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Managing Groundwater from the Ground Up: An Ex Ante Assessment of the Potential for Collective Action

RESEARCH ARTICLE

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ABSTRACT

Common pool groundwater resources may be susceptible to overexploitation but can potentially be managed collectively. However, few studies explore the potential for successful collective action ex-ante. We conduct an ex-ante assessment of the potential for collective action by users of a groundwater body, to identify whether necessary conditions are in place, using a mixed methods approach based on literature, expert consultation, and Q methodology. While some aspects were conducive to collective action, under current conditions it appears unlikely that users will self-organize. Four user sub-groups were identified, differing in terms of resource perceptions and prosocial behavior, with potential for tapping into the skills of *potential leaders* and capitalizing on the prosocial intent of *team players*, while building bridges for cooperation with *sceptics* and *non-users*. Such ex-ante assessment can serve to identify which conditions need to be cultivated to foster cooperation and to identify strategies for engaging with different user sub-groups.

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1. INTRODUCTION

The challenges of freshwater resource management necessitate good governance of available water resources, particularly in areas under water stress. There are various generally recognized principles of good water governance, examples of which include implementation and enforcement of sound regulatory frameworks, adoption of innovative water governance practices, promotion of stakeholder engagement, and management of water resources at appropriate scales (e.g., OECD, 2015). However, the appropriateness and effectiveness of different governance arrangements depend greatly on the status of a resource, as defined by criteria of rivalry and excludability. In this paper, we focus on common pool resources (CPR) that are rivalrous (i.e., consumption of one unit of water directly prevents other users from making use of that unit) and non-excludable (i.e., it is not feasible to exclude others from use). Groundwater bodies that can be directly tapped by multiple users meet these criteria. A characteristic feature of a CPR is that of diminishing marginal returns, where the resource is freely consumed but yields ever decreasing benefits as usage increases (Schauf and Oh, 2021). The absence of mechanisms for excluding users from the CPR may give rise to resource overuse, a situation classically referred to as the Tragedy of the Commons (Lloyd, 1833; Hardin, 1968). As has been extensively documented by Ostrom (e.g., 2009; 2010), the solution to the challenge of CPR management may not lie in centralized regulation or privatization but rather in the adoption of alternative governance modes, such as successful self-governance institutions, i.e., those yielding productive outcomes despite the temptation to free-ride (Ostrom, 1990). Recognizing that self-governance is not always nor necessarily successful, Ostrom identified design principles that are shared by successful, long-enduring CPR institutions, which have been tested empirically by Cox et al. (2010). She also identified variables that may positively or negatively affect the likelihood of users self-organizing to manage a resource (Ostrom, 2009), which are discussed in Section 2 (Theoretical Framework). In this paper, the latter are referred to as the Ostrom Variables.

While there have been numerous empirical studies of the nature and performance of CPR institutions (e.g., Aguilera, 2018; Baerlein et al. 2015; Chhatre & Agrawal, 2008; Madani and Dinar, 2012; Villamayor-Tomas et al., 2016; Yami et al. 2009; Yu et al. 2016), what these generally have in common is that they are ex-post in nature, i.e., they are primarily concerned with empirical analysis of the functioning of already-established CPR institutions. Relatively few studies have focused on ex-ante prediction of the potential for self-governance, to assess whether resource management powers could *potentially* be devolved to communities. In one example, Heenehan et al. (2015) set out to assess the feasibility of community-based conservation of spinner dolphin populations in Hawaii, noting the presence or absence of Ostrom Variables in two bays. Similarly, Colin-Castillo and Woodward (2015) explored the potential for self-governance among fishing communities at the Lázaro Cárdenas Reservoir in Mexico, using a mathematical model fed data generated via a survey, to measure six conditions identified by Ostrom as having a significant influence on a user group's decision to adopt community-based management. There are, however, few other examples. While ex-post evaluations are useful in providing insights regarding the effectiveness of existing self-governance mechanisms and ways in which these can be rendered more effective, we argue that there is also an important complementary role for ex-ante assessments (as discussed in Section 2 below).

In view of the above, this study used a case within the small island state of Malta to explore the potential for collective management of a groundwater body, the Mgarr-Wardija perched aquifer, which is used for agricultural purposes. The research question addressed by this work is: *What is the potential for users to successfully self-organise to collectively manage the Mgarr-Wardija aquifer?* To answer this question, we adopt a mixed methods approach that draws on secondary data, expert consultation, and Q methodology to assess the extent to which the Ostrom Variables are present. The following section elaborates on the theoretical framework that underpins this work (Section 2), with Section 3 then providing an overview of the case study context and methodology. Section 4 presents the key results obtained, while the remainder of the paper (Sections 5 and 6) discusses related implications and conclusions.

2. THEORETICAL BACKGROUND

2.1 OSTROM'S FRAMEWORK FOR ANALYZING SUSTAINABILITY OF SOCIAL-ECOLOGICAL SYSTEMS

Ostrom argued that long-term sustainability requires governance mechanisms that match the attributes of both resources and their users. She identified characteristics shared by governance systems that are compatible with sustainable resource use and rule compliance by resource users (Ostrom, 1990). Adopting a framework focused on social-ecological systems (SES), i.e., linked systems of people and nature, Ostrom recognized that the sustainability of resource management was dependent on relationships across multiple levels of these complex systems at different

temporal and spatial scales (Ostrom, 2009). She identified four core first-level subsystems of SESs (Figure 1), which affect each other as well as linked social, economic and political settings, and related ecosystems. Each sub-system is in turn composed of second-level variables, made up of third-level variables, and so on, in a nested framework.

Ostrom inductively identified variables that are posited to affect the likelihood of users engaging in collective action to self-organise. She noted that since SESs are inherently partially decomposable, not every variable is necessarily relevant to every study of CPR regimes, identifying ten second-level variables (Table 1) (the Ostrom Variables) with a disproportionately high influence on the potential for collective action. A few authors have applied these to the study of irrigation and groundwater systems (e.g., Ma'mun et al., 2020; Luo et al., 2019), showing that localized self-governance solutions to water use often yield positive results. Nevertheless, application of these variables to groundwater governance research and implementation remains somewhat limited (Seward and Xu, 2019).

2.2 EX-POST VS. EX-ANTE POLICY ASSESSMENT

Ex-post and ex-ante evaluation are both integral elements of the policy cycle, collectively contributing to two essential goals of evidence-based policymaking – using what we already know to improve policy decisions and building knowledge to inform future decisions (Evidence-Based Policymaking Collaborative, 2016). Several ex-ante assessment tools have been developed and widely applied, with examples including environmental, economic, fiscal, administrative, regulatory and social impact assessments, as well as a wide variety of multicriteria forecasting and predictive methods in fields ranging from financial planning to risk management. Nevertheless, experiences with ex-ante assessment at institutional policy level remain somewhat limited (Theesfeld et al., 2010). Because of their inherently predictive nature, ex-ante tools are necessarily constrained by uncertainty and may fail to correctly identify and account for relevant influences; they are also consequently more reliant on assumptions, experience and judgment (Samset and Christensen, 2017). Indeed, various studies have pointed to inaccuracies of ex-ante predictions (e.g., Brinkman et al, 2019; Wang et al., 2022) and its various limitations may at least partially explain the dearth of ex-ante studies pertaining to CPR institutions. However, and notwithstanding these limitations, the value of ex-ante assessment is widely recognized across the policy literature, even if it remains an imperfect tool; indeed, Hertin et al.

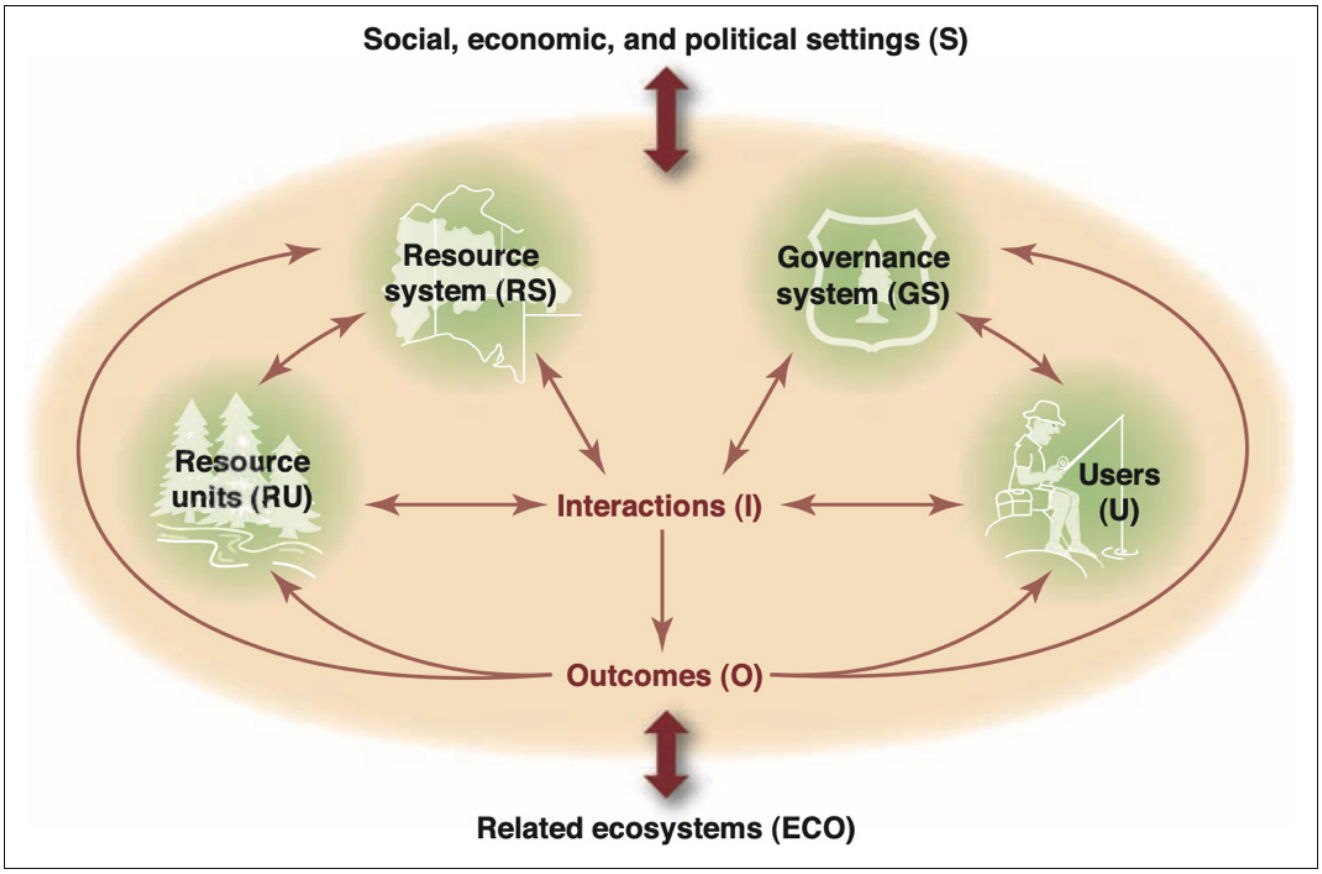

Figure 1 Core subsystems in a framework for analysing social-ecological systems (reproduced from Ostrom, 2009).

VARIABLE	JUSTIFICATION
Size of resource system (RS)	The cost of monitoring boundaries of a large resource system may be too high to justify collective action and it may be difficult to obtain reliable information relating to environmental conditions. Conversely, a resource system that is too small, with low flow of resource units, may not justify investment in collective action and may be too rapidly degraded. Resource systems of moderate size are therefore best suited for collective action.
System productivity (RS)	If there is no perceived scarcity, users will undervalue the benefits of collective action. Conversely, if users perceive the resource to be past a point of no return, they will likely not invest in its management. Some perceived scarcity must be present to trigger collective action.
Predictability of system dynamics (RS)	High predictability of system dynamics is positively correlated with collective action, allowing users to reliably and accurately plan resource use, as well as judge whether damage to the resource stock was perpetuated by user actions or exogenous causes.
Collective choice rules (GS)	Costs of collective action are reduced when users are given sufficient autonomy to create and enforce their own rules. Top-down enforcement of rules hinders the capacity of local actors to effectively self-manage.
Resource unit mobility (RU)	A resource system is easier to manage if resource units are relatively stationary in space, as monitoring and management costs are positively related to resource unit mobility.
Number of users (U)	The higher the number of users, the higher the cost of self-organization, thereby decreasing the chances of collective action. Conversely, a small number of users may constrain collective action if the tasks involved in managing a resource are costly in terms of labour or other resources. However, there is conflicting evidence regarding the relative cost-effectiveness of small vs. moderate-sized groups, with the relationship between number of users and self-organization seemingly highly affected by other variables.
Leadership/ entrepreneurship (U)	Individuals within a user group who possess prior organizational experience and leadership skills increase the likelihood of self-governance.
Norms/social capital (U)	Users who share similar social norms relating to trust and reciprocity have a higher chance of banding together to collectively manage a resource. Community cohesion has been shown to be a key element in setting up and maintaining successful co-management institutions; strong social capital acts as a buffer against shocks to the system and increases overall resilience.
Knowledge/mental models of the system (U)	Users who share a common understanding of the system, sub-systems, variables, and interactions between these, are more likely to adopt cooperative management strategies.
Salience (U)	Users must value the resource sufficiently in order to perceive the benefits of collective action as higher than the costs of organising. If users do not rely on the system for a major part of their livelihood or do not attach a high value to the sustainability of the resource, the cost to maintain a CPR institution may be higher than the benefits of having one.

Table 1 The Ostrom Variables, representing pre-existing attributes with a disproportionately high influence on decisions to self-organise, based on Ostrom (2000; 2009) and Baland and Platteau (1996). RS, GS, RU, and U refer to resource system, governance system, resource units, and user subsystems respectively.

(2009) observe a remarkable increase in the level of interest in ex-ante policy-level assessments across and beyond the European Union (EU), reflecting an interest in upstreaming assessment to earlier decision-making stages.

In the context of CPR institutions, we argue that ex-ante assessment can make several contributions. First, through an assessment of existing conditions, an ex-ante_assessment can potentially be used to customize policy interventions designed to foster community self-governance so that they are better tailored to the specific implementation context; for example, key user groups, such as community leaders or potential free-riders, can be identified and proactively engaged. Second, an ex-ante assessment can serve to identify practical barriers to potential community-led interventions, allowing mitigating and/or transformative measures to be considered. Third, points of disagreement across user groups can be identified, making it possible to proactively minimize frictions. Fourth, the cost of conducting an ex-ante assessment is very likely lower than the cost of implementing an intervention and having it backfire due to an unforeseen nuance (which might have been captured in an ex-ante assessment). As noted by Samset and Christensen (2017), it is somewhat paradoxical that considerable resources are often invested in a single, specific solution, without appropriate early consideration of alternatives; the same authors note that a key benefit of ex ante evaluation is precisely its ability to help avoid expensive and ineffective solutions. Fifth, an ex-ante study could form the basis for longitudinal analysis when combined with ex-post assessment of a particular intervention; this would allow more accurate pinpointing of where interventions have succeeded or failed and why, allowing finetuning of future efforts. The failure to adequately connect ex-post and ex-ante assessments has been recognized as a key gap

in the policy cycle. Smismans (2015) notes a discursive and institutional divide between the two approaches at EU level that is reflective of a similar divide between the respective policy and academic communities dealing with ex-post and ex-ante approaches. Mergaert and Minto (2015) likewise note that the link between ex-ante and ex-post assessments remains significantly under-theorised. Development of robust ex-ante assessment approaches for CPR analysis can therefore potentially offer significant benefits.

3. MATERIAL AND METHODS

3.1 CASE STUDY

The Maltese Islands lie in a semi-arid climatic zone, receiving an average of 500–600 mm of precipitation annually but with high variability from year to year (Cassar et al., 2007). Annual precipitation is projected to decline under various climate change scenarios, while average temperatures are set to increase, exacerbating water stress. The Maltese Islands also experience very high water demand due to their dense population (1628 per km^2) and heavy reliance on mass tourism. The country has no rivers, lakes, or snowmelt and its natural freshwater sources are limited to groundwater, replenished through rainfall. The country has only been able to meet water demand through additional use of desalination technology. Notwithstanding, groundwater bodies continue to be an important source, contributing an average of 44% of the public water supply between 2005 and 2017 (NSO, 2018). These are of two main types – perched aquifers, limited in extent, found beneath the Upper Coralline Limestone/Greensand stratigraphy and resting on aquifugal Blue Clay, and the larger mean sea level aquifer (Ghyben-Herzberg lens), comprising a freshwater lens that floats on denser seawater. While the latter contributes most significantly to public water supply, perched aquifers are an important local freshwater source and are directly tapped by several agricultural users; they also have more obvious potential to be collaboratively managed.

Both the quality and quantity of groundwater in Malta have been severely affected over the years due to over-abstraction, saline intrusion, and nitrate pollution, in turn raising water and food security concerns. The most recent Water Catchment Management Plan (WCMP) (ERA, 2016) identified only 3 of the 15 groundwater bodies in the Maltese Islands as having 'good status' as per the requirements of the Water Framework Directive and Malta's water governance challenges have frequently been highlighted (e.g., D'Agostino et al. 2020; ERA, 2016). Solutions that have been explored or proposed include stronger regulation of water (mis)use, use of non-conventional or alternative water sources, increasing public awareness, and supporting farmer training, among others (Hartfiel et al., 2020; Sapiano, 2020; D'Agostino et al., 2020). While all of these are valid, they share a common presumption that successful resolution relies on top-down measures that emanate from central government. This study is based on the premise that community water management also merits consideration.

Our work focuses on the Mġarr-Wardija perched groundwater body (Figure 2), situated in north-western Malta, comprising two main units: the Wardija Ridge and Binġemma trough. The groundwater body is an upthrown block of Upper Coralline Limestone sitting atop Blue Clay stratigraphy, while the Binġemma trough is a graben, bounded to the south by two strike faults. Four major synclines running east to west, parallel to the Victoria fault, occur on this depressed stretch of land. Water storage occurs in these synclinal structures atop the clay. The main overlying land use is agriculture (Figure 3). The characteristics of agriculture in the area are very similar to those of the Maltese Islands more generally. Micro-scale holdings belonging to a sole owner or to families are the norm; over 69% of Maltese agricultural holdings have a Utilized Agricultural Area of less than 1 ha (NSO, 2020). The age structure of agriculture in Malta also tends to be top heavy, with over 64% of farm managers aged > 54 (NSO, 2020). Within the Mgarr-Wardija area, farmers primarily engage in mixed cropping practices, cultivating a range of vegetables and fruits over the year, primarily for local markets (pers. comm. P. Vella, 2023). The local Mgarr Farmers' Cooperative Society, which holds regular meetings, has around 160 members, all of whom are farmers in the area. The cooperative provides support to its members, provides equipment and other farm material for sale, and acts as a point of liaison with relevant authorities to further farmers' interests. Farmers are the main consumers of aquifer water, abstracting groundwater directly for irrigation purposes. While agricultural production in the area is of critical importance from a national standpoint, it is the main source of negative externalities affecting the aquifer, both through direct consumption of water in a water-scarce environment, and through impacts on the quality of water contained therein, largely because of the use of agricultural inputs. Malta's first Water Catchment Management Plan (MEPA and MRA, 2011) classified the aquifer as at risk, with poor quantitative status and high levels of nitrate pollution. The second and most recent WCMP (ERA, 2016) revised its quantitative status to good (with an estimated balance between inflow and outflow of 1.17 Mm^3) but confirmed its overall poor qualitative status, with mean nitrate content of 117.6 mg/kl exceeding the EU Nitrates Directive threshold of 50 mg/l. Other relevant characteristics of the aquifer are described in Section 4.1.

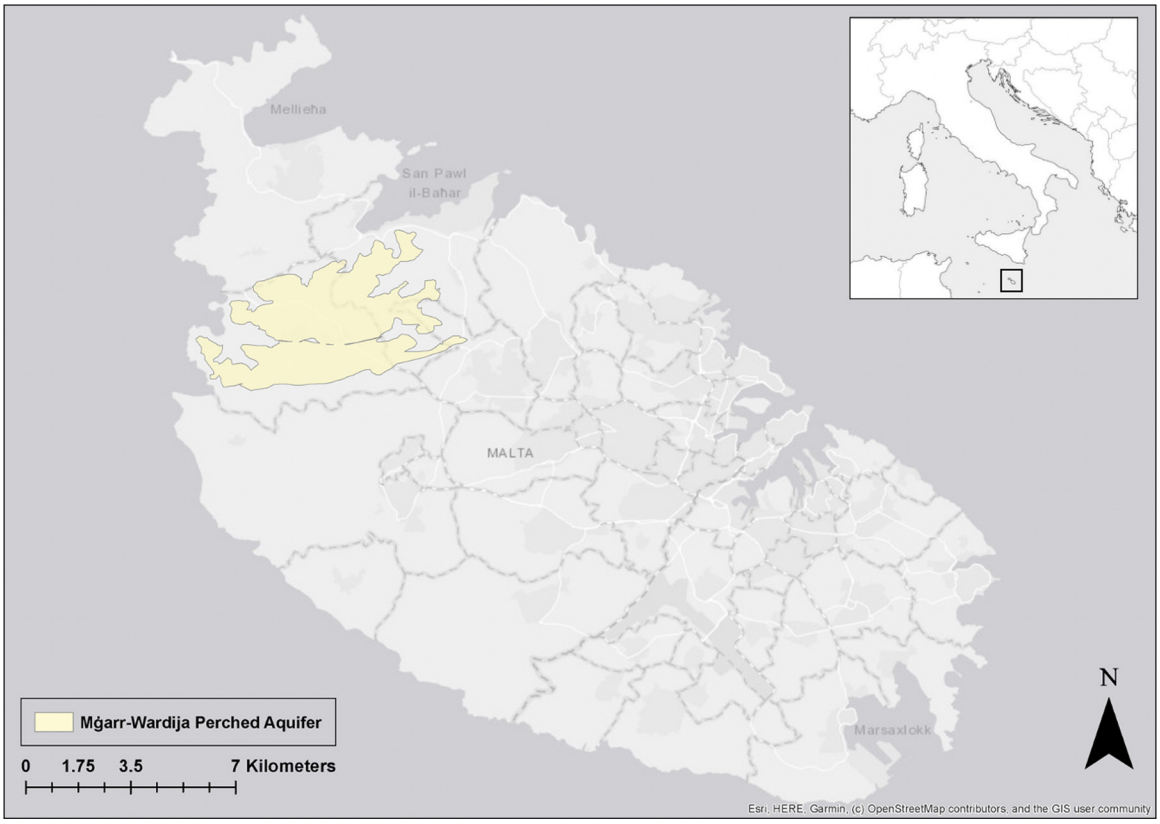

Figure 2 Location of the Mġarr-Wardija perched aquifer within the island of Malta, with the location of the Maltese Islands south of Italy shown in inset.

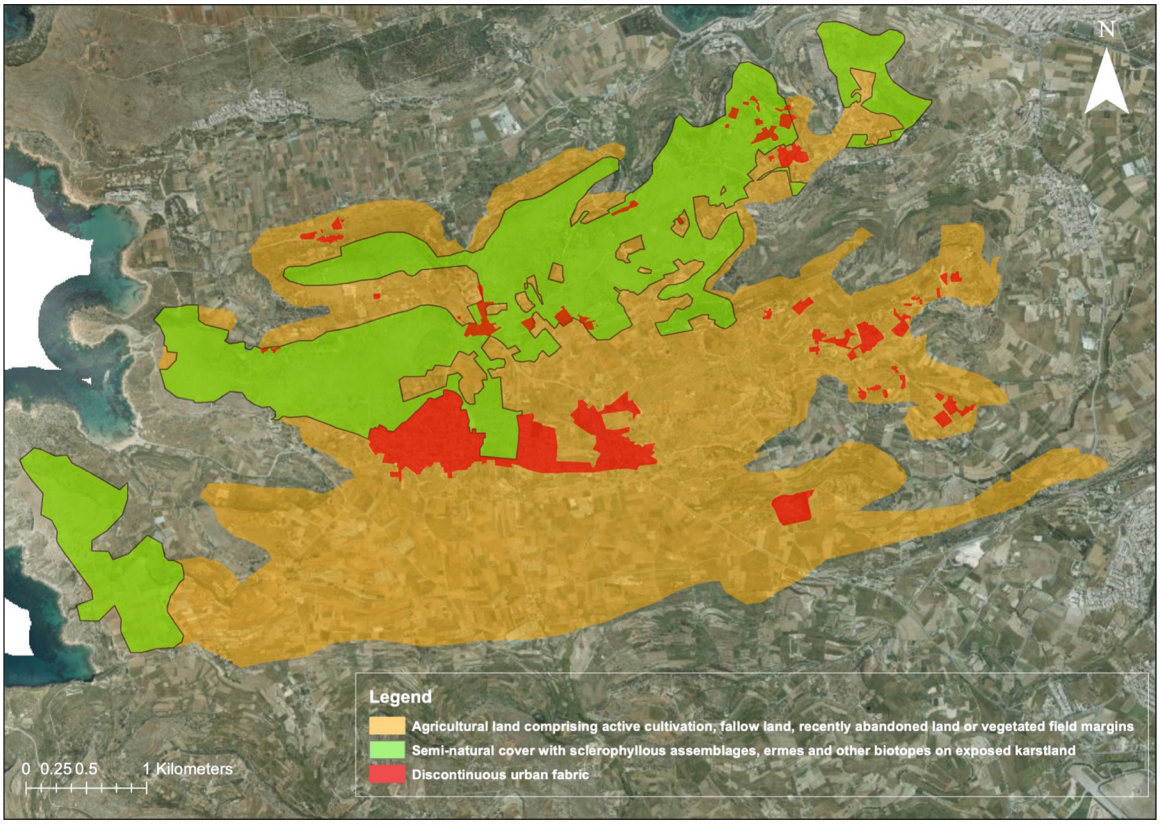

Figure 3 Main land uses in the Mġarr-Wardija area (updated by authors from earlier version provided in Malta Resources Authority, 2005).

3.2 METHODS

3.2.1 Overview

To assess the feasibility of managing the Mġarr-Wardija perched aquifer via collective action, the ten Ostrom Variables (Table 1) were assessed through a variety of methods. Q methodology was used for assessing the influence of some variables, while others were assessed on the basis of secondary data collection and expert consultation (Table 2). Relevant details are given in the table and sections below.

3.2.2 Secondary data collection and expert consultation

Expert knowledge was sought to support the assessment of five of the Ostrom Variables (Table 2). An expert from the regulatory authority which, at the time of study was responsible for water management, was consulted to provide background on the aquifer. This was supported by secondary data made available through the same contact, which comprised mostly statistical data pertaining to the aquifer system under study. An expert in Maltese environmental law was consulted to assess the extent to which the present-day national legal framework would facilitate or hinder implementation of collective choice rules. Finally, a meteorologist was consulted to provide an assessment of the variability of rainfall, which is the main source of aquifer recharge.

3.2.3 Q methodology

Q methodology provides a systematic measure of people's subjectivity, merging quantitative and qualitative techniques by using a form of inverted factor analysis to identify clusters of like-minded participants, allowing the researcher to determine the characteristics of individuals who share similar viewpoints, attitudes, beliefs and values. Its aim is thus not to estimate population statistics but to sample the range and diversity of views expressed (Cross, 2005). It has been described as an ideal method for exploring topics that are complex or that are likely to elicit differing perspectives (Farrimond, 2017; Dean et al.,

VARIABLE	SECONDARY DATA COLLECTION	Q METHODOLOGY*	EXPERT CONSULTATION
Size of resource system	✓ Based on Malta Resources Authority, 2005		✓ Consultation with regulatory authority
System productivity		✓ Q-set statements: 8, 15, 17, 22, 27. 30, 33	
Predictability of system dynamics	✓ Analysis of precipitation data based on Galdies, 2011	✓ Not included in Q-set but emerged as discussion theme during interviews	✓ Consultation with meteorologist
Collective choice rules			✓ Consultation with legal expert
Resource unit mobility	✓ Based on Malta Resources Authority, 2005		✓ Consultation with regulatory authority
Number of users	✓ Based on statistics provided by the Malta Resources Authority and estimates given by study participants		✓ Consultation with regulatory authority
Leadership/ entrepreneurship		✓ Q-set statements: 1, 6, 9, 19, 21, 23, 31, 36, 43, 44	
Norms/social capital		✓ Q-set statements: 5, 7, 10, 11, 13, 24, 28, 35, 39, 42	
Knowledge/mental models of the system		✓ Q-set statements: 2, 12, 14, 20, 25, 29, 32, 34, 37, 40, 41	
Salience		✓ Q-set statements: 3, 4, 16, 18, 26, 38, 45	

Table 2 Data collection methods/sources for the ten Ostrom Variables.

*Q-set statements are given in Table SM1.

2018) and offers advantages in terms of offering a holistic, person-centered view (Churruca et al. 2021). It provides a systematic, replicable and statistically interpretable method to analyze subjectivity, whilst requiring a lower number of respondents when compared to other conventional methodologies. For purposes of ex-ante assessment, it can provide a holistic overview of typologies of resource users and the views that these hold on the shared resource and can help in identifying the presence of sub-groups that may be particularly influential in CPR systems. By revealing these typologies, interventions can be tailored to meet the specific needs of distinct groups (Ho, 2017). Q methodology has been described as especially useful when used in the early stages of a decision-making process, particularly in order to better understand how the variety of perspectives surrounding a topic are interlinked (Mukherjee et al., 2018).

The five basic steps involved in performing a Q methodological study, as defined by Van Exel and De Graf (2005) and as applied in this study, are briefly explained below.

(i) Definition of the concourse

The concourse reflects the breadth of subjectivity related to a particular topic, often sampled from interviews, scholarly literature, or media sources (Sneegas et al., 2021). In this study, the concourse was derived from a literature review of academic journals focused on pre-existing conditions for collective action. Literature sampled mainly revolved around Ostrom's development of the set of conditions associated with collective action, as also related empirical studies spanning different applications of the social-ecological systems framework discussed in Section 2.1. Studies were not limited to a specific region or environmental sector.

(ii) Development of the Q set

The Q set comprises a representative sample of the concourse, typically consisting of 30–60 concise statements that require little to no intervention from the interviewer for interpretation by respondents. It should also contain a more or less equal number of positive and negative statements (Webler et al., 2009). In this study, the Q set consisted of 45 statements (shown in Table SM1), grouped according to the variables that they sought to test for (Table 2). The Q set was made available in both English and Maltese (the two official languages of Malta). The concourse was sampled deductively, i.e., on the basis of *a priori* themes determined in relation to each of the five Ostrom Variables assessed through this method. Care was taken to ensure each variable was adequately represented in the Q set. Ostrom Variables (Table 1) were thus used as guiding themes in the selection of the Q set, and statements representing key aspects of these were selected. The Q set statements related to each Ostrom Variable are listed in Table 2.

(iii) Selection of the P set

The P set is the sample of participants involved in the Q study. Small samples are commonly utilized in Q methodology, with sample sizes typically in the region of 12–40. P set selection is purposive (as in qualitative research) with the aim of capturing a wide breadth of possible subjectivity by including individuals with diverse views, as opposed to random sampling to achieve representativeness, which is more typical of quantitative research. To this end, structured sampling should be used to acquire a range of participants representing the various points-of-view that may eventually define different factors (Van Exel & De Graaf, 2005).

In this study, participants were farmers within the study area. Given that water user data could not be accessed by the authors directly due to data protection constraints, it was not possible to utilize structured sampling and a snowball sampling strategy was thus adopted. While opportunistic sampling is not ideal for Q methodology, it is recognized that this may often be the only feasible option (Watts and Stenner, 2012). A personal network of contacts of the authors was used to identify a first group of participants, who then referred other potential participants. A total of 15 participants took part. While 15 participants are adequate for Q methodology, it is acknowledged that a larger number of participants could have potentially allowed for the uncovering of additional factors. In order to capture diversity, the sample included members and non-members of a local farmers' cooperative. A secondary distinction was between farmers who abstract water from the Mġarr-Wardija perched groundwater body and those who abstract water from the mean sea level aquifer. Whilst the latter do not make direct use of the perched water body, they may nevertheless impact it, particularly when applying fertilizers on land sitting atop.

(iv) Q Sorting

During the Q sorting process, participants are typically presented with a pack of randomly numbered cards, each with a different statement from the Q set, with these to be sorted and placed on a Q sheet, representing a continuum ranging from strongly agree to strongly disagree in a quasi-normal forced distribution. The distribution of the Q sheet is determined by the number of statements in the Q set and the kurtosis. According to Van Exel and De Graaf (2005), the latter should be determined by how controversial the topic under study is, with a flatter distribution preferred for more controversial topics. The Q sheet distribution used in this study was relatively flat, as participants were predicted to hold strong views relating to the subject matter.

Q sorts were administered through individual in-person interviews. Participants were first asked to read through each statement, before dividing the Q set into statements (i) with which the participant agreed, (ii) disagreed, and (iii) statements considered conflicting or about which the participant was indifferent. The participant was then asked to place statements along the Q sheet. The process typically lasted 30–60 minutes per respondent. All participants were also asked supplementary questions before and after the Q sort (Table 3), with these serving as a basis for a semi-structured discussion. Interviews are considered to improve validity of Q methodology by minimizing the possibility of the researcher misinterpreting factor arrays produced (Gallagher and Porock, 2010). To facilitate open discussion and ensure anonymity, interviews were not audio-recorded and no personal details were noted.

PRE Q SORT QUESTIONS
Are you a full-time or part-time farmer?
How many years have you been a practicing farmer?
What type(s) of agriculture do you practice?
POST Q SORT QUESTIONS
What are your thoughts on managing the aquifer via a cooperative?
Do you wish to hold a leadership position in an organization?
Are you a member of the Mǧarr Farmers' Cooperative Society?
What are your thoughts on the cohesion of the community in Mǧarr/Wardija?
Is it every man for himself or do farmers help each other out?
How knowledgeable are you when it comes to the physical characteristics of the aquifer?
Is protecting the perched aquifer something which you are concerned about?

Table 3 Interview questions.

(v) Analysis and interpretation

Factor analysis is used to identify various natural groupings which exist amongst different Q sorts. A factor extraction method is employed to uncover latent factors and the variance each factor accounts for within the dataset. The number of factors used for interpretation is at the discretion of the researcher. Webler et al. (2009) suggest four guiding criteria: (i) simplicity, (ii) clarity, (iii) distinctness, and (iv) stability. After an initial set of factors is established, the number of factors must be rotated to minimize statistical variation; through factor rotation, Q-sorts are loaded to each factor, and Q-sort factor loading scores are generated. This process is repeated until the researcher decides on a factor scenario (number of factors) which best describes the dataset. The most commonly used methods for factor extraction and factor rotation in modern Q methodology studies are Principal Component Analysis (PCA) and varimax rotation (Akhtar-Danesh, 2017a). Akhtar-Danesh (2017b) suggests that if several Q sorts are expected to be associated with a general factor, then quartimax rotation could be preferred; however, this was deemed unsuitable for the case study as we expected a large variance in Q sorts amongst participants.

Finally, each statement's z-scores are calculated. The z-score is the normalized weighted average statement score for each statement in a given factor; a negative z-score indicates that the hypothetical respondent would sort towards the negative end of the scale (disagree), and a positive z-score indicates that the hypothetical respondent would sort towards the positive end of the scale (agree). Z-scores can be used to construct a composite idealized Q sort representing how a respondent who has 100% loading to that factor would have sorted (Van Exel & De Graaf, 2005). Factors can then be characterized, allowing construction of a narrative to describe the breadth of subjectivity around the topic (Van Exel & De Graaf, 2005; Webler et al., 2009).

In this study, analysis was carried out using PQMethod (version 2.35 – maintained by Schmolk), through the following steps:

i. Factor analysis conducted via Principal Component Analysis (PCA).
ii. Factor rotation conducted using the varimax method.
iii. Four factors selected to best reflect the variation in Q sorts.
iv. PQROT program used to associate each Q sort with a specific factor, based on the computed factor loading score (p-value of 0.01, with minimum factor loading of $\geq \pm 2.58(1\sqrt{n})$, where n = the number of statements in the Q set).

4. RESULTS

4.1 OSTROM VARIABLES MEASURED VIA SECONDARY DATA/EXPERT CONSULTATION

Five Ostrom Variables were evaluated primarily on the basis of secondary data/expert consultation, with key results as follows:

Size of resource system: The Mǧarr-Wardija perched groundwater body spans an area of 13.7 km^2, with maximum width and length of 6.7 km and 3.2 km, respectively; mean aquifer thickness is 32.6 m, whilst maximum depth is 128 m (MRA, 2005). Van Steenbergen

(2006) describes seven case studies involving successful community management of groundwater bodies and concludes that local community-based management is well suited to groundwater bodies smaller than 30 km^2. On the basis of this latter study, the scale of the Mġarr-Wardija perched aquifer can thus be considered conducive to community management.

Resource unit mobility: The Mġarr-Wardija perched groundwater body acts as a store of water in which resource units are relatively bounded. Whilst some natural springs do occur, significant outflow is limited to abstraction of water for agricultural use. When compared to other CPRs, resource unit mobility for this aquifer is relatively low and therefore conducive to community management.

Predictability: An analysis of climatic data for Malta indicates somewhat erratic precipitation patterns, with high variability (pers. comm. C. Galdies, 2017). As noted above, precipitation (and hence aquifer recharge) rates are likely to become even more variable under climate change scenarios. The ability to predict quantitative output from the aquifer therefore appears limited. Q-sorts (discussed in Section 3.2) also showed disagreement on the qualitative state of the aquifer. These factors may limit predictability and thus the potential for successful collective action.

Collective choice rules: Malta's legal framework allows both informal and formal arrangements between two parties to be upheld in Civil Court through rulings based on precedents. However, the enforcement of such arrangements via the Civil Courts can be cumbersome and time-consuming, with inefficiency of the legal system often leading to cases dragging out over several years (pers. comm. S. Borg, 2017). The possibility of using legally-established tribunals for dispute resolution exists, although costs involved in setting up and running these would pose significant constraints (pers. Comm. S. Borg, 2017). While alternate dispute mechanisms are possible, the enforcement of sanctions through less formal means could potentially be difficult, particularly given that free-riders may perceive non-binding legal mechanisms to be unenforceable.

Another relevant consideration is state involvement in collective choice rules. Article 38.3 of the Maltese constitution allows the government to expropriate groundwater, while Legal Notice 241 (2010)[1] mandates the metering of private groundwater abstraction sources and authorizes the competent authority to decommission or limit any groundwater abstraction source for any reason. Whilst Malta's legal framework theoretically allows for the setting up of collective user institutions such as cooperatives, this top-down approach to water governance is not considered especially conducive to the genesis of collective action.

Number of users: There were 278 registered privately owned water sources used by farmers overlying the Mġarr-Wardija perched aquifer at the time of study (pers. comm. G. Cassar, 2017). However, several agricultural water users are known to have unregistered water sources, meaning that the reported number of water sources may be less than the actual amount. A member of the local cooperative estimated the working population of farmers in the area at the time of study at around 400. In the case of private shafts abstracting water from the perched aquifer, water sources are often shared amongst a group of users (typically between five to ten). When compared to the number of water users (and sources) present within case study areas presented by Van Steenbergen (2006), the figures described above are relatively low. In one example, a Water User Association was successfully set up in the Salheia area in the East Delta of Egypt to manage agricultural use of a groundwater body in a 10 km^2 area with around 400 landowners. This is comparable to the area under study and overall, the number of agricultural water users of the Mġarr-Wardija perched aquifer thus appears conducive to collective action.

4.2 OSTROM VARIABLES MEASURED VIA Q METHODOLOGY

Q analysis resulted in four factors, labelled as follows: (i) team players, (ii) non-users, (iii) sceptics, and (iv) potential leaders. Each of these is described briefly below, with Q-set statements and related results in Supplemental Material (Table SM1). Results of Principal Components Analysis, distinguishing statements, z-scores, and composite Q sorts are also given in Supplemental Material (Tables SM2 and SM3, and Figures SM1–SM4).

Factor 1: The team players

Nine Q sorts loaded to factor 1, explaining 32% of the variance within the dataset. Overall, respondents in this factor were highly dependent on the perched aquifer but not concerned about its productivity. Several argued that farmers simply cannot afford to run their operations unsustainably because of the monetary cost of agricultural production. However, there appeared to be inaccuracies in understanding of system dynamics. Six respondents believed that the majority of water abstracted originated from 'somewhere far away', often citing the neighboring island of Sicily as the place of origin and hypothesizing that such water flows to Malta via a series of underground veins. This is factually incorrect. Respondents also disagreed that the quality of abstracted water is inadequate; on the contrary, they were proud of the quality of water abstracted and were unsure of the significance of fertilizer pollution, with many blaming a degrading sewerage infrastructure for any pollution. This suggests an apparent lack of knowledge of the source, nature, magnitude and impact of pollution,

as well as a failure to link individual actions with resultant systemic impacts.

Six respondents were active members of the local farmers' cooperative and generally agreed that a water user cooperative could be beneficial. However, respondents were unsure of their own leadership abilities. Of the four factors, respondents in factor 1 were most optimistic about the social cohesion of farmers in the area. However, a number did note gradual erosion of the sense of community, with reasons identified including an increasing number of retiring farmers, as well as rising monetary costs of agricultural production leading to increased competition between farmers.

Factor 1 therefore represents a group of agricultural water users who place a high importance on the perched groundwater body, possess adequate organizational experience, and form part of a strong community but tend to lack leadership skills. The lack of perceived issues with system productivity and misunderstanding of system dynamics may contribute to disinterest in community management.

Factor 2: The non-users

Two Q sorts loaded to factor 2, which explained 13% of the variance. Unlike other respondents, those belonging to factor 2 do not abstract water from the perched groundwater body but rather from the mean sea level aquifer via a borehole. Factor 2 was the only factor to agree with statement 33 *The aquifer is not being used sustainably* (z-score of 0.24), while also being the only factor to disagree with a statement suggesting that a degraded aquifer can recover over a relatively short time period (5–10 years). Whilst respondents did not perceive issues with water quality, they did note issues with meeting demand. However, respondents were apathetic regarding the perched aquifer, expressing their disinterest in investing time and money to better manage a resource they do not use. Factor 2 was the only factor to agree with statement 18 *It is not worth investing in conservation of the aquifer for future use, as current use is more valuable* (z-score of 0.9).

Neither of the two respondents in factor 2 were members of the farmers' cooperative (also sorting against notions of organizational experience and leadership) and both expressed a strong desire to not hold a leadership position and doubts about their own leadership capabilities. Respondents were also unconvinced about the capability of a cooperative to better manage the perched aquifer. They expressed little faith in rules, admitting to disregarding these themselves and expressing their distrust in other farmers obeying rules. The sorting of several statements suggested lack of community cohesion, although farmers still identified positive experiences in cooperating with other farmers.

Borehole users who have agricultural land atop the perched aquifer may exert a significant qualitative pressure on the resource through their use of fertilizers and associated pollution impacts, despite not abstracting water from it directly. Nevertheless, the results from this factor suggest disinterest from these users, with no evidence that they feel a sense of responsibility to contribute towards mitigation of impacts resulting from their practices.

Factor 3: The sceptics

Two Q sorts loaded to Factor 3, explaining 15% of the variance. Another two respondents also had significant factor loading at the 0.01 p-level for factor 3. Respondents in factor 3 exhibited some awareness of qualitative and quantitative issues with the perched aquifer and highly valued its protection. Whilst they believed that the quality of water being abstracted is somewhat inadequate, they disagreed that fertilizer use is the main culprit, blaming degradation of sewerage infrastructure. Both respondents showed cognizance of scarcity issues, reporting water sources which dried up over the years.

Of the two respondents making up this factor, one was a passive member of the local cooperative, never attending the monthly meetings held by the cooperative and only maintaining their membership to reap financial benefits. Respondents did not appear to have a good understanding of how local organizations operate. Whilst both were confident in their leadership qualities, they were disinterested in assuming a leadership position and were ambivalent about the role a cooperative could play in management of the perched aquifer, in common with factor 2 respondents.

Whilst respondents in Factor 3 noted that farmers often share experiences and knowledge, they disagreed that there is a spirit of cooperation. They also appeared undecided on other statements related to social capital, sorting many of these towards the middle. Statement 14 (*All farmers will benefit if rules are set in place to manage the aquifer*) was a distinguishing negative statement (z-score of –1.71). During interviews, participants also strongly distinguished between farmers abstracting from the perched aquifer and from the mean sea level aquifer, describing an 'us and them' scenario. Nevertheless, respondents expressed a desire to manage the perched aquifer for the long-term, particularly as they do not perceive other water sources to be as easily accessible and because of dependence on the aquifer for their agricultural needs.

Factor 4: The potential leaders

Two Q sorts loaded to factor 4, which explained 11% of the variance. Respondents in factor 4 were concerned with

both the qualitative and quantitative state of the aquifer. Overall, these respondents had the highest perception of scarcity. While respondents were aware of quality issues, they were unsure as to the significance of the role fertilizer plays in this regard. Much like factors 1 and 3, factor 4 respondents blamed degrading sewerage infrastructure for the decline in water quality. The discourse in factor 4 also reflected an inability to effectively predict system dynamics, as exemplified by the positive sorting of statement 20 *I am not capable of predicting water quality and planning water use accordingly* (z-score of 1.25) and the negative sorting of statement 41 *I am capable of predicting the flow of resource units and planning water use accordingly* (z-score of –0.97).

Five of the seven distinguishing statements for factor 4 were related to leadership/organizational experience. Respondents were active members of the local cooperative, distinguished by their level of administrative and organizational experience, likely to assume a leadership role, and had confidence in local leadership and institutions. Only respondents for this factor disagreed with statement 9 *There is a lack of authoritative/leadership figures in the area*) (z-score of –1.16), whilst they were also the only factor to agree with statement 23 *The local council (or government) can support me, should I propose to set up a water user cooperative* (z-score of 1.06). Their confidence in local organizations is best illustrated by the distinctive sorting of the statement 44 *A cooperative can improve the qualitative and quantitative conditions of the aquifer* (z-score of 1.64).

Even though factor 4 respondents did not rely upon the perched aquifer to the extent that factor 1 and 3 respondents did, and despite having access to other water sources, they still assigned the highest rank to statement 16 *I deeply care about protecting the aquifer, regardless of economic gain* (z-score of 1.36). However, they also expressed discontent with their livelihoods, citing issues such as rising costs, increasing competition resulting in pressure to lower produce prices, lack of paid leave, and the increase in alternative jobs with attractive working conditions.

Factor 4 respondents could be potential leaders of a water user cooperative, with a strong sense of wanting to serve for the common good of the community. Overall, respondents belonging to factor 4 are therefore highly conducive to the genesis of collective action.

4.3 OVERALL FINDINGS

This assessment of the Mġarr-Wardija perched aquifer indicates that some conditions that may facilitate collective action are present (Table 4), with these spanning different elements of the SES framework, including the resource system, resource units, and users; however, significant constraints are also evident, including the lack of predictability of system dynamics. The typology of community members revealed through Q methodology also appears to indicate user-related constraints to effective community management, including inaccurate knowledge of the SES and inaccurate related mental models, inconsistent perceptions of productivity and scarcity, and differing levels of community trust and engagement. One sub-group of users appeared to lack any perception of scarcity, while two sub-groups seem somewhat estranged from the wider community. While Q methodology does not provide any indication of the proportion of these views within the wider population, the presence of these

VARIABLE	CONDUCIVE TO COLLECTIVE ACTION?
Size of resource system	**Yes:** small size
System productivity	**Poorly:** lack of consensus regarding scarcity, recognized to varying degrees by some respondents but denied by others
Predictability of system dynamics	**Poorly:** significant precipitation/recharge variability that is likely to increase and varied perceptions of predictability among users
Collective choice rules	**Poorly:** legal framework not conducive to facilitating collective choice rules
Resource unit mobility	**Yes:** mostly bounded resource units
Number of users	**Yes:** number of users within range shown to be conducive to collective action
Leadership/entrepreneurship	**Yes:** at least some users with relevant skills and interests
Norms/social capital	**Poorly:** evident differences in perceptions of trust and reciprocity among users
Knowledge/mental models of the system	**Poorly:** responses suggest differences in knowledge of the system among users, as well as differences between user's mental models and scientific models
Salience	**Mostly:** resource appears to be highly valued by several users

Table 4 Overall results for the ten Ostrom Variables.

sub-groups in the sample would appear to indicate that under current conditions, there are notable constraints that may limit the likelihood of users self-organizing to manage the waterbody – even if it is recognized that self-organization may come about through many different pathways. Based on our assessment, it appears that for several users, the perceived costs of collective action would appear to outstrip the potential benefits. Furthermore, there are limitations relating to governance, with a slow, unwieldy and top-heavy legal system.

5. DISCUSSION

5.1 FACTORS THAT HINDER COOPERATION

Why are the Ostrom Variables absent or weak in some cases? In the case study, **difficult industry conditions** were found to be a relevant factor, with issues within the agricultural sector including an ageing population, relatively low income and high costs, the high level of commitment required, and competition with international imports (MEAIM, 2015). Although there is a farmers' cooperative in our study area, results from this study suggest that some of its members may be driven by the financial benefits of membership rather than by a deep founded interest in collaboration, while others appear content to participate only passively, in some cases seemingly content to free-ride on the efforts of their peers. **Social cohesion** is also a relevant consideration. Raja et al. (2017) suggest that prosocial behavior decreases with the degree of urbanization of society, and this could be a relevant influence in highly-urbanised Malta, where even the few remaining rural societies are embedded in a strongly urbanized context. OECD social indicators have also noted comparatively low levels of pro-social behaviour in Mediterranean countries (OECD, 2011), while Luria et al. (2014) likewise observe significant differences in pro-social behaviour between countries, notwithstanding the influence of individual factors. This points to the wider influence of **culture**. Prediger et al. (2011) highlight the influence of cultural and historical variables on cooperative decision-making, noting how a prior history of autonomous management and cooperative decision-making can facilitate cooperation. Such a history is lacking in the study area. Boissevain (2012) observes that Malta's long history of feudalism and colonialism, as well as the historically strong position of the Roman Catholic Church, have led to a culture that is accepting of hierarchy and reluctant to question authority. This also translates into a heavily centralized approach to resource management, with weak local governance institutions. Culture is also one factor affecting **civic responsibility**, albeit not the only one. Boissevain (2012) notes that the ethic of amoral familism, found throughout the Mediterranean region, may lead to a disregard of the effects of one's behaviour on others (outside the family), as actions that benefit the family are considered morally justified even if they come at the expense of the wider good. Furthermore, Malta is known to be characterized by a culture of patronage and clientelism (Veenendaal, 2019), in part derived from the country's small size and widespread friends-of-friends networks that provide easy access to decision-makers. All of these combine to produce a generally weak sense of civic responsibility that may provide a poor basis for cooperative decision-making.

5.2 AVENUES FOR ENHANCING COOPERATION

In such circumstances, can missing enabling conditions be created? Amirova et al. (2019) note that, although they are relevant influences, historic antecedents and cultural endowments are not fixed determinants of water user cooperation, i.e., policy makers *can* intervene to enhance cooperation. Having said that, some fundamental attributes identified by Ostrom may be relatively fixed. The size of the resource system, predictability, and resource unit mobility, for example, are dependent on contextual physical factors such as geology and climate. In our study area, however, these were found to be mostly conducive to cooperation. Other attributes are products of a variety of economic, social, cultural and political influences. Resource salience, for example, can change in response to **economic and political driving forces**. Individuals' **past experiences of leadership and organizations**, whether positive or negative, are likely to affect their confidence in these. Likewise, the feasibility of having collective choice rules is at least in part dependent on the **presence or absence of an enabling legal system**. The extent of knowledge and accuracy of mental models can be directly influenced by **effective awareness-raising and educational initiatives**. More broadly, and as noted above, **social capital** is itself a complex of factors such as trust, networks, and ease of cooperation, all of which are created over time through interactions amongst resource users and between resource users and institutions. It is therefore possible, through policy and practice, to gradually build up the conditions necessary to facilitate successful collective action.

Should there be efforts to facilitate community self-organization? Collective action has advantages for resource management that range from decreased costs of action, increased knowledge and improved monitoring and enforcement, to internalization of externalities (Koka and Prescott, 2002). Indeed, there is ample evidence that, given appropriate conditions, self-governed CPR institutions can be significantly more successful at sustainably managing a local resource than external top-down governance

mechanisms. It is true that such self-organized institutions may not emerge in our study area in the short term. However, it is likewise evident that the same conditions that were found to limit the feasibility of collective action in this study will likely also limit the effectiveness of *any* efforts to manage resources more sustainably. For example, a lack of trust in fellow resource users is likely to promote more short-sighted and self-interested behaviour, regardless of whether a resource is managed via self-organization or through centralized authority. In this sense, there are clear benefits to enhancing community cooperation, even if this may not lead to self-governance. Amirova et al. (2019) also note that top-down regulation may actually crowd out voluntary cooperation. Efforts to explore alternatives to the former and enhance cooperative behavior or establish hybrid agri-environment policy instruments (Amblard, 2021) can therefore be a win-win. Particularly critical is the need for government agencies to actively facilitate community involvement in decision-making, as well as the establishment of more effective communication mechanisms (Lopez and Villamayor-Tomas, 2017).

Institutional changes are also needed, including the creation of a legal framework that allows the vesting of power in an autonomous user-led organization. Such an organization, which could be an existing cooperative or a new water user cooperative, would need to have the right to access metered data in order to be able to make informed decisions pertaining to water use, the power to craft rules in relation to groundwater use, and the ability to enforce said rules via sanctions, as well as an easily accessible and efficient dispute mechanism (such as a tribunal). A variety of incentives (monetary or otherwise) can also be considered, to entice more users towards cooperative membership and collaborative behavior. Furthermore, such an organization would need to have legitimacy and perceived authority in the eyes of both its members and the public. In the current polarized cultural and political climate, this would require ensuring that it is not aligned (or perceived to be aligned) to any specific political party or interest group. For this latter reason, a common attachment to "place" is proposed as a key factor that can be used to connect potential users and cut across other differences, as in the case of the already-existing farmers' cooperative.

5.3 THE ROLE OF EX-ANTE ASSESSMENT

Ex-ante assessment as conducted in this study can be valuable in identifying the feasibility of a community self-organizing to manage a shared resource and can serve as a useful planning tool.

Should ex-ante assessment reveal that conditions on the ground are likely conducive to self-governance, policy-makers can act accordingly to decentralize decision-making powers and empower communities if appropriate, in the knowledge that there is a reasonable likelihood of success. If, on the other hand, significant constraints are identified, policy-makers can use results to identify which conditions need to be cultivated to foster stronger stakeholder engagement and community collaboration – and ultimately more effective resource management, whether in the context of centralized or eventual decentralized governance. In our case, results point to an urgent need to ensure that there is a shared accurate understanding of the resource system among its users, with this tied to three of the variables (*system productivity, predictability of system dynamics, knowledge/mental models of the system*) that have been found to potentially constrain the likelihood of collective action (Table 4). There are also clear potential gains to be made from providing opportunities for positive experiences of trust and reciprocity among users. Based on our results, such efforts could be designed to utilize the skills of the identified sub-group of *potential leaders* and build on the prosocial intent of the *team players*, while building bridges to enhance cooperation with *sceptics* and *non-users*.

5.4 LIMITATIONS

A number of study limitations should be borne in mind. First, the study was limited by its focus on a single case study; additional local case studies that share a similar political, economic, historic and cultural context, could potentially help facilitate a distinction between factors that are specific to the particular SES and others that are more generic in nature. A further limitation arises from the fact that Q-sorts were administered through in-person face-to-face interviews; while this was considered the best option to guide respondents as necessary, and is typical of Q methodology, it could also give rise to experimenter demand effects, even though efforts were made to ensure the interviewer remained objective and did not display any judgement as the Q sorts took place. Finally, it is pertinent to note that the uncertainty which is inherent to any ex-ante assessment is also relevant to this study; by its nature, ex-ante assessment is predictive in nature and therefore lacks the validity check of ex-post assessment

6. CONCLUSIONS

In this study, we conducted an ex-ante assessment of the potential for successful community-based management of a groundwater body. Using a combination of secondary data, expert consultation, and Q methodology, the extent to which the Ostrom Variables are present was assessed. Our results showed that while some enabling conditions

are present, other attributes that may facilitate successful self-organization are currently absent or insufficiently developed. These results suggest notable constraints to users self-organizing to manage the aquifer at present. However, there is the possibility for policy-makers to intervene to facilitate cooperation and it is argued that there is good reason for such intervention. Establishing appropriate preconditions for cooperation is important, not only for CPR institutions, but also to enhance the success of any water management initiatives that likewise depend to a large extent on the strength of relationships and shared norms amongst stakeholders. Ex-ante assessment is useful for this purpose.

While our work has shown that ex-ante assessment can contribute valuable information, further work is needed to extend the evidence base, in particular to further develop methodologies and to gain a better understanding of the relationship between ex-ante assessment of enabling conditions and ex-post success of CPR institutions. This would enable further evidence-based refinement of ex-ante assessment.

NOTE

1 Groundwater Abstraction (Metering) Regulations.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Supplementary Material File.** Tables SM1–SM3 and Figures SM1–SM4. DOI: https://doi.org/10.5334/ijc.1258.s1

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COMPETING INTERESTS

The authors have no competing interests to declare.

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