DOI: 10.31276/VMOSTJOSSH.64(1).25-35

Citizen science matters: theorizing citizen science and exploring its promises for addressing Mekong environmental problems

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Received 6 October 2021; accepted 4 January 2022

Abstract:

Starting with the view that the emergence of citizen science initiatives proves the fullest potential to address environmental problems and promote sustainability from the ground up, this conceptual paper aims to explore why citizen science matters for a low-carbon future in the Mekong region. Based on a literature review and semi-structured expert interviews, this paper highlights the importance and unique impacts of citizen science in science, policy, and sustainability education spheres. These impacts are reflected in case studies of United States and Belgium. Results from empirical data also reveal that citizen science is transforming research, educating and informing the public, and decentralizing and informing policy. The results further provide promises for addressing environmental problems in Mekong countries where environmental degradation seems to be getting murkier. The paper concludes with a discussion as to how citizen science should be embedded in local environmental governance as it revolutionizes our understanding of the environmental challenges and promotes evidence-informed policy making.

Keywords: **citizen science, environmental governance, Mekong environmental problems, sustainable development.**

Classification number: **4.1**

Introduction

The promise of economic growth pulls Mekong countries to rapid urbanization and damming of the Mekong river. But, across the region, two of the most pressing problems facing their new-found strengths also come together: biodiversity degradation and environmental insecurity. These problems are human-induced, cross cutting in nature, and accelerating in pace and severity as urban areas swell. Businesses and people will be in danger of a "double crisis" should human stressors intersect with climate change effects such as extreme weather conditions and geophysical disasters. While strong policy planning and technological innovations are essential in managing environmental insecurity issues, there exists little evidence that demonstrates the success of top-down policies and solutions.

Against this background, in recent years there has been an increasing popularity of "citizen science" in environmental, ecological, and climate change fora in the world. Even in times of global crises, such as Covid-19, numerous curious people across the world are online and contributing useful data

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for science [1]. In some pharmaceutical and biotechnology think tanks and universities, scientists are employing citizen science tools and strategies to harness the power of the crowd to generate robust and diverse data sets for predicting outbreaks, understanding infectious mechanisms and symptoms, and validating treatment models that might have been otherwise unavailable [1, 2].

Advances in science and technology, the rising penetration of the internet, and the ubiquity of smartphones are all currently fostering citizen science. The cooperation between researchers and local communities becomes less challenging thanks to easy data collection on mobile apps that facilitates user engagement. Current citizen science tools are designed on the basis of strict data management standards applied to both input and output including data quality assurance, data infrastructure, data documentation, data governance, and open-data access norms. Some widely known citizen science platforms include Scistarter, iNaturalist, OpenStreetMap, BioCollect, CitSci.org, Citizen Science Alliance, NASA's GLOBE Observer, PlantNet, Open Development Mekong, Zooniverse, and many others. Citizen science platforms are web-based infrastructures or portals that enable multiple functions including identifying real time projects; displaying data and information; providing guidelines and tools; and offering lessons, examples, and scientific outcomes [3].

Furthermore, multiple citizen-science organizations are banding together to form a worldwide group - the Citizen Science Global Partnership. This network seeks to promote and advance citizen science for a sustainable world. Launched in December 2017, it assists in monitoring progress towards the United Nations' Sustainable Development Goals (SDGs) and brings together citizen science researchers and practitioners with advisory boards representing policy, business, and community-based perspectives.

Globalization and international scientific cooperation have promoted the presence of citizen science in policy advocacy nationwide, regionally, and globally. Recent research of the National Aeronautics and Space Administration (NASA) and the United Nations (UN) have stressed the role of citizen science in "democratizing science" and making scientific research more accessible. Community contributions to data collection are rapidly becoming more important and popular to researchers, think tanks, government agencies, and Non-Government Organizations (NGOs). The broader use of citizen science is reflected in biodiversity, environment, climate change, biogeography, agro-forestry-fishery, and the prevention and control of disasters and pandemics to name but a few. Many governmental agencies in countries like Australia, Canada, Ireland, Japan, Scotland, and the United States have institutionalized citizen science. Crowd-sourced data are being used by the UN bodies for humanitarian activities, disaster response, and implementing SDGs [4, 5].

The fresh surge of interest in citizen science across societies has resulted in an inevitable shift towards multi-actor and bottom-up environmental governance that enables and encourages public participation in collecting and sharing information of all kinds, in policy making process, and evaluation [4, 6]. It seems likely that breakthroughs in environmental

governance - nationally and globally - will increasingly occur through citizen science fora that support the society's growing demands for more participatory decision-making through interaction between government policy-making agencies and non-state actors, including scientists and citizen science communities [7-10]. But efforts to define and strengthen the role of citizen science within this shifting architecture of governance, and in environmental governance in particular, are still at early stages [11].

By acknowledging that the promise of economic growth pulls the Mekong riparian countries to urbanization, this narrative review aims to understand the promises of citizen science in the Lower Mekong countries where environmental security challenges are threatening to undermine their new-found strengths and where digital infrastructure is available for public participation in scientific work. Although citizen science is not the only participatory approach in environmental research and governance, it can generate crowdsourcing data more quickly, enhance the sustainability of research projects more effectively, and disseminate the research findings wider than other existing participatory approaches [11]. This paper first conceptualizes citizen science from a historical perspective to trace the origin of citizen science and explore its nature as an approach to scientific research. The second section discusses the importance of citizen science in terms of policy, science and public awareness. Case studies of two different countries are briefly presented to provide empirical evidence to the impacts of citizen science in environmental governance. The last section analyses some promises for citizen science in the Mekong countries and prompts a call for mainstreaming citizen science in environmental action in the region as a bottom-up approach to addressing environmental challenges.

Conceptualizing citizen science

Although citizen science has recently attained worldwide attention, there has been a long history of citizens supporting scientific research. Wells W. Cooke, a member of the American Ornithologists' Union, was arguably the first scientist to develop research programs that allowed for public participation in the United States in the late 19th century [12, 13]. Cooke built a network of volunteers in North America, mainly farmers and conservation agents, to collect data related to the patterns of bird migration and bird population figures, which were recorded on cards. Those data cards are currently being digitize and recorded into a public database for historical analysis [13]. His efforts to empower public participation in research activities triggered the birth of citizen science in the world.

Cooke's successful community-based bird research programs inspired the practice of citizen science in bird research and conservation for decades afterwards. The increasing availability of the internet in the western world in the late 1990s facilitated data collection and sharing without geographical constraints. This enabled scientists and organizations to employ Cooke's public participatory research methodology in their ecological and environmental research and conservation of rare plants and animals [13]. Given the rising role of public participation in research "citizen science", "open

science" or "community science" are termed interchangeably to label scientific research activities that involve ordinary citizens. "Citizen science" has been more formally used over the last decade. Environmentalists, climate change scientists, and urban planners, among others, have actively encouraged local public participation to collect field-based data.

As such, "citizen science" refers to community-based scientific research. Community members, from kindergarteners to senior citizens, are empowered and encouraged to collect and contribute information, knowledge, and data to enrich and test scientific theories [5, 6, 13]. Viewed in that light, citizen science is widely conceptualized as the public participation and collaboration in scientific research. In other words, the term "citizen science" is best described as the collaboration of scientists and volunteers to broaden the scope of research and enhance the compiling of scientific data [14].

Citizen science continues to distinguish itself by the following characteristics: the participation of citizens is voluntary, local communities are one of the major beneficiaries of the research, citizen science and crowdsourcing data are updatable and linkable, which allows further research at different levels and scopes, i.e., local, subnational, national, and international. The mobilization of citizens fosters an active stewardship toward their land and water among other natural assets.

The public participation and collaboration in scientific research are classified into three dimensions as follows: contributors (citizens act as data collectors), collaborators (citizens are employed to collect and analyse or interpret data), and co-creators (citizens participate in research stages, from problem identification, question defining, to research design, to data analysing and visualization) [5, 15]. Co-creators are "citizen scientists" who are well-trained to lead and introduce mobile research tools to their communities in citizen science projects. They are local change agents.

Why is citizen science important?

Citizen science really matters owing to its positive impacts on science, education, and policy [15]. Researchers are primary beneficiaries of community-driven science. The standardized and globally contributed crowdsourcing data enable researchers to access data sources that are visually and explicitly presented without efforts and costs. In early 2020, the popular people-powered research platform zooniverse successfully recruited approximately 200,000 participants for its image-based animal classification project. With more than five million classifications within a week, the result they contributed is equivalent to that in 48 years of research [2]. Joining data sharing and information itself help communities enrich their scientific knowledge and realize challenges facing them, which inspire greater behavioural changes [15, 16].

Collective perceptual changes together with real-life experiences and rich data demonstrate significant policy information for local authorities. For example, community data on seasonal air pollution trends enable the authority to proactively adjust emission sources by, for example, relocating factories, and cutting coal-fired power, etc. Data on endangered animals tracking allow early warning and accelerate conservation plans

[17]. In addition, community-contributed data, including indigenous knowledge and experience that cover new viewpoints or field evidence, ensure that research and policy match local contexts. This shows bottom-up approach and decentralized policymaking in citizen science, or evidence-based policy, in other words. However, the level of decentralized decision-making power in terms of resource management or rights to clean water has proven a challenge in a number of places, including Mekong countries, when laws and regulations do not always permit decentralized management actions. Consequently, the government faces mounting pushback from citizens who resent the damage wrought by pollution-intensive industries.

More importantly, citizen science becomes popular with more ambitious and broader connections [5]. The boom in citizen science data over a wide range of fields likely results in big data - solid foundations of the knowledge economy and key pillars for a transparent society and sustainable development in many countries. Big data is understood as data sets that are so large that they become difficult to analyse and manage with traditional means [18].

Finally, citizen science offers an opportunity to build public trust in science and authorities [19, 20]. Some scientists have placed their trust in the possibility of clearing public doubts from the collaboration of science and community [2, 5]. Consequently, investing in citizen science is not only an investment in the science-community partnership but also in public trust and support. The governments of Australia, the United States, the United Kingdom, and some other European countries have been aware of the benefits of citizen science and have intensified investment in strategic community science programs regardless of environmental protection, climate resilience, public health, or policy review [21-23].

Addressing environmental problems through citizen science: examples

Advanced science and technology help actualize community science-led ideas and generate practical impact in addressing environmental problems. A number of mobile apps have been developed to expedite the public research process. The number of open science projects surged to 800 in 2019 from 200 in 2010, which was revealed by the statistics from the crowd-sourced data platform SciStarter at Arizona State University, Tempe, Arizona. Community-controlled science has been applied in various fields, namely, air and water quality monitoring, plastic pollution, animal migration tracking, and observational astronomy [21-23]. The following case studies show how citizen science is used and the perspectives it offers for specific riparian and urban environmental problems.

Mississippi river plastic pollution initiative (the United States)

In 2018, policy makers and governments of cities along the Mississippi river were committed to reducing plastic waste in the basin by 20% by 2020. To make the goal possible, the United Nations Environment Programme (UNEP), the National Geographic Society, and the University of Georgia launched the Mississippi river plastic pollution initiative. The community science-led project records data and generates a plastic pollution map along the riverbank and in riverside

communities empowering policy makers and stakeholders to make proper decisions. The Debris Tracker mobile app simplifies steps like tracking plastic waste, taking photos with automatic locations, classifying them into types (industrial or household use, nylon, bottles, etc.), counting debris on-site, and uploading to a public database.

Debris Tracker is also a popular community science-driven software for global plastic waste tracking. The open database stores roughly three million observations on plastic trash collected by a network of more than 50,000 volunteers. Its convenience and significance enable the app's continued popularity and user loyalty. As a result, the Debris Tracker generates new daily downloads from increasing numbers of land and ocean stewards from the largest producers of plastic waste like China, India, Indonesia, and the United States.

"Street science" (CurieuzeNeuzen) in Belgium

Filip Meysman, a biogeochemist at the University of Antwerp in Belgium, conducted an air quality monitoring project in Flanders, Belgium, in May 2018. With the support of the Flanders Environment Agency and local media, the air quality measurement campaign drew approximately 20,000 urban participants who paid EUR10 each to install devices on their windows (of the first floor) that faced the street. The month-long project ended with the results from 17,800 spots measured by 99% of sensors installed. The data enabled the team to measure nitrogen dioxide (NO_2) concentrations at "nose height" - a level of the atmosphere that can't be discerned by satellite. The community contributions generated reliable data on the air pollution situation in Flanders.

Dawn of citizen science in the Lower Mekong sub-region

The Lower Mekong subregion, a transnational region in mainland Southeast Asia, spans the following five countries: Myanmar, Laos, Thailand, Cambodia, and Vietnam. While it has survived the trauma of wars, the region now faces mounting environmental threats from climate change, upstream dams, deforestation, and declines in biodiversity, food security and water resources. Since Conservation International places this rich biodiverse basin as one of the five most threatened hotspots, the ranks of professional scientists, researchers, and policy experts may not prove sufficient to reduce the escalating dire environmental problems.

Since more dams are planned for the Mekong river and rapid industrialization of riparian countries, there has been an increasing number of technocrats and policymakers recognizing the potential benefits of greater connectivity to promote openness and transparency in decision making. This environmental awakening has been on a fast growth trajectory with the advent of new technology and smartphone apps to monitor the environment.

Katherine Rowland, a journalist, wrote in *Nature* about the capacity of citizen science to empower local citizens explains, "the next generation of citizen science attempts to make communities active stakeholders in research that affects them, and uses their work to push forward policy progress" [24]. Thus, citizen science action represents a greater attention shift in the region enabling local NGOs and international development partners to mobilize local voices and democratize science

in response to the widening transboundary injustice along the Mekong.

Citizen science projects have been available in the Lower Mekong countries for at least a decade. In Thailand, several citizen science teams of students and environmentalists from 13 provinces in the central, western, and eastern parts of Thailand brought together by Sommuck Jongmeewasin, an environmental management lecturer at Silpakorn University International College in Bangkok, successfully investigated and developed a database of 40 illegal dumps of hazardous industrial waste, which were previously unreported by government agencies [25]. In Vietnam, a small-scale collective research into illegal sand mining in the Red river and air pollution were carried out in Hanoi. Meanwhile, a group of students and young journalists who were trained to collect data and report environmental news in the Cham islands attempted to clean up the maritime environment from plastic waste and restore local ecosystems towards sustainable community-based tourism.

In the Mekong delta, the Mekong Environment Forum (MEF) based in Can Tho city (Vietnam) has held a number of impactful citizen-science projects in recent years in the disaster-prone areas of the Mekong delta. The Mekong Security Atlas was recognized and established in March 2019, which was supported by the Earth Journalism Network that built an open-access web-GIS citizen platform enabling citizen scientists to contribute datasets and report about environmental issues. Locals, including environmental practitioners, students, provincial government representatives, and experts were encouraged to identify major issues threatening their livelihoods and ecosystems in their communities and then post their stories and observations, suggestions, and photos/video clips about the issues. The platform serves as a gateway for marginalized groups to engage in reporting environmental and natural resource-management issues that threaten their communities. MEF has trained a number of students, women, and provincial government representatives from diverse backgrounds and different universities in Southern Vietnam.

The chart in Fig. 1 outlines the major approach to citizen science in MEF projects. First, young professionals and students are trained in citizen science training workshops. They work in groups, and each group is usually comprised of two senior researchers, four to six undergraduate students majoring in environmental studies, social science, or geography, and two local liaisons that help handle administrative and logistics arrangements. Local liaisons fully participate in the training workshops and a field research design course to be fully aware of the research objectives and fieldwork plans. Their knowledge and updates about local situations were helpful for the field research groups to timely adjust the fieldwork plans. These research groups network scientists and experts with local farmers by introducing new techniques and solutions to local communities. Some field schools are established in host villages to implement and test new techniques or solutions. The cooperation of citizen scientists and local communities in the field in turn provide evidence and data back to the scientists to enrich their theory or research findings.

Fig. 1. Key stakeholders engaging in a citizen science project. Source: MEF.

Local men and women take part in the fieldwork and learn new solution. By doing so, they act as the change agents who learn to master new techniques introduced by academic and solution partners. Another key to the impacts of citizen science is that it focuses on economic self-reliance and nature protection by networking local stakeholders to build local value chains and bottom-up sustainability. This enables local communities to sustain their livelihood without degrading environmental resources. As farmers are trained to get familiar with the new technologies, they are able to adjust the solutions to fit within future changes.

Citizen science illustrates how to translate multi-stakeholder governance down to local levels in a centralized, top-down administrative context. As the citizen science projects involve different disciplines and sectors to address the complexity of food-water-energy security nexus, they also reflect the inter-sectorial coherence and interconnectedness in coping with the environmental changes.

Concluding remarks: promises and a need for mainstreaming citizen science in environmental action

This article is the very first to conceptualise citizen science as a crowdsourcing approach to scientific research and a grassroots, bottom-up approach to environmental action. For more than a decade, citizen science has been receiving increased attention because of its potential as a cost-effective method of gathering data sets and as a way to bridge the intellectual divide between citizens and scientists.

Worldwide, media-based citizen science is changing how science is communicated to the public, how the voice and concerns of local disadvantaged groups are heard, and on-the-ground data contributors can contribute their stories to enrich the scientific theories and support policy reforms. In short, this new generation of citizen science attempts to make active community stakeholders in research that directly affects them. So, citizen science becomes a potential solution strategy for grassroots communities in the Lower Mekong region and the rest of the developing world where they currently experience top-down, centralized political administration.

The Lower Mekong Subregion, in particular, is poised to become a necessary destination of community science projects to better address its environmental challenges such as climate change, resource degradation, wildlife trade, sea and river pollution, natural disasters, pandemics, etc. Although citizen science has not been formally institutionalized and recognized by the riparian governments, many state agencies such as those in Vietnam have begun to receive feedback regarding policy [26]. Furthermore, the advances of social media and open-data sharing, together with the growing rate of smartphone and internet users, work as an important digital platform that supports the growth of citizen science across the region. For example, with Vietnam's professional ranks of software developers and the increasing interest in digital-age technology, there are increased opportunities to draw upon the talents of young citizen scientists who are watchful environmentalists. For that reason, guiding/directing part of the public in community science forums both helps enrich their scientific knowledge, curb fake news-related consequences, and avoid wasting open data resources as well.

Throughout the region, incubators of the power of citizen science are visible. In the most hardscrabble villages, access to a smartphone is beyond the reach of many. Based on the past, current, and upcoming citizen science workshops in Thailand and Vietnam as mentioned above, there is compelling evidence to support students and the broader public in helping to mitigate the environmental challenges in rural and urban areas. For Mekong countries, one of the most pressing issues is environmental pollution and the immediate need to mitigate and adapt to climate changes, which is an issue that overlaps with the UN SDGs of combating global issues and promoting sustainability.

Local governments can and should take a leadership role in embracing the benefits in citizen science as part of an overall educational initiative. The purpose is to engage young citizens to help bolster the country's environmental enforcement and monitor the rapidly growing anthropogenic stressors. Rollouts of citizen science workshops in schools foster a participatory turn in science policy and support the claim in this paper, which is that citizen science can and does lead to a democratization of science by turning science from a closed to an open activity [27]. These trained citizen scientists can support the efforts of local government agencies to work closely with the public to complete data collection on the impacts of a wide range of issues from transboundary environmental degradation, water crisis, strengthening food

systems, preserving agricultural biodiversity through seed exchanges, tidal flooding and air pollution in cities, and they are cost-effective in the promotion of sustainability in resource-limited economies.

In order to meet the nation's sustainable development goals, policy planners realize that there's an urgent need to improve society's awareness of sustainability issues and to mobilize all citizens just as they have done in response to the current pandemic. The success in the implementation of the 2030 Agenda for a better, safer, and more secure future for all its citizens require a complete "buy-in" from all. The key is to train more student volunteers or citizen scientists as it is an important vehicle in democratizing science and promoting the goal of universal and equitable access to scientific data and information. It is our recommendation that institutions and think tanks established alongside select NGOs, like MEF, create a task force on the contributions of citizen science that will help advance local government objectives to meet the 2030 SDGs.

COMPETING INTERESTS

The author declares that there is no conflict of interest regarding the publication of this article.

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