002). This will be useful to target the indicators to be developed or monitored in priority.

- A post-seminar follow-up was assessed by sending all participants a long Excel table which covered all the disciplines that were included as part of the SICMED socio-environmental issues through indicators with the hope of combining them into multidisciplinary ones. Nevertheless, very few answers were obtained during the first 2 months, since some respondents clearly stated a short time frame to meet all the planned objectives.
- Global results of the seminar raised the issue of the equitable/equal representativeness of the scientific community since, for instance, hydrology was the dominant field in terms of themes proposed and of number of researchers/experts. Water thematic was therefore dominant and described as a main biophysical issue during the workshop due to the fact that scientists tend to stick to their discipline (hydrologists among themselves and sometimes soil scientists and climatologists, agriculture, and economics, etc.).
- The animation team noticed the difficulty encountered by the participants during the session to distinguish between a socio-environmental indicator and a variable that may be directly measurable or not on the field. A socio-environmental indicator is a result which provides an insight to the state and dynamics of a socio-environmental issue clearly understandable by the general audience (for instance the water availability per capita and per day) and/or an environmental measurement (water depth obtained for a piezometer) and a variable that can be measured or not (water of a local groundwater layer). On a more epistemological point of view, the attempt to propose an analytical way (i.e., distinguishing variables of an issue) for apprehending a systemic issue is not easy. Indeed, some variables are well-characterized but difficult to establish in a quantitative way, such as subterranean or nival contributions to many Mediterranean watersheds. Some elements may be known as separated but one may find covariances or mutual influences such as the demography-resources nexus. Some parameters may be hidden or blurred or inductively defined such as the hypothesis of "religion" or "culture" for explaining what seems to be irrational or misunderstood behaviors (Hofstede, 1983; Bredillet et al., 2010; Rees-Caldwell and Pinnington, 2013). And so on for even more fuzzy and hard-to-distinguish variables.
- Finally, the outcome was hardly of a concern for the overall community, mostly because the combination of many indicators, intended to be exhaustive as a goal, was somehow difficult to comprehend for the community. Indeed, most environments assessed in Maghreb and Lebanon are facing very different risks, nuisances, and environmental threats, which complicates the construction of indicators and the process of priority hierarchization.

TABLE 1 The 10 indicators sorted out as necessary during restitutions of the four Hammamet sessions.

	1	2	3	4	5	6	7	8	9	10
Indicator	Water exploitation rate	Water quality	Water social value	Health	Water governance and Information	Ecosystem vulnerability	Water economic value	Anthropogenic Pressure/Human Impact on Water	Biodiversity	Landscape

TABLE 2 Example of one indicator of one Action: Indicator 1.

Sub-indicator type		Usefulness	Social relevance	Sensitivity/ robustness	Multiplicity of target groups
Surface water that can be mobilized	Hydro-climatic data	(1,1,1,1,1,1)[a]	(1,1,1,1)[b]	(1)[c]	(1,1,1,1,1,1,0)[d]
	Evapotranspiration by remote sensing	(1,1,1,1,1,1)	(1,1,1,1)	(1)	(1,1,1,1,1,1,0)
	Dam siltation	(1,1,1,1,1,1)	(1,1,1,1)	(1)	(1,1,1,1,1,1,0)
	Models (e.g., WEAP)	(1,1,1,1,1,1)	(1,1,1,1)	(1)	(1,1,1,1,1,1,0)
Ground water that can be mobilized	Hydro-climatic data	(1,1,1,1,1,1)	(1,1,1,1)	(1)	(1,1,1,1,1,1,0)
	Evapotranspiration by remote sensing	(1,1,1,1,1,1)	(1,1,1,1)	(1)	(1,1,1,1,1,1,0)
	Groundwater recharge	(1,1,1,1,1,1)	(1,1,1,1)	(1)	(1,1,1,1,1,1,0)
	Models (e.g., MODFLOW)	(1,1,1,1,1,1)	(1,1,1,1)	(1)	(1,1,1,1,1,1,0)
Mobilized surface water	Agriculture surveys	(−1,1,1,0,0,1)	(1,1,1,1)	(1)	(1,0,0,0,0,0,0)
Mobilized ground water	Agriculture surveys	(−1,1,1,0,0,1)	(1,1,1,1)	(1)	(1,0,0,0,0,0,0)
	Illegal boreholes	(−1,1,1, −1, −1,1)	(1,1,1,1)		(1,0,0,0,0,0,0)
Partial scores of indicator 1		(5,11,11,7,7,11) Total = 52	(11,11,11,11) Total = 44	(11) Total = 11	(11,8,8,8,8,0) Total = 43
Total score of indicator 1		(52 + 44 + 11 + 43)/(66 + 44 + 11 + 77) = **76%**			

Water resources exploitation rate for AMETHYST project for both sites of Tensift (Morocco) and Merguelllil (Tunisia).
[a]Usefulness: Practicality = 1, Measurability = 1, Coverage = 1, Accuracy = 1, Synthetic = 1.
[b]Social relevance: Understandable = 1, Practical = 1, Generic = 1, Illustrative = 1.
[c]Sensitivity/Robustness = 1.
[d]Multiplicity of target groups: Public Services = 1, Associations = 1, Foundations = 1, NGOs = 1, Agencies = 1, Specific Programs = 1, General public = 1.

As a partial conclusion, such a seminar might be considered as a failure but, because of the involvement of many researchers from different disciplines, it can also be considered as a success from a sociological perspective. Indeed, one of the main challenges was the mental burden mainly due to "results" obligations in a research context of data-scarcity and lack of administrative and logistic supports, added to the fact that, for the educational context, the structures rarely met the needs of the growing number of students. In light of that, the working groups had coordinated their efforts to overcome the issues enhancing the scientific collaborative aspects in their works.

PSI: using a call for small projects to investigate academic perceptions

Over the two calls (2019 and 2020), 13 projects were submitted, of which eight projects were selected, meaning a 61.5% ratio of success. We here consider all the submitted projects to be representative of the above-described community on multidisciplinary methodologies. Nevertheless, were all the projects apprehended and considered useful? Figure 1 shows an overall representation of the projects according to three criteria:

a. The scientific disciplines involved
b. The number of disciplines involved per project
c. The distribution of planned and funded tasks

Five countries were involved in this program: France (Island of Corsica), Tunisia, Morocco, Algeria, and Lebanon. Figure 1a exposes the fact that the program mainly concerned hydrological issues. Indeed, due to the fact that serious ecological crises related to water had occurred since the independence of Maghreb countries and Lebanon (for instance, the 1973–1983 drought period in Maghreb), water issues were quickly acknowledged as serious and even vital at all levels and sectors of the society and the state, from public infrastructures to scientists (Taleb, 2006; Kuper et al., 2009; Hamrita et al., 2017). Furthermore, demographic growth, great and progressive changes in consumption and habits, and an average increase of incomes and urban transition had also impacted the environment (Sebti et al., 2009). Thereby, the most used spatial scale of study was the watershed.

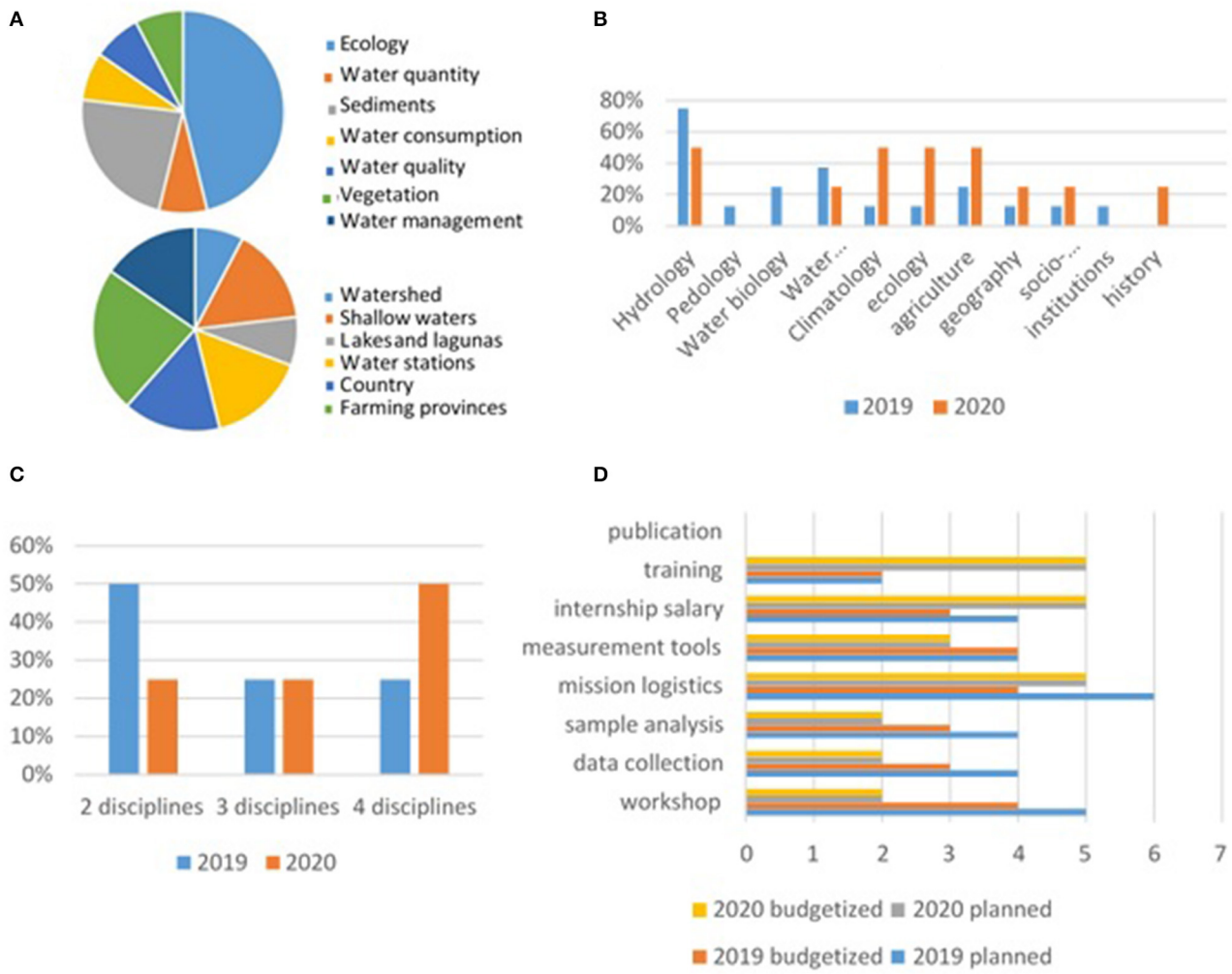

FIGURE 1
Distribution of PSI projects according to issues and scales, disciplines involved, number of disciplines and tasks. **(A)** Distribution of PSI projects according to scientific issue and scales, **(B)** Distribution of PSI projects according to disciplines, **(C)** Distribution of PSI projects according to the number of disciplines per project, **(D)** Distribution of PSI projects according to the actions planned to be funded.

This situation has directly impacted the involved disciplines (Figure 1b), leading to an overrepresentation of themes related to hydrology in the projects submitted in both 2019 and 2020. The call procedure did consider this tendency and promoted a formal balance between disciplines. Finally, actions tasked and applying for funding were mostly operational elements, especially student internships, logistics, materials for field measurements, etc. This statement is directly related to two major challenges in academic research: the overall lack of funds which characterizes less-endowed research budgets and the specific lack of recurrent and easy-to-get small funds, i.e., funds that do not need long selection procedures. These two points are frequently used to justify long-term and community-based research programs that can last over 10 years. It allows research to be planned in stages over several years, which in practice becomes extremely difficult around the Mediterranean Sea and especially on its southern shores.

At the same time, the research follows a very stable methodological framework which includes measurement campaigns and debates among experts before the diffusion of the work. It is important to notice that, paradoxically, all projects were settled from academics and cities toward rural areas. Except for one project, cities are seen as not affected by projects perceived as mostly dedicated to rural areas and issues, as if there is no direct connection between them. All the issues raised in the projects mainly concern rural areas and one project planned a workshop ex ante in order to identify the environmental issues which need to be studied according to the rural stakeholders. The rest of the projects (6) had workshops planned ex post because of time constraints. Finally, nine projects out of 13 did plan biophysical investigations along the dominant watershed perspective, and only two projects were defined according to (partially) socially-defined units, i.e., agricultural regions.

In practice, the action was wronged and/or lost a part of its credibility because of both the COVID-19 period and the accelerated end of the program funding by MISTRALS SICMED, 2 years after the launch of the program. However, the researchers from the different countries involved in the SICMED program were well aware of the program funding issues because of their good knowledge of the institutional and organizational aspects of research policies. One researcher stated that the Indicators initiative

was considered as a comet tail which means an attempt at the end of the program to try out innovative or original approaches.

The Bouregreg: understanding of the impact of dam structures on dam shores

Results

1. The first step was effective: all expert teams did agree to involve themselves in this not-so-obvious participatory process and exchanged descriptions on how they read and analyzed the environment according to their disciplines, which also helped the whole team to better know one another on a personal level. It was a key moment for the whole program as all the experts had the opportunity to learn different points of view on things they were used to studying according to the perspective and criteria of their own discipline;
2. The second step provided several compromises: a cross-assessment of multiple sources of data (meteorological data) allowed (Goussot et al., 2014) to explain the discrepancies between remote sensing land-cover analysis and cereal production variability over time. Another example concerns the acceleration of the gully erosion phenomenon on the banks of the dam. For some decades the issues were poorly understood by physicists until geographers and historians exposed the fact that, by pushing out the local population after 1920, the French colonial power strongly influenced the industrialization of local agricultural and pastoral practices, thus enhancing the vulnerability of the land surfaces to gullying. The major changes in land cover led to the amplification of surface runoff, which ultimately triggered the gullying of the banks, without any major changes after independence in 1956 (Goussot et al., 2014). As a result, on a local scale, the kinetics of local processes was undoubtedly much higher in this area in comparison to the rest of the basin (Laouina et al., 2010). This common reflection helped the team to identify the main origin of sediments in the dam reservoir.
3. In the third and more intertwined step, a sediment sampling campaign along the riverbanks between the dam and in the coastal zone (under the sub-tidal zone) combined with bathymetric surveys and new UAV and LIDAR technologies (Hout et al., 2020) allowed researchers to document sediment fluxes and surface erosion all along the watershed. Results were counter-intuitive: 80% of the dam sediment came from the erosion of the dam's banks and micro basins associated with and not from the river watershed as initially expected (Ezzaouini et al., 2020). Sediment discharges downstream were reduced by 80% after the construction of the dam in 1974, to the point where no more sand reached the sea. Therefore, this implies focusing future efforts on the local erosion of the banks of the dam and on the understanding of the environmental consequences of the strong decrease of sediment supply from the Bouregreg over the coastal zone.

Discussion

At the origin, the research question covered large spatial areas and involved only two disciplines, physics and hydrology. After the first year, the problem evolves and the approach becomes more focused on a local spatial scale and encompasses further scientific disciplines in addition to hydrology and physics. This evolution was possible through a combination of factors:

1. Institutional support: Long-term institutional support was mandatory. This support was provided by international agencies through the 35-year partnership between UNESCO and IHP through the FRIEND-Water program (support and development of regional capacities through workshops and training; Mahé et al., 2021), as well as the watershed basin agency in Morocco and the CNRS in France (INSU MISTRALS research program; Mahé et al., 2020). This common longstanding effort helped to envision reflections and paradoxically support radical and meaningful changes in scientific orientations, as opposed to the usual norms involving short-term projects.
2. Time: As mentioned above, the temporality is a crucial notion in the implementation of projects. Agendas must include and manage field campaigns, workshops, and seminars, which may appear time-consuming but can help to adjust visions on main issues and eventually clarify how each team will contribute to the solving of the main problem of the program (however it can lead to slight differences in the speed of production of results between different teams and fields of investigation, depending on the success of different calls, but is also a source of motivation for the involved research teams).
3. Inclusion: Reporting, meetings, and field campaigns were crucial in order to open the debate within the research community. In addition, another key point was also to keep the research team open to newcomers. In practice, the 10-year program was developed according to this line of thinking, with 15 workshops and 10 training sessions in the three countries (France, Algeria, and Morocco), accelerating the sharing of knowledge and expertise between involved teams. Inclusion, therefore, is a main factor in accordance with the formal assumption of a multidisciplinary research program based on debate and multidisciplinary approaches to the problem. Inclusion, however, is a major challenge for most research programs because newcomers are often assigned to undefined actions which are poorly integrated into the general schedule.
4. Generalization: The share of a multidisciplinary vision over the watershed is not relevant enough to validate the approach. The extension of the debate to similar issues increases its value through parallel actions in Algeria and Tunisia. For instance, results in Algeria (Hadour et al., 2021) were enhanced by surface sediment flux data (time series) from the National Hydraulic Agency (Algeria is the only country in Africa performing this type of survey), allowing a calibration between sediment cores and surface fluxes. In Tunisia (Kotti et al., 2017), the combination of studied samples from estuary and near shore areas with a remote sensing study of the coastal erosion exposed the same reduction in sedimentation after 1981 and the building of the dam of the Mejerda River in northern Tunisia (Amrouni et al., 2019; Ben Moussa et al., 2019; Hzami et al., 2021). The results also showed that beach sand dunes were in a process of intense erosion in this area due to the combined effect of the littoral dynamics and the stopping

of the arrival of new sedimentary materials (Amrouni et al., 2019).

Because similar causes produce similar effects in equivalent situations/contexts, characteristics and physical dynamics of one site may be interpreted as reliable proxies for studies of other sites.

The working environment was, however, not characterized by a complete social harmony, leading to several oppositions due to inherent structural constraints within the academic community:

- The first point was the necessity to share an important amount of data within the group and without any formal recognition and/or clarification of property or acknowledgment rights. This issue was solved by convincing several teams to simultaneously share their data (meteorology, hydrology, and geographic GIS maps), leading therefore to new collaborations;
- This difference within research groups also highlighted some hidden drawbacks. As a matter of fact, the average number of co-authors varied considerably from one discipline to another (from geosciences with usually more than 10 co-authors to social sciences with rarely more than three), constraining mutual co-authorship invitations for common publications;
- Another major but quite usual issue was the timeline of the project: no teams followed the same chronogram, adding difficulties and delays in the general timeline of the project and slowing down some teams. For instance, some teams had to wait for data to continue their program. At the end, respecting the project timeline frame was very challenging.

It is important to point out that one of the main financers, the AUF (Agence Universitaire de la Francophonie), greatly helped in the success of this multidisciplinary cooperation program. Indeed, not only did they allow to redistribute credits from different lines to others with great flexibility (allowing integration of new partners within the run of the program), but they also extended the duration of the program by 1 year, which induced many collaborations and made this period the most productive time of the program (with all teams having enough results to discuss). Moreover, this rapidly formalized the main lines of a new program, more focused on some specific topics and areas, and which were quickly funded and extended to Algeria and Morocco. Finally, a few years later, this project has become one of the major research axes of the CNRS INSU MISTRALS Mediterranean program.

Against all odds: the Franco-Lebanese multidisciplinary collaborative laboratory: O-*LiFE*, an over-ambitious project with some successes

A first component-based mandate

Initiated in 2012, the "Observatoire Libano-Français de l'Environnement (O-LiFE)" is a research observatory and platform based in Lebanon with the aim to study the establishment of a multidisciplinary observatory in a multi-challenge context such as Lebanon. Indeed, this country was chosen because it aggregates most if not all the socio-environmental issues and challenges encountered along Mediterranean shores and because the one-century-long institutional connection and cooperation between French and Lebanese research and academic institutions has helped foster collaboration, through common languages and research traditions, and there are already settled conventions for students and academic exchange and easier visa procedures. Furthermore, the size of the country (10,452 km^2) enables the possibility to directly observe the results and make spatial extrapolations but also reduces the costs of field missions and measurement campaigns. Finally, the environmental, economic, and political contexts of Lebanon are highly sensitive to climate changes, allowing the ecological and societal vulnerability of the country to increase further in the near future (Füssel, 2007).

Given the inevitability of global changes and their (already) devastating impacts on citizens, the corresponding research communities (considering that observation is etymologically and thematically essential to understanding environmental and anthropic changes) see as urgent the need to collect, perpetuate, share, and enhance the value of environmental information. Moreover, the synergy between systematic observation of the environment and modeling allows the possibility to analyze such mechanisms. However, it requires long-term spatialized data covering a wide variety of features and structured in databases coupled with spatial modeling. As a result, some researchers from French and Lebanese institutions wished to lay the foundations of a shared observatory as a first step toward a future network of circum-Mediterranean observatories. This initiative was conducted in partnership with the CNRS MISTRALS program, IRD,[3] and CNRS-Lebanon and supported by several universities in France (Montpellier, Toulouse, Grenoble, Aix-Marseille, and Avignon) and Lebanon (UL, USJ, AUB, USEK, and Balamand).[4] The approach was based on a pragmatic way to associate actors along a common action to collect and preserve environmental data in addition to defining a common body of variables.

After its initiation in 2012, O-Life network was validated as LIA[5] for the 2014–2018 period, then as GDRi[6] for the 2018–2022 period. Its missions were progressively defined firstly to face the (lack of) data availability and connection between scientists in different disciplines. During the establishment phase, three priorities were enhanced: conducting observation services, build databases and create models. Thematic priorities were, first, biodiversity, water, and environmental management before the highlighting of issues involving air and sea pollution and seismic risks over the country. Therefore, during the 2014–2018 period, O-Life was structured around four thematic axes:

3 Institut de Recherche pour le Développement.

4 Université Libanaise, Université Saint Joseph, Université Américaine de Beyrouth, Université de Saint Esprit Kaslik, Université de Balamand.

5 Laboratoire International Associé.

6 GDRI-Sud/IRN (Groupe De Recherche International/International Research Network), initially settled for the 2018-2021 period, extended to 2022 due to COVID-19 and Lebanese events affecting all the research actions: researchers' salaries decreasing, pushing them to leave or to find secondary jobs, students leaving the country, riots, etc.

- Water-LiFE: Issues related to water resources were quickly pointed out as a connection between biophysical and social disciplines (including political and geostrategic).
- Bio-LiFE: Biodiversity on the other hand was highlighted to expose the fact that it is hardly taken into consideration in Lebanon despite the knowledge that the country is part of the 10 mini biodiversity hotspots of the Mediterranean Sea.
- Geo-LiFE: The forecasting and management of seismic risk was addressed as Lebanon is subject to a number of natural earthquakes and because scientific work around this theme had already been executed but the majority of the information had stayed within academic circles and was poorly communicated to the population.
- Sea-LiFE: This component was added afterwards in order to highlight the importance of the marine environment and address issues of pollution and other anthropogenic degradation.

During this phase of the program, 40 researchers representing the 17 partner institutions (from which 14 were Lebanese) were involved in O-LiFE. The institutional organization and funding process did reflect this organization along the different themes (Figure 2A):

- The network constituted a place of debate, orientation, and consensus in which actors with various thematic and methodological tools determined together the priorities and harmonization of the means and resources available or to be sought. Indeed, the fragmented research context pushed all partners to build their own financial and research network with foreign and/or local partners. Building a place of debate was not an obvious process and we had to avoid any social competition among members and formalize all the decision processes to reassure all the partners of the network;
- Affirming external and valuable standards throughout the network: Scientific such as the Sustainable Development Objectives; Participatory with an aim to support multidisciplinary collaboration; and Environmental with the inclusion of the socio-ecosystem concept, thereby fighting both conservationist and liberal postulates (Van Asselt and Rijkens-Klomp, 2002; Cornwall and Jewkes, 2006), and bringing together all the emblematic pressures (coastline, mountains, cities, etc.).
- By labeling/supporting actions abroad and at national and regional levels, O-LiFE federated some of the requests made to international donors (large European global programs, etc.). O-LiFE was also asked to extend its experience to the Mediterranean region, based in particular observatories as "frontier" objects, between cultures, themes, methodologies, and organizations along a Euro-Mediterranean research network of observatories.[7]

Further mandates toward transversal components

Although initially effective for its first objectives pushing scientists from the same discipline but scattered across institutions and programs, this organization faced a threshold beyond which the institution itself became an obstacle. Hence the fact that the organization is strongly based on "project-orientated structuration," the global project was managed in silos to address disciplinary-related issues, themes, and research actions. The main obstacles were the difficulties to go beyond this framework of thematic divisions and also to think in a more sustainable way regarding research teams even they came from different institutions, implying therefore a more perennial establishment of the research in Lebanon. The second proposal for the 2018–2022 mandate (Figure 2A) was envisioned as carrying on the effort and facilitating these interactions by adding:

- A transversal axis, dedicated to experimental observations (Tool-LiFe with the objective to develop methods and tools), was proposed to facilitate the transition from a research-equipped structure to an equipment-based but issues-oriented structure. Practically, it is a support for instrumentation, data and information collection, storage, and sharing;
- Formal support to increase the effect of the O-LiFe label through continuous review of appropriate tenders with a focus on multidisciplinary tenders and connection between partners for drafting responses;
- A new axis: Socio-LiFe to include social issues and to answer the needs of scientists to communicate with the public and decision-makers, which should be a component of every project when needed.

This intermediate phase is reconsidered in the latest mandate proposed in 2022 for supporting a more transdisciplinary and mutual integration. All the components are to be defined and justified according to the actions to overpass the environmental component/silo approach (Figure 2B). This may be seen as a 90° shift in the diagram of the program, however, in practice it implies that the sub-managers of the program are focusing on the actions and not the environmental components, therefore encouraging future projects to be organized from an action perspective.

Questioning the efficiency of the project

After 8 years, O-LiFE was able to:

- Successfully gather a pool of multidisciplinary experts in the various fields of biodiversity, water science, geo risk management, sea-based research, air quality, and social sciences. However, the main limitation of this action is that these experts are rarely consulted by Lebanese national and local actors and stakeholders;
- Develop transdisciplinary research. One of the main successes of O-LIFE is that thematic researchers involved in the project have proposed and coordinated multidisciplinary research topics;
- Include social science and integrated human impacts and retroactions. It also included a connection with national

7 Consequently, each observatory site of O-LIFE and partners in Lebanon has been the object of several monitoring campaigns from several thematic priorities (e.g. The Nahr Ibrahim watershed with Water-LiFe, Bio-LiFe, and others,), allowing different disciplines to meet on the ground.

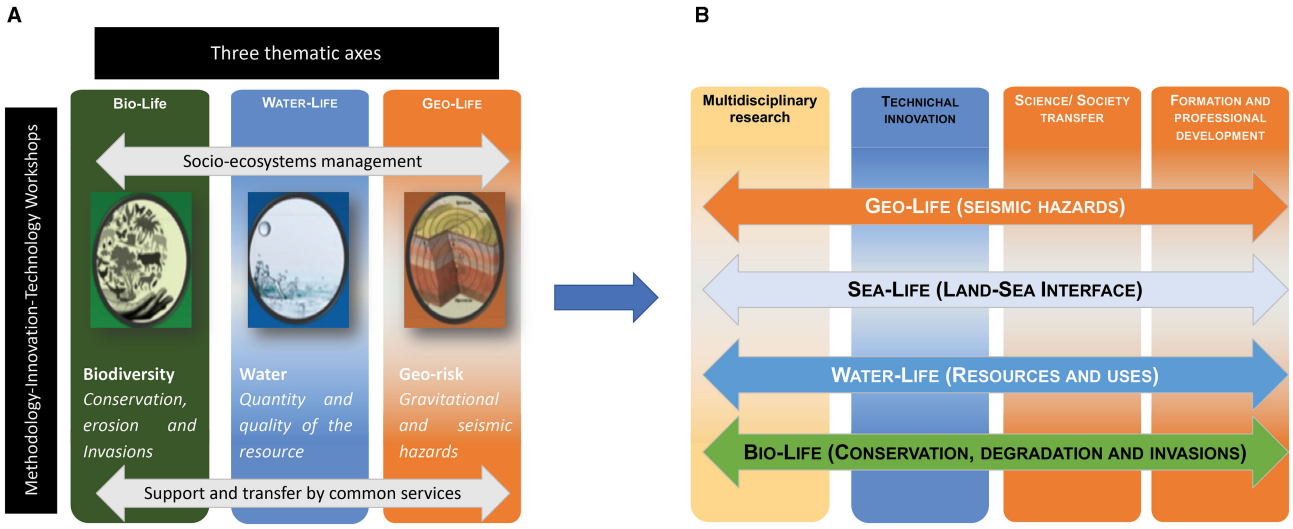

FIGURE 2
Institutional organization of O-LIFE: **(A)** 1st version of 2014–2018 then 2018–2022. **(B)** 2022-....

extension services and transferred scientific research results to the general audience through various media. This actually helped O-LiFE to be recognized as a reliable and visible research institution in environmental sciences[9];
- Act as a funding and labeling support to multilateral groups with a power of more than 300% (more than 3 US$ raised for each US$ provided by O-LiFE);
- Build a solid network of back-up, storage, and transferring tools dedicated to equipping and supporting data collection in a wide variety of areas;
- Conduct research based on approaches requesting little and often low-cost means, support the deployment of sensor networks, and facilitate studies in complex environments (either because of physical inaccessibility or because of the social and political situations in Lebanon). O-LiFE has therefore progressed toward the needs of investing into "frugal science."

Nevertheless, despite the considerable improvement in research and the building of trust within the O-LiFE team and among the partner institutions, O-LiFE failed to:

- Build a data collection system on physical and social attributes which involve the various research and teams and also to constitute a unique multi-thematic and multi-institution database which it aimed to implement. Data sharing remains therefore as one of the major obstacles to the objectives of O-LiFE;
- One of the hypotheses behind the reluctance for data sharing could be related to extremely tight competition on time and resources where researchers do not invest time to format their data in a sharable form and where no financial, publication, and institutional advantages could support this action in addition to the risk of data theft after being shared. Data sharing remains one of the major obstacles to the objectives of O-LiFE, due both to the inner research competition and to the lack of financial and institutional support for the researchers;
- Go beyond the network level to become the first network/institution to be considered by the community to join formal and successful responses to largely funded international calls for tenders but also for common publications. This is difficult for a number of reasons: obtaining funds in countries considered as "risky," the existence of other national and international networks that can provide equivalent support with other legitimacies (such as common languages or beliefs), the fact that monodisciplinary calls are much better funded especially in biophysical sciences, and finally, the effective unavailability of the French and Lebanese researchers who must respond to various responsibilities of management and publication and for some of the Lebanese members, responsibilities also in remunerative expertise missions.

At present, O-LiFe is also associated with a team spirit to be considered as a specific resource in the face of any calamities that befall Lebanon (the 2019 economic breakdown, the 2020–2021 COVID-19 pandemic containment, and the 2020 Beirut explosion). The vanishing of technical means (gas and data recorders) is aggravated by the huge decrease of the value of financial incomes and the blocking of banks. Solidarity between O-LiFe members offers temporary resources and means, small financial support, and job transfers or job offers in French laboratories to limit brain drain.

Discussion and conclusion

Representativeness of the proposed experiments

These multidisciplinary research programs were clearly not the only ones to be evaluated on the shores of the Mediterranean, and it must be recognized that there is an institutional bias as well. Even

within the framework of cooperation between France and the other Mediterranean members of the AUF, several other projects were evaluated for the interweaving of disciplines in action:

- The ANR[8]-funded TRANSMED-call AMETHYST project (2013–2017) "Assessment of changes in MEdiTerranean HYdro-resources in the South: river basin Trajectories" in Morocco and Tunisia, largely connected to SICMED and integrating socio-economic trajectories into watershed futures;
- The Almira project[9] from the same ANR TRANSMED-call (2013–2017) "Adapting Landscape Mosaics of Mediterranean Rainfed Agrosystems for a sustainable management of crop production, water, and soil resources"
- MISTRALS-SICMED ReSAMed (2010–2012)[10] and METASIM (2011–2013),[11] or even CNES[12] EVA2IRT (2013–2014), all programs orientated toward remote sensing-based hydrology modeling on the same sites in Morocco and Tunisia.

At the same time, the biggest weakness of these actions is related to their project structure: how can we capitalize on the experiences and networks once the projects are completed? This is where the value of perennial structures such as observatories and long-term joint programs becomes clear.

Formalization of multidisciplinary knowledge

Actually, many scientific problematics do not require a multidisciplinarity approach (Lélé and Norgaard, 2005; Alvargonzález, 2011; Nicolescu, 2014; Schroeder, 2022) and dividing the research themes into various pieces each attributed to a specific discipline along the analytical method is an easier way to acquire information. Academic literature and research institutions have promoted more and more detailed structures for too complex and sometimes (even often) contradictory objectives: (i) understanding complex issues such as SES ones and (ii) a more socially-orientated research for better advising stakeholders (Brewer, 1999; Jacobs and Frickel, 2009; Lam et al., 2014). The related contradictions have been described, acknowledged, and largely debated in several publications (Olivier de Sardan, 1990; Albaladejo and Casabianca, 1997; Montmain and Penalva, 2003; Cornwall and Jewkes, 2006; Bousquet et al., 2009; Lavigne-Delville, 2011). Indeed, some institutional elements are quite often observed to exacerbate these trends (Hamad, 1982; Jerneck et al., 2011; Lyall et al., 2013). There are several reasons for this, which can be clear but not always obvious:

- The first argument is honesty: Various conceptual and methodological constraints but also the sole habit induces a low use of systemic approach. Scholars and researchers often prefer a more analytical analysis which is poorly suited for the study and complex systems such as SES. In this case, methods such as multi-criteria analysis, relying on the combination of factors governing a given socio-environmental context, are therefore favored (Lélé and Norgaard, 2005; Hajkowicz and Collins, 2007). However, being able to break down an SES issue into its components is a prerequisite for such an analytical demarche: components should have been defined and classified within the system. It is therefore hidden multidisciplinarity, without assuming it. Most of the time, unfortunately, hierarchizing elements to be investigated is not explicated, formalized, nor justified,[13] helping one specialist to focus on their own specialty with the traditional and falsely honest "I focus on my domain." However, formally linking pieces together for solving socio-environmental issues is the necessary step after accumulating data: the establishment of theories from data and information previously collected. This approach (or modality of inference) is commonly called "inductive" and functions alongside a hypothetico-deductive research approach (deduction vs. induction vs. abduction) (Blecic and Cecchini, 2008, p. 539–540), and involves combining together "elements," pieces of science, according to a plan that can shed light on a question. Therefore, dealing with socio-environmental issues implies necessarily to organize and hierarchize its components; therefore, multidisciplinarity cannot be avoided to understand the structure of a socio-ecosystem;
- The second point is exhaustivity: these components are in trophic, energetic, spatial, social, political, or economic interaction/interdependency and constitute a coherent system. Each element moves in relation to another and all the components form a system. It means that results from an analytical demarche, for instance prospective and/or predictive results, are intrinsically false and/or reductive. Multidisciplinarity is by then necessary for understanding the functioning of a socio-ecosystem. However, the large debate between multi, inter, and transdisciplinarity is flawed: definitions are not always mutually exclusive,[14] lacking a common agreement on the terminology even after a debate starting in the 90/s. It is not practically operative as no one can see the differences on the field. As a response, we consider that these concepts matter because it is the way humans rationalize and act, and humans are the most powerful force in SES.[15] Defining the borders of a system is far more important and

8 ANR: Agence Nationale de la Recherche.

9 https://www.umr-lisah.fr/?q=fr/content/projet-almira

10 Recharge des Systèmes Aquifères en Méditerranée.

11 Modélisation de l'Evapotranspiration ET Assimilation de données Satellitaires pour la gestion de l'Irrigation en Méditerranée.

12 CNES: Centre National d'Etudes Spatiales.

13 Justified implies avoiding truisms such as ≪ it is well known…", "since the beginning of time…" or "this point is important".

14 Apart from the difference between multi- and interdisciplinarity, hypothesis-testing process, whatever it can be, is assessed within the discipline and the mental process of one methodologically consistent group of scientific practices (for instance social sciences) in the first term, or is assessed across such groups in the second one.

15 The problem is that humans do not order things and act accordingly in the same way, thereby justifying with this sole argument the value of social

implies simplifications (as there is no closed systems on earth in the present time). One should order disciplines, issues, and stakes and separate what is important for the study of the system and what is not. This is the fundamental element in our neologism: holodisciplinarity (Saqalli, 2020), the methodological process of building and providing arguments to establish the criteria/criterion able to establish the exhaustivity regarding disciplines and processes for the study of the system, the stake, or the issue we considered;

- The third point could be formal balance: Indeed, biophysical sciences having enough funds and more legitimacy from stakeholder audiences provides very little incentive to cooperate. Social sciences do face opposite contexts. Actually, one may consider the first two points as the methodological bedrock for acknowledging the primordial position of social sciences (with primordial in its etymological meaning: first to consider), solely because humans, the main natural force activating and transforming territories especially along Mediterranean mostly urbanized shores, are driven by social factors. One should then point out that not considering this main natural force is a bias and there are already methodological tools, such as socio-anthropological agent-based modeling (Saqalli, 2020), to combine social information, including from qualitative socio-anthropological methods, and biophysical data and dynamics, each one in its rank and with its weight. Not considering social sciences because "we do not have enough data" is not a scientific argument (Saqalli, 2020);
- The last point is efficiency: As pointed out by Bachelard (1938), the need for a change such as multidisciplinarity arises while facing an "epistemological obstacle." However, this is a necessary but not sufficient condition. It only means that a researcher from one discipline is confronted with a problem that goes beyond the "normal" science to which they belong. In practice, going beyond is not rewarding as stated above for the reason that institutional and financial rewards are by far higher and safer for a researcher if they stay in their field of competence. This explains the overall difficulty for promoting multidisciplinarity: this obstacle here implies either a constraint within each community or from outside as stakeholders encourage more operational research:

    - The inner "pull" may appear only when the first two points are not only acknowledged but also considered as mandatory for getting research funds, which is far from a reality. Unfortunately, the evolution of funds in the southern Mediterranean remain structurally low in terms of absolute values and in proportion to the economies of the Mediterranean countries (El-Jardali et al., 2012; Pouloudi et al., 2012; Ismail et al., 2013; Mandil et al., 2018). Even worse, the orientation toward "excellency" as quantified by publication and funding metrics did discourage the promotion of challenging research regarding these criteria (Laraus, 2004; Porter et al., 2006; El-Jardali et al., 2012);
    - The external "push" for orientating projects toward advising stakeholders is counterbalanced by the non-transparency wall in the choices of decision-makers, i.e., the reluctance of stakeholders to justify their actions, reducing thereby their contacts with scientists in most of the countries of the Mediterranean basin. This is even intensified by French *Napoleonic* technocratic traditions, where engineer traditions are dominant. Facing "doubt-providers" is more disturbing and seems less efficient than solutions-providers, amplified recently by the use of consulting firms for everything (Barthel and Verdeil, 2008);
    - Risks and risk information: Since Ulrich Beck's book in 1986 (Beck, "The society of risks," 1986), environmental research started to be more interested in risks, hazards, and vulnerabilities, mostly from an analytical point of view. In a society where risks and crises occupy a central position in the development of a comparing, hierarchizing, and prioritizing risk procedure has become crucial. However, such a process is mainly based on environmental data and their analysis and interpretations. Consequently, data acquisitions and treatment methodologies should be considered as important as the decision making itself during a crisis event because of the uncertainties involved with data collection and analysis.

Public policy limitations and priorities:

a. Lack of operational procedures in the public sector to be applied over threats, risks, and nuisances: On the contrary, one may see the multiplication of technical reports provided by dedicated consulting companies focusing on one point and by then having difficulties to also envision the local SES context but also the various uncertainties regarding both the quality of the measurements and the conceptualization of the issue. Managing environmental threats, risks, or nuisances need first to define what matters, meaning what variables are to be selected as necessary to investigate to define and measure such settled issues. Then only, measurement procedures can be defined. Indeed, diagnosis should be separated to management to avoid dealing with issues researchers have little information on. Admittedly, during the last decade, many project calls in the Mediterranean region encouraging multidisciplinary research have also supported their pragmatic implementations and more involvement of concerned stakeholders, NGOs, public services, and other institutions.

b. Information in and out of crises: As a consequence of the previous point, even if crisis prevention is more efficient than crisis management but implies long and well-structured data collection campaigns, crisis times urge the need for rapid measures and procedures. Practically, it means that prevention increases connections between stakeholders while crises reduce them drastically to minimize interferences. Nevertheless, crisis management is even more obviously dependent on diagnoses, at the very least to check what emergency we deal with.

sciences as the only ones able to define in which the various motors of a SES push.

c. Communication problems between public operators and the scientific community lead to motivation issues in the scientific community. However, some public structures such as hydraulic services in Algeria, Morocco, Tunisia, and Lebanon, are on the contrary well connected to the national scientific sector following a technocratic model of development. Nevertheless, the other environmental issues are far less valued compared to the water sector.
d. Professional competition within different scientific communities. Combining and analyzing a large set of parameters from distinct disciplines implies considering them on the same level of importance after a selection in accordance to a series of criteria based on the environmental context of the studied area. The problem here is that in most cases, the academic financial context is composed by scattered public funding which rarely covers at the same level all the needs in each different domain. In the light of that fact, public governmental funding priorities should be reconsidered regarding each different environmental context (Heberlein, 1988; Van Dusseldorp and Wigboldus, 1994; Stojanovic et al., 2016);
e. Institutional instabilities, especially in southern Mediterranean countries, represent another main constraint to setting-up multidisciplinary research structures. Although scientific research has allowed the growth of a solid network between many academic institutes (privates and publics) on the area of interest, the sector is extremely vulnerable to socio-political contexts and academic institutions, thus scientific capacity strongly relates to the political and economic situations. In the four considered countries er (Algeria, Lebanon, Morocco, and Tunisia) for instance, scientific works rely mainly on foreign funding because of the severe socio-economic and political instabilities. In general, the most resilient local universities (the best-funded) are dedicated to technical and applied knowledge linked to an essential resource for development (engineering schools: oil, mines, energy, agriculture, water, sea) or on hazard studies (desertification, drought, geologic and geomorphologic hazards, human health and demography) (Hamad, 1982; Van Dusseldorp and Wigboldus, 1994; Lyall et al., 2013; Bark et al., 2016);
f. In the continuation of the previous idea, some fields are therefore considered as strategic by public authorities and thus may polarize the majority of local funds allowed for the research. Nevertheless, despite investments by public authorities on scientific research, the impact on the actors directly in link with the main environmental issues is weak (Steele and Stier, 2000; Bredillet et al., 2010; Hassenteufel, 2010; Santamaría et al., 2010; Lyall et al., 2013).

Specific situations from case studies

The point that can be inferred from the experiences described above is that these obstacles are exacerbated in MENA[15] countries located along the shores of the Mediterranean Sea:

- First and above all, the absence of stable and consequent funding and the support of traditional approaches instead of a multidisciplinary framework;
- Second, and because the first point implies that network quality is the main stable source of funds and even income for Lebanon, the risk of rejection within disciplinary communities with hidden social sanctions in case of "betrayals" and protective competence shelters;
- The third point is that scientists are seen by public offices not as researchers, meaning providers of doubts and questions, but rather available (and cheap) experts (Barthel and Verdeil, 2008) providing deliverables into international projects and sometimes offering national prestige and providing solutions or at least confirmation to ministries and public offices: they are not seen as needing support but on the contrary are to bring support to action.
- These three points are actually the strongest ones by far, meaning that scholars and academics are de facto adaptable to trends and dynamics unless it is a threat to their social position. As a matter of fact, the following points are supportive arguments for a position regarding multidisciplinarity firstly defined by the first three points above:

    - A mutual misunderstanding between disciplines based on reciprocal clichés.
    - A conflict of agenda between tasks, duties, and objectives for all researchers.
    - Misconceptions between variables, data, objectives, measurements, and indicators.
    - A fear of losing the decision power from stakeholders.
    - The non-consideration of the transdisciplinary research in academic evaluations of research.

More specifically, the four experiences illustrate several specific elements (El Kenz, 2005):

1. Money: A stable budget is fundamental despite the "Simpler, Better, Cheaper" ideology. Even more, instability distorts the balance between disciplines, as social sciences are often the first to be sacrificed to the austerity principle. The countries considered in these studies (Algeria, Lebanon, Morocco, and Tunisia) suffer from versatile and low budgets but some countries offer more solid funding and the resulting scientific production and international implications are in direct correlation (World Bank, 2018; UNESCO Statistics Institute, 2022);
2. Time: Building metrics collectively such as in the SICMED experiment and the Bouregreg collective work requires a progressive impregnation and time cannot be avoided. Past colonial tensions, political internal struggles and conflicts, or competition for funds are not confidence-building elements. As a result, the more a country faces such elements and others that structurally and regularly create issues (such as in Algeria or Lebanon), the less multidisciplinarity is acknowledged;
3. Winner-takes-it-all: Hydrology, seen as essential, benefits in all MENA countries from both a long tradition of national

expertise and a very strong legitimacy among governmental administrations, research institutions, and other stakeholders as the result of the strong dependency of these countries toward water in their arid environments. It is then by far the most developed discipline in socio-ecological systems in addition to being the discipline where most of the efforts toward multidisciplinarity were assessed: SICMED, Bouregreg, PSI, and O-LiFE are all dominated by hydrology-related issues and projects and the self-recognition of this constraint is primarily due to the fact that "pull" and "push" incentives for hydrology have been actively effective for a long time. Hydrology is the domain where applied research and complementary actions with public policies are the strongest, as in the watershed-defined ORMVA[16] in Morocco for instance (El-Alaoui, 1999). But the richer a discipline is, the less orientated toward multidisciplinary it is, and most of the cases we studied are hydrology-based. This simple qualitative correlation assertion could be of course justified and does not imply a causality;

4. Measuring is nice: while focusing on combining methodologies, the PSI program did actually fund mostly measurement campaigns, field missions, training, and internships. Water parameters are the most characterized ones in the SICMED experiment. The Bouregreg program is defined by a series of measurement campaigns and innovations related to water. It is then useful to ask about the threshold criteria of completeness beyond which the measurement is sufficient: when can we say that the measurements are sufficient to go further?
5. Decentralization and concentration of power: all these countries are very centralized, with the exception of Lebanon. This statement means that, apart from government-defined local structures such as the ORMVA in Morocco, all decisions remain in ministries and other local powers are rarely acknowledged. For instance, the well-considered hydrology-related issues are well considered among state-defined stakeholders, however, there are still no areas where local actors are involved, as if the strategic importance of water limited its management to higher government levels. Biodiversity and land use/land cover are only considered politically interesting when ancient customs allow local authorities to be part of the negotiation, as in the case of the pastoral management of Moroccan Agdals (Dominguez, 2017). Therefore, multidisciplinarity and development-oriented research are dependent on a very small number of interlocutors;
6. Culture: we previously stated that, alongside religion, culture is most of the time the default explanation when no obvious explanations are found. The issue with "culture" is that it provides a permanent and structural "explanation" ("they are like that") without having to explore it, while going after hidden, blurred, or inductively defined and temporary factors such as more institutional, political, or economic parameters is far more complicated but more open to analysis (Hofstede, 1983; Bredillet et al., 2010; Rees-Caldwell and Pinnington, 2013). As a response, we propose to use the culture point only when all other factors have been exhaustively explored.

16 Office Régional de Mise en Valeur: Regional Development Authority.

Suggestion proposals for promoting inter- and holodisciplinarity

As a conclusion, one should acknowledge that the two components, logistical and epistemological, are both effectively acting:

- Acknowledging the structural and logistical reasons, including balance of power based on fund availability and recognition from the society and public services, domination relationships, institutional instability, and other points we stated above. As a matter of fact, a tradition of long-term public service exists in these countries, including the maintenance of long-term and intertwined public- environmental infrastructures such as dams (Mahé et al., 2021). Scientific research efficiency is directly linked to the stability of national institutions which draw organigrams and funding. International partnerships encourage more global approaches regarding population and environment nexuses. Such partnerships are essential on a short-term for keeping research infrastructures when they are the most needed as during a crisis and/or shortage times. They also ensure the stability and often the funds necessary to provide the time and means required by a more multidisciplinary understanding of natural phenomena, economy, and population. It is also the occasion to acknowledge some common cultural trends from both sides of the Mediterranean area and not only the southern one;[17]
- Holodisciplinarity: The epistemological principles we deduced from the various projects and experiments tend to build a demarche for (i) listing variables, (ii) formalizing and clarifying corresponding parameters, (ii) evaluating them according to clear criteria, (iv) building indicators from these parameters to facilitate the comparison, and (v) hierarchizing and prioritizing socio-ecological issues and stakes according to these indicators (Saqalli, 2020). In any case, we plea here for a first understanding of an issue and the circumscription

17 The success of this approach can be illustrated by the recent distinction obtained by Tunisian colleagues for their study of the coastal Ghar el Melh lagoon in the North of Tunis, in collaboration with local populations and associations, and national and international NGOs including WWF. Thus the national institution for marine studies (INSTM in Tunis) officially launched an observatory of the Ghar le Melh lagoon in December 2022, which obtained the UNESCO "Ecohydrology" program label, as the first African/Mediterranean coastal Ecohydrology demosite of UNESCO. Among the criteria to fulfill to get this label, there are clear scientific questions, environmental challenges linked to ecology/hydrology related questions, operational survey means, scheduled mitigation/remediation measures, strong connections with local/regional communities, and high levels of capacity for local/regional/international sharing of experience, for instance through international networks like UNESCO programs –FRIEND-Water, Ecohydrology, G-WADI, etc.).

of it through what should overcome the whole debate on the fuzzy notions of multidisciplinarity, multidisciplinarity, and transdisciplinarity: holodisciplinarity, the idea that we should reach exhaustivity of the dynamics and disciplines regarding an issue, whatever the criterion for establishing it (Saqalli, 2020). Formalizing, applying, and diffusing such approaches in agreement with legitimate stakeholders, public officers, and political actors is a satisfying pattern to follow for the following years and decades. Nevertheless, it is unclear if the race between these positive approaches and the coming environmental changes is still attainable.

Author contributions

MSaq: initiating, coordinating, and writing first frame and Section 2. LK: rewrite all the document, check coherence, and consistency. HC wrote Section 1. GM wrote Section 3. CK and LD wrote Section 4. JF, SC, ZC, J-LP, and MSae checked coherence and consistency, respectively on cognition and game theory, social sciences, ecology in Maghreb, and ecology in Lebanon and France, hydrology. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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