Participatory Methods and Approaches for Engaging Stakeholders in Managed Aquifer Recharge Planning:

Review and Future Directions

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Participatory Methods and Approaches for Engaging Stakeholders in Managed Aquifer Recharge Planning: Review and Future Directions

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CHAPTER ONE

INTRODUCTION

Introduction

My Partnership with the N-EWN MAR Team

For my project, I have partnered with the Managed Aquifer Recharge (MAR) team within the Network for Engineering with Nature (N-EWN). My role on the N-EWN MAR team was to lead the development of a review paper analyzing literature on the usage of participatory methods in MAR planning and to assess areas of improvement in using these methods going forward. The N-EWN MAR team is a team of engineers, geological scientists, and social scientists working to advance research on the social and ecological impacts of Managed Aquifer Recharge (MAR) projects. The team is a part of the Network for Engineering with Nature (N-EWN), a larger collaborative of scientists working to develop nature-based solutions to enhance the resilience of built infrastructure in the western U.S. Part of N-EWN's objective involves investigating the feasibility of MAR across the US and creating well-structured guidelines for MAR implementation.

Background

Overexploitation of groundwater combined with droughts hindering groundwater replenishment has led to the rapid decline in the world’s aquifers (Lall et al. 2020; Jasechko et al. 2024; Cooper and Hiscock 2024). Researchers have found that Managed Aquifer

Recharge (MAR), an engineering method involving the artificial replenishment of groundwater, can help prevent and mitigate water scarcity (Dillon et al. 2019; Kwoyiga and Stefan 2019; Lall et al. 2020; Marwaha et al. 2021; Harvey et al. 2024). MAR systems operate by redirecting runoff water into aquifers through structures, such as infiltration ponds, check dams, and injection wells (Dillon et al. 2019). Researchers expect the implementation of MAR systems to continue to rise (Dillon et al. 2019).

Researchers and countries are increasingly putting more effort into MAR research to create comprehensive guidelines for planning (Sprenger 2017; Dillon et al. 2019). While there is an abundance of research examining hydrogeological MAR feasibility factors, the implementation of MAR hinges on a complex array of feasibility factors (Dillon et al. 2019; Escalante et al. 2023; Harvey et al. 2024). Of these feasibility factors, recent MAR scholarship has argued for further examination of the social impacts of MAR projects and the inclusion of local stakeholder knowledge in MAR planning (Rawluk et al. 2016; Dillon et al. 2019; Fathi et al. 2020; Laukka et al. 2021; Marwaha et al. 2021; Harvey et al. 2024; Saidani et al. 2024; Sufyan et al. 2024; Zakir-Hassan et al. 2024).

Water resource management research has notoriously taken a top-down approach, favoring technical approaches (Roque et al. 2021; Aslekar et al. 2022). Many water management projects that have disregarded the social aspects of watershed management have had negative outcomes (Aslekar et al. 2022). In MAR literature, disregarding local stakeholders during the planning process can have unfavorable outcomes for some stakeholders, potentially affecting their livelihood (Laukka et al. 2021; Laurita et al. 2021). Because of these issues, more researchers have incorporated participatory research methods into their projects (Brunner et al. 2014; Mankad et al. 2015; Page et al. 2020; Laukka et al. 2021; Laurita et al. 2021; Harvey et al. 2024; Saidani et al. 2024).

Significance & Deliverables

The deliverable for this project is a review article planned for submission to the *Journal of Water and Climate Change*. My goal in writing this paper is to synthesize current MAR literature and condense it into an easily accessible source for future researchers to reference. Additionally, this review article contains a discussion section assessing the strengths and weaknesses of participatory methods in MAR research. Identifying these strengths and weaknesses helps pinpoint areas of improvement for future MAR research. While this paper focuses on MAR, it could also extend to other areas of social science research. Social sciences that frequently utilize participatory research methods, such as anthropology, may find this review helpful for research projects that aim to co-create solutions with stakeholders that involve implementing other complex technical systems.

Participatory Research

Researchers use participatory research as a framework in which stakeholders act as co-producers of knowledge. Researchers use this research to develop actionable solutions to complex social problems, promote community engagement, and ensure that local stakeholders are involved in decision-making processes (Reed 2008). Through these methods, stakeholders have a more active role in research, allowing them to help inform policy and build a network of shared knowledge with other stakeholders and researchers (Reed 2008; Roque et al. 2021).

In anthropology, more researchers are transitioning from the solitary work of ethnography to collaborating with their community and organizational partners through participatory research (Kennemore and Postero 2021; Nebie et al. 2024; Negrón et al. 2024). Scholars have had a long-standing ethical debate about research, discussing how anthropologists can do research that prevents harm and is mutually beneficial to the researcher and stakeholders (Borofsky 2019; Kennemore and Postero 2021; Negrón et al. 2024). Participatory research provides a framework for anthropologists to move toward this ideal by placing stakeholder needs at the forefront of the project (Gubrium and Harper 2016). Anthropology's use of ethnography also positions researchers to use participatory methods well since ethnography engages and promotes the understanding of local knowledge systems (Koskinen 2014). Understanding local knowledge systems is crucial to participatory research since it aids researchers in understanding how stakeholders conceptualize and approach problems and events (Koskinen 2014).

Participatory research methods challenge the top-down approach to water research and focus on applicable solutions co-created by stakeholders and researchers (Conallin et al. 2017; Roque et al. 2019). In MAR literature, participatory methods have been a useful tool for researchers to ensure local stakeholders participate in the decision-making process of MAR planning. Researchers have incorporated these methods into their projects through participatory modeling, stakeholder analysis, citizen science, and participatory mapping (Brunner et al. 2014; Mankad et al. 2015; Page et al. 2020; Laukka et al. 2021; Laurita et al. 2021; Harvey et al. 2024; Saidani et al. 2024). These methods have helped researchers understand and address stakeholder needs, co-create solutions with stakeholders, and incorporate local knowledge into their work. Overall, participatory methods have helped researchers produce actionable insights for MAR projects.

CHAPTER TWO

PARTICIPATORY METHODS AND APPROACHES FOR ENGAGING STAKEHOLDERS IN MANAGED AQUIFER RECHARGE PLANNING: REVIEW AND FUTURE DIRECTIONS

Abstract

This paper explores the role of participatory research methods in managed aquifer recharge (MAR) planning and examines improvements researchers can incorporate in future MAR research. As climate change intensifies and groundwater continues to be overexploited, researchers are exploring more methods to conserve water and replenish groundwater. MAR, a method of artificial groundwater replenishment, is effective in combating water scarcity. Researchers have advocated for more research examining the social feasibility factors of MAR planning. Participatory research methods challenge the traditional top-down approach to water management research and are essential in the inclusion of local stakeholders in the decision-making process of MAR planning. In this paper, we review and critique the existing literature on how participatory research methods have been used so far in MAR planning and implementation. Following this review, we provide recommendations and advocate for integrating transdisciplinary approaches in future MAR research.

Keywords: Managed aquifer recharge, participatory research, stakeholder engagement

Introduction

Groundwater is a vital resource, accounting for roughly half of all drinking water, and is also widely used in agriculture (Cooper and Hiscock 2024). While groundwater is abundant, overexploitation has led to a rapid decline in 30% of the world's aquifers (Jasechko et al. 2024; Cooper and Hiscock 2024). Climate change exacerbates this decline by preventing aquifer recharge and increasing groundwater extraction due to drought (Lall et al. 2020). As this issue has progressed, researchers look for more ways to become climate resilient, conserve water, and restore aquifer levels. Managed Aquifer Recharge (MAR) is an engineering method that researchers believe has the potential to help alleviate water scarcity in many regions (Dillon et al. 2019; Kwoyiga and Stefan 2019; Lall et al. 2020; Marwaha et al. 2021; Harvey et al. 2024).

MAR is a water management system involving the artificial replenishment of groundwater for future use and recovery. MAR systems come in many forms, such as infiltration ponds, check dams, and injection wells (Dillon et al. 2019). These artificial systems involve preventing water runoff from being wasted by redirecting it into existing aquifers (Dillon et al. 2019). Researchers predict that MAR usage will rise in the future, and many countries and researchers are putting considerable effort into creating government frameworks or clearer guidelines for MAR planning (Sprenger 2017; Dillon et al. 2019). Most MAR research has involved hydrogeology, but in recent years, more studies involving government policy, risk assessment, public acceptance, and other feasibility factors have emerged, highlighting that MAR feasibility is dependent on numerous factors (Dillon et al. 2019; Escalante et al. 2023). Natasha Harvey and colleagues (2024) propose that MAR planning should consider the economic, technical, social, environmental, and regulatory factors when examining MAR feasibility. This diverse research is a reflection that MAR is very complex, containing many factors that affect feasibility.

Recent scholarship has argued that examination of the social impacts of MAR projects is crucial for successful implementation (Rawluk et al. 2016; Dillon et al. 2019; Fathi et al. 2020; Laukka et al. 2021; Marwaha et al. 2021; Harvey et al. 2024; Saidani et al. 2024; Sufyan et al. 2024; Zakir-Hassan et al. 2024). In some cases, water resource management research has had a top-down approach (Roque et al. 2021; Aslekar et al. 2022). Some water management projects have disregarded local knowledge, favoring more technical approaches, resulting in poor project outcomes (Aslekar et al. 2022). Researchers have suggested that stakeholders should have a more active role in MAR planning and groundwater management to prevent negative outcomes (Corre et al. 2021; Laukka et al. 2021; Laurita et al. 2021; Aslekar et al. 2022; Shalsi et al. 2022). Researchers have found that a lack of stakeholder engagement in MAR planning is detrimental to some stakeholders' livelihoods (Kwoyiga and Stefan 2019; Laukka et al. 2021; Laurita et al. 2021). Other research suggests that stakeholders’ preexisting knowledge of MAR systems and groundwater management may aid researchers in MAR planning (Saidani et al. 2024). Additionally, stakeholders may help upkeep MAR systems post-installation (Kwoyiga and Stefan 2019).

Participatory research methods offer important tools for conducting social impact research, promoting community engagement, and helping mitigate potential pitfalls associated with a lack of participatory initiatives. Participatory approaches provide a framework where research participants have more agency, act as co-producers of knowledge, and participate in the decision-making process of a research project (Roque et al. 2021). Water management and governance projects typically take a top-down approach where stakeholder opinions and concerns are not included in the planning process (Tsuyuguchi et al. 2019; Roque et al. 2021; Laukka et al. 2021). By using participatory methods, stakeholders have a more active role in the research process, allowing them to potentially shape outcomes in a way that is beneficial to them and addresses their needs (Roque et al. 2021). Overall, incorporating participatory methods in MAR planning can foster a mutually beneficial relationship between local stakeholders and researchers. In the following sections, I examine how participatory methods have been used in MAR research thus far and how researchers can implement participatory methods in future research.

Participatory Methods in MAR Research

Stakeholder Research

Stakeholder research is a participatory method that seeks to engage groups of people in the decision-making process of a particular issue or project. Stakeholder research facilitates engagement and consensus-building between stakeholder groups (Reed 2008; Roque et al. 2021). This engagement allows researchers to focus their research efforts on issues and concerns relevant to the stakeholders, thus challenging traditional top-down research approaches (Conallin et al. 2017; Roque et al. 2021). While this method challenges top-down approaches, it is usually used during the beginning and end stages (Roque et al. 2021).

In MAR research, scholars have mainly used stakeholder research to gauge the feasibility and stakeholder perceptions of MAR projects in different regions and countries (Brunner et al. 2014; Mankad et al. 2015; Page et al. 2020; Ayala et al. 2022; Bernat et al. 2023). Researchers have typically used surveys, semi-structured interviews, workshops, and focus groups to collect data on these topics (Brunner et al. 2014; Mankad et al. 2015; Page et al. 2020; Ayala et al. 2022). This research has been particularly helpful in the exploratory phases of MAR planning and understanding what barriers researchers may encounter throughout their projects. The most pressing concerns uncovered with this methodology were related to the effectiveness, land usage, the lack of understanding, financial costs, health concerns, and the regulatory challenges of MAR (Mankad et al. 2015; Page et al. 2020; Ayala et al. 2023; Bernat et al. 2023).

While gathering these insights is important during the beginning stages of MAR planning, stakeholder research is focused on information rather than action (Roque et al. 2021). Researchers have used this data to inform policymakers and for future guidelines (Brunner et al. 2014; Mankad et al. 2015; Page et al. 2020; Ayala et al. 2023; Bernat et al. 2023). Norbert Brunner and colleagues (2014) also found that stakeholder groups lacked a common vision regarding MAR projects and felt that a state authority should oversee MAR projects. While stakeholder data may be useful in future policy changes, stakeholders ultimately are not involved in the final decision-making process.

Participatory Modeling

Participatory modeling is a methodology that focuses on transdisciplinary collaboration between stakeholders, non-scientists, and scientists to develop complex models that support decision-making in planning processes (Falconi and Palmer 2017; Roque et al. 2021;

Quimby and Beresford 2023). Scholars use this method to bring together and solicit perspectives from different stakeholder groups, usually through workshops, focus groups, or interviews, to find an agreeable solution to a problem based on local and expert knowledge (Roque et al. 2021; Quimby and Beresford 2023). Participatory modeling is an iterative process where stakeholders should be involved in most development stages (Falconi and Palmer 2017; Quimby and Beresford 2023). Integrating stakeholder knowledge into these models facilitates collaborative learning between researchers and community members while democratizing knowledge production (Quimby and Beresford 2023).

In MAR, researchers have used participatory modeling to develop scenarios involving MAR feasibility and management (Laurita et al. 2021; Perdikaki et al. 2022; Rojas et al. 2022; Harvey et al. 2024; Mustafa et al. 2024). Researchers have facilitated stakeholder workshops discussing potential MAR planning and management strategies (Perdikaki et al. 2022; Rojas et al. 2022; Harvey et al. 2024; Mustafa et al. 2024). Some researchers have also implemented other methods, such as surveys, group discussions, and interviews (Wurl et al. 2018; Laurita et al. 2021; Rojas et al. 2022; Mustafa et al. 2024). These methods aided researchers in creating and developing scenarios that incorporated stakeholder knowledge and concerns.

While this method allows stakeholders to be on equal footing and come together to create a favorable outcome that benefits all stakeholders, there are some flaws. Researchers may fail to include every key stakeholder group in their workshops (Harvey et al. 2024). Vuokko Laurita and colleagues (2021) have pointed out that stakeholders not included in the planning process for MAR are at risk of being negatively affected by the project. Civil stakeholders may be overlooked in the recruitment process, reluctant to participate, or lack knowledge about MAR (Rojas et al. 2022; Harvey et al 2024). Stakeholders lacking MAR knowledge may need supplementary education about the subject to participate in model workshops effectively (Rojas et al. 2022).

Recruitment strategies may also affect stakeholder engagement. Syed Mustafa and colleagues (2024) used snowball sampling in their study, Vuokko Laurita and colleagues (2021) relied on a key authority figure for recruitment, and other scholars reached out to key stakeholder groups they felt were most relevant to their project (Wurl et al. 2018; Laurita et al. 2021; Harvey et al. 2024). While these recruitment strategies are standard for participatory research, they are still not fully inclusive and can result in certain stakeholder groups being left out (Reed et al. 2008). These methods rely either on the research team or another figure to identify who is most relevant to these projects. Depending on the selection criteria to seek out these stakeholders, researchers may miss out on including informal community organizations and marginalized communities (Butler and Adamowksi 2015).

Participatory Mapping

Participatory mapping is a process where community members and experts combine their place knowledge to craft maps that identify places of physical and cultural significance (Chambers 2006; Cochrane and Corbett 2018; Ilboudo Nébié et al. 2021). These maps act as a participatory approach that facilitates community engagement in the planning or exploratory process of a change-driven project (Cochrane and Corbett 2018). This method can manifest as various mediums such as sketches, global positioning systems (GPS), satellite imaging, three-dimensional models, and geographic information systems (GIS) (Cochrane and Corbett 2018). Researchers use these maps in a wide range of fields such as healthcare, climate change, cultural resource management, and urban planning (Cochrane and Corbett 2018). Participatory mapping can be beneficial to research projects based on infrastructure planning, identifying areas of conflict, assessing lifestyles and behaviors, and facilitating group learning between stakeholders and experts (Chambers 2006; Cochrane and Corbett 2018; Ilboudo Nébié et al. 2021).

In MAR, researchers have used participatory mapping when exploring areas where MAR projects are most feasible. Researchers have incorporated stakeholder input on areas where MAR is most feasible (Dahlqvist et al. 2019; Aloui et al. 2022; Martins et al. 2024; Panagiotou et al. 2024; Saidani et al. 2024). The process begins with researchers conducting a Geographical Information System Multi-Criteria Decision Analysis (GIS-MCDA), where they look for sites that are most suitable for MAR systems based on aquifer storage capacity, geomorphology, and soil in the area (Dahlqvist et al. 2019; Aloui et al. 2022; Martins et al. 2024; Panagiotou et al. 2024). After identifying these sites, researchers will share their findings with local stakeholders through workshops or interviews, allowing stakeholders to express their concerns and thoughts about MAR systems being built in these locations (Dahlqvist et al. 2019; Aloui et al. 2022; Panagiotou et al. 2024). Researchers may also use this process to incorporate any local knowledge about these sites that may have been missed through their analysis or aid their analysis (Aslekar et al. 2022; Saidani et al. 2024). Ultimately, participatory mapping promotes community engagement and empowers local stakeholders to be involved in the decision-making process of MAR projects.

Despite participatory mapping engaging stakeholders in the decision-making process for MAR projects, there are drawbacks to this method. The projects discussed thus far have utilized GIS mapping in their research. GIS mapping requires expertise and training to properly utilize, which may limit stakeholders from effectively participating in mapping activities (Cochrane and Corbett 2018; Sallwey et al. 2019). Fortunately, researchers have developed web-based tools to increase map accessibility for stakeholders who lack expertise (Sallwey et al. 2019). These web tools are designed to provide stakeholders a user-friendly way to interact with GIS mapping (Sallwey et al. 2019).

Participatory Rural Appraisal

Participatory Rural Appraisal (PRA) is a participatory methodology that uses a transdisciplinary approach to increase stakeholder involvement in rural development (Sadanandan et al. 2007; Roque et al. 2021). In PRA, researchers focus on incorporating stakeholder knowledge, experiences, and concerns into community development decision-making. Researchers use methods such as interviews, discussions, and workshops to identify community needs and concerns. They may also deploy other participatory methods such as art-based participatory methods, citizen science, educational workshops, and mapping (Sadanandan et al. 2007; Maheshwar et al. 2014; Jadeja et al. 2018; Saidani et al. 2024).

In MAR, researchers have used PRA to empower local stakeholders to engage in MAR management and planning (Maheshwar et al. 2014; Jadeja et al. 2018; Saidani et al. 2024). Researchers have used educational workshops to educate village stakeholders on sustainable groundwater usage through recharge structure management, mapping, groundwater monitoring, rainfall monitoring, and groundwater pumping (Maheshwar et al. 2014; Jadeja et al. 2018). Researchers hope that these educational seminars will address the knowledge gap between local stakeholders and experts and that stakeholders will help educate others going forward (Maheshwar et al. 2014; Jadeja et al. 2018; Saidani et al. 2024).

Photovoice

Photovoice is a participatory method that uses photography to identify stakeholders' needs and concerns (Gubrium and Harper 2016; Nykiforuk et al. 2011). In this method, researchers provide participants with cameras to capture pictures of key themes regarding the research focus. The photos are discussed and analyzed in interviews, workshops, or focus groups. This method is effective in raising awareness about community problems and building relationships between stakeholder groups and researchers. Photovoice can be a valuable tool to assess a community’s needs and promote stakeholder engagement in a way that requires little expertise (Gubrium and Harper 2016; Hergenrather et al. 2009; Nykiforuk et al. 2011).

In MAR research, there have not been many cases of researchers using photovoice or other art-based participatory methods. There has been one use of photo voice in MAR literature (Maheshwar et al. 2014). Nisha Maheshwar and colleagues (2014) used photovoice as a low-barrier method to help build engagement in their research, better understand their participants' perceptions of groundwater management, and foster relationships with their participants.

Citizen Science

Citizen science is a participatory approach where community members actively collaborate with researchers and assist them in data collection and analysis (Fraisl et al. 2022; Haklay et al. 2021). In water research, Citizen scientists typically assist with tasks such as monitoring water quality, rainfall, groundwater levels, and soil moisture (Roque et al. 2021). In doing so, citizen scientists can gain a deeper understanding of research processes, alleviate research workload, and aid in raising public awareness (Bonney et al. 2016; Haklay et al. 2021). Furthermore, citizen scientists act as liaisons between scientists and community members by disseminating research findings (Bonney et al. 2016).

In MAR research, researchers have used citizen science for monitoring purposes, community outreach, and education. Citizen scientists have conducted groundwater monitoring, rainfall monitoring, and groundwater pumping (Maheshwar et al. 2014; Jadeja et al. 2018). Citizen scientists have also examined water quality, tracked flooding, and aided in mapping current MAR systems that locals had already implemented (Saidani et al. 2024). In all instances of citizen science in MAR literature, Citizen scientists have been involved in community outreach and educating other local communities about MAR systems and groundwater management (Maheshwar et al. 2014; Jadeja et al. 2018; Saidani et al. 2024).

While citizen science often serves as a mutually beneficial approach for local communities and researchers, there are ethical concerns about its processes. Citizen scientists are unpaid volunteers, raising concerns about labor exploitation (Roque et al. 2021). Some have also expressed concern about their limited involvement and imbalance in power dynamics (Roque et al. 2021). Overall, citizen science should be conducted with great attention to these potential downsides to prevent the exploitation of participants.

Discussion

Thus far, one major weakness of the MAR scholarship is a lack of engagement with certain stakeholder groups (local communities, community leaders, etc.) and non-water-related organizations. Some researchers have expressed difficulties getting stakeholders to participate in their research despite researchers inviting them to attend workshops and other meetings about MAR (Laurita et al. 2021; Harvey et al. 2024). One case highlighted that they had to provide education note cards for some stakeholders so they could understand different terminology about MAR, hinting that there may be a knowledge gap among certain stakeholder groups (Perdikaki et al. 2022). Declan Page (2020), Mary-Belle Cruz Ayala (2023), and colleagues have noted that many stakeholders may lack a general understanding of MAR. This research suggests an ongoing knowledge gap between experts and stakeholder groups. Further attention should be given to closing this knowledge gap between stakeholders and experts.

Norbert Brunner and colleagues (2014) noted that stakeholders do not hold a common vision for MAR planning and would prefer to leave it to the state. Audrey Richard-Ferroudji and colleagues (2018) have argued that a lack of stakeholder engagement may also result in poor communication between researchers and local stakeholders. Others have noted that stakeholders are weary of regulatory challenges and lack incentives to implement MAR projects (Page et al. 2020; Ayala et al. 2023; Bernat et al. 2023). Based on this research, it may not be that stakeholders do not have the desire to implement MAR projects. Instead, they may face too many barriers that make MAR not worthwhile to them. Regardless, researchers and policymakers should pay further attention to work regarding MAR regulations and guidelines to alleviate some of these stressors for stakeholders.

Incorporating participatory approaches with lower barriers to entry may be beneficial in gaining increased stakeholder engagement. Maheshwar et al. 2014 had success in gaining stakeholder engagement using photovoice. Photovoice and other art-based methods focus on what stakeholders know about certain issues and their concerns regarding those issues (Gubrium and Harper 2016). Understanding what stakeholders know about MAR at the beginning of the research process would allow researchers to have time to figure out how to accommodate any stakeholder groups that may not have much understanding of MAR. Furthermore, increasing stakeholder knowledge of MAR systems could have long-term benefits as they could assist in the upkeep of these systems (Kwoyiga and Stefan 2019).

With the development of web tools that simplify GIS mapping, participatory mapping shows promise for MAR planning (Sallwey et al. 2019). Much of the MAR literature that uses GIS-MCDA to evaluate MAR feasibility fails to consider social factors or engage local stakeholders (Martins et al. 2024). Fathi et al. 2020 have also highlighted the potential of incorporating stakeholder engagement in GIS-MCDA. Several researchers who used GIS-MCDA without considering social factors have also recommended stakeholder engagement in future research (Rath and Hinge 2024; Zakir-Hassan et al. 2024).

Conclusion

The successful implementation of MAR projects is dependent on a variety of factors. Many scholars have advocated for researchers to pay more attention to social factors when considering MAR feasibility (Rawluk et al. 2016; Dillon et al. 2019; Fathi et al. 2020; Laukka et al. 2021; Marwaha et al. 2021; Harvey et al. 2024; Saidani et al. 2024; Sufyan et al. 2024; Zakir-Hassan et al. 2024). Not considering the social impacts of MAR planning could have negative results in the long term that may negatively affect stakeholder groups (Laukka et al. 2021; Laurita et al. 2021), result in MAR projects becoming more expensive (Kwoyiga and Stefan 2019), and overall result in poor project outcomes (Aslekar et al. 2022). While social aspects are crucial in MAR planning, MAR planning is very complex, and many fields make valuable contributions to MAR projects (Harvey et al. 2024). Convergence research involving transdisciplinary knowledge is crucial to the success of MAR projects.

CHAPTER THREE

CLOSING THOUGHTS

Summary

Participatory research methods provide researchers with a rich toolkit to incorporate stakeholder opinions and needs into MAR planning. Disregarding stakeholder concerns or simply not including them in MAR planning may negatively affect certain stakeholder groups. MAR can be overly complex for some people, and regulations and guidelines are not always clear, depending on the country and region. Participatory methods can mitigate and improve some of these situations. Ideally, researchers should use a range of participatory methods throughout different stages of MAR planning.

Stakeholder analysis is appropriate for the beginning and ending stages of MAR planning. This method is useful in gauging stakeholder knowledge and concerns about MAR (Mankad et al. 2015; Page et al. 2020; Ayala et al. 2023; Bernat et al. 2023). Researchers having access to this information may benefit research design elements, as it provides the researcher a baseline understanding of what challenges they may face with stakeholders and what accommodations they might need throughout the design process. Stakeholder analysis is an excellent method for informing policymakers in areas where MAR guidelines are not fully developed (Ayala et al. 2023). Researchers could also use stakeholder analysis to follow up on completed MAR projects to measure whether the project was successful.

Participatory mapping, citizen science, and participatory modeling are most valuable in the actual design phase of MAR planning. These methods are valuable for soliciting input from stakeholders and involving them in the decision-making process for MAR installation. During this phase, stakeholders can share their local knowledge to highlight different feasibility concerns researchers may overlook (Dahlqvist et al. 2019; Aloui et al. 2022; Panagiotou et al. 2024). There have been cases where some stakeholders either did not know much about MAR or could not understand the jargon surrounding MAR during workshops (Rojas et al. 2022). Coupling these methods with other art-based participatory methods may help mitigate some issues since they have a lower barrier of entry, which may encourage participation and learning. Participatory mapping presents issues for stakeholders, as researchers frequently use GIS tools for MAR planning that may be too complex for some stakeholder groups. Fortunately, researchers have been developing more tools to make GIS more accessible to people without a technical background (Sallwey et al. 2019).

Limitations & Future Recommendations

There is a lack of studies investigating stakeholder opinions and concerns after MAR systems have been installed with stakeholder input. While some scholars have highlighted the harms of not including stakeholders in MAR planning, no literature shows the long-term benefits of including stakeholder input in these projects. Doing a follow-up study could also help researchers pinpoint weaknesses in their research design that they may have missed during the original study, such as not identifying all stakeholder groups or missing certain feasibility risks. Following up on these studies would benefit MAR literature immensely as it would help develop a best methods approach for MAR planning.

MAR feasibility is complex. Natasha Harvey and colleagues (2024) have advocated for an approach that considers the economic, technical, social, environmental, and regulatory factors in MAR feasibility. While most of the MAR literature regards the economic, social, and environmental factors, the social and regulatory aspects of MAR planning could benefit from further exploration. With so many factors affecting the success of MAR projects, a transdisciplinary approach may benefit MAR planning. Participatory convergence offers a framework that enables researchers to take a rigorous approach to MAR planning while still incorporating stakeholder knowledge and opinions.

Participatory convergence is a holistic research approach involving multidisciplinary teams collaborating with local stakeholders and institutions to address complex issues (Castro-Diaz et al. 2024; Birthisel et al. 2020; Lakhina et al. 2021; Roque et al. 2021). This approach helps ensure stakeholders actively participate in MAR planning, and researchers can look at a wider range of feasibility factors. The facilitation of shared knowledge between multidisciplinary researchers and stakeholder groups could improve stakeholders' understanding of MAR, potentially allowing them to be more involved in decision-making processes. This shared knowledge may also expand the capabilities of citizen scientists, which could help maintain MAR systems, potentially resulting in cheaper long-term maintenance (Kwoyiga and Stefan 2019). Furthermore, in participatory convergence, shared knowledge expands past learning between researchers and stakeholders, by facilitating knowledge exchange between researcher groups. Shared knowledge from different fields could result in researchers and stakeholders co-producing MAR systems that account for more complex issues (Birthisel et al. 2020; Lakhina et al. 2021).

Closing Remarks

Traditional top-down research approaches for water management projects that ignore stakeholder knowledge can result in poor outcomes that negatively affect some stakeholders. Collaboration between researchers and stakeholders is imperative to the successful implementation of MAR systems. While researchers have established a greater need for MAR research on social feasibility factors, this research would also benefit from longitudinal studies examining the outcomes of projects produced with participatory methods. Furthermore, MAR is incredibly complex, causing misdesigns that potentially have tremendous economic, environmental, technical, and social consequences. MAR's complexity promotes the need for convergence research to help prevent design consequences.

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