Chapter 55
Citizen Science on Water Resources Monitoring in the Nhue River, Vietnam

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Abstract The explosion of citizen science (CS) in data collecting, including hydrology and water resources management, results from information and communication technology development. This approach is still a new topic in Vietnam, while CS development stages are not popular in the previous works. This paper demonstrates how a CS project can be developed, a pilot area at Lien Mac 2 sluice, Noi Bridge, and Dong Bong 1 pumping station on the Nhue River, Vietnam. There are seven main stages to implement a CS project, in which monitosring observation choose is a crucial factor to attract participants and obtain long- recorded observations. Social network and smartphone are a tool to boost CS development and the young generation is interested in this approach. Citizen-based water level monitoring was conducted by images that will be uploaded on social networks. The water levels obtained from the CS on the Nhue River are as good as the conventional approach. The step-by-step CS approach can be applied in other aspects of water resources management such as land use, water quality monitoring to promote the CS development.

Keywords Citizen science · Citizen science approach · Water resources monitoring · Water level · Nhue River

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M. Babel et al. (eds.), *Water Security in Asia*, Springer Water,
https://doi.org/10.1007/978-3-319-54612-4_55

55.1 Introduction

Citizen Science (CS) is defined as the participant of local people in projects organized by government institutions, researchers to collect data (Walker et al. 2016), while Buytaert et al. (2014) illustrated CS as an involvement of the general public in creating new knowledge, which can help to address local problems. CS is a new and innovative approach to collect and gather data in the all field, including hydrology and water resources (Buytaert et al. 2014), (Cohn 2008), (Beza 2017). Data amassed by communities can be at low cost, more spatially distributed, and relatively accurate (Buytaert et al. 2014; Gardiner et al. 2012; Zeng et al. 2020; de Bruijn et al. 2019). With the explosive development of Internet and Information Technology, CS has been stimulated by using social media like Facebook, Tweeter, or Web-based platforms to attract and retain local people's participation in collecting data and information (Davids et al. 2019).

There are several CS projects to collect water-related data over the globe over the past 50 years. In the 1970s, Minnesota Pollution Control Agency implemented citizen-based water quality observation to protect the environment, which helps people change participation attitudes from curiosity at the starting time to self-responsibility about environmental protection after 30 years (MPCA 2020). Peters-Guarin (2008) researched on applying the local knowledge in flood risk assessment for urban areas in the Philippines. The work emphasized that local knowledge had a crucial contribution to flood risk assessment. The author concentrated on exploiting information and data from communities through stories, oral descriptions and narratives. In order to improve hydro-meteorological monitoring networks in Ethiopia, a community-based monitoring program from 2014 to 2015 was established to monitor daily rainfall, surface, and groundwater level to maintain the conventional observations stopped due to lack of funding (Walker et al. 2016). Recently, Davids et al. (2019) developed CS in precipitation monitoring in Nepal, known as Smartphone4Water.

Apart from mining data from local communities, CS is considered non-structural measures for solving water resources (Buytaert et al. 2014) or flood risk management problem (Ferri et al. 2019). Some researchers presented that CS projects help local people raise their awareness about water resources and strengthen their capacity to react to natural catastrophes (Cheung and Feldman 2019; Starkey et al. 2017). For example, local people involved in flood observation of flood risk projects can reduce annual flood damage, while the cost of CS approach is less expensive than structure measures (Ferri et al. 2019). The citizen participation can create transparent information in order to promote democratization, which stimulates debate and supports the decision-making process between stakeholders (Buytaert et al. 2014) and policy building (Minkman et al. 2017).

Despite the significant development of CS on water resource monitoring globally, it is still an alien approach in Vietnam. Since 2009, CS has been applied in transportation to inform the traffic situation in the Vietnam capital (VOV Giao thông 2019), Hanoi, which can help listeners choose an appropriate road in rush hours. This

model could be considered the first CS approach in Vietnam. Le (2015) and Đinh Hoe et al. (2011) highly recommended the contribution of local people on water resources management in general and reservoir operation in particular. However, these previous research on water resources have just been the ideas. It is necessary to implement a CS project in water quality, quantity, and morphology in Vietnam (Nhan et al. 2015).

The water level is one of the primary parameters in water resources information, while it does not require some special equipment and physical installation like discharge measurement or rainfall (Etter et al. 2020). This paper presented the stages to implement a CS project on water level monitoring on the Nhue River, Vietnam, which can be scaled up in other basins or other objects.

55.2 Material and Methods

55.2.1 Nhue River Overview

The Nhue River is a distributary of the Red River, a primary river flowing through Hanoi. It transfers on water from the Red River at Lien Mac sluice to irrigate for the Dan Phuong - Hoai Duc irrigation area and surrounding area. In addition, The Nhue River is responsible for draining off water for the Western districts of Hanoi city, water generating from To Lich, Cau Nga, and Pheo (other name Dam) River (Tran et al. 2016). The Nhue River flows into the Day river at Phu Ly city, Ha Nam province, a 74 km length (Fig. 55.1). In recent years, the water level of the Nhue River did not change much except during rainstorms in the flood season. The Nhue River receives the wastewaters without treatment from households, the craft villages, and the small to medium-sized industrial zones leading to the serious-polluted river. The mean annual water level is around 3.06 m for Ha Dong.

The pilot river is of 18 km length, limited from Lien Mac sluice to Ha Dong sluice, far Ha Dong Bridge about 2 km toward the downstream river. There are some key water-work along the section, such as Lien Mac, Lien Mac No.2 and Ha Dong sluices, Thuy Phuong, and Dong Bong pumping stations (Tran et al. 2016). A manual staff gauge was erected on these positions to monitor the water level. The monitored daily water level at 7 am and 1 pm at Lien Mac, and Ha Dong are updated on the website of Day River Irrigation Development Investment Co., Ltd (shorturl.at/acgw7).

There are several universities located on the basin, including HUNRE. It might be a favorable condition to organize field trips and recruit participants.

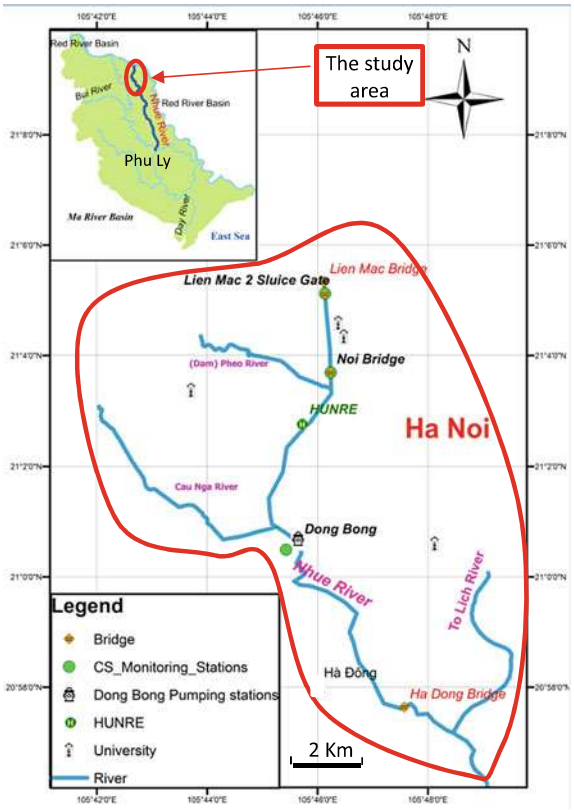


Fig. 55.1 The diagram of the study area and SC monitoring locations

55.2.2 Research Method

The approach to developing a CS model in the water level monitoring of the Nhue River consists of seven main steps, are shown as Fig. 55.2.

The first step needs to have an overview of research on CS and features of the study area. Following this, the research conducts surveys of monitoring works in the study area. Afterward, we select the monitoring locations with existing works such as pumping stations, bridges, culverts, and locating areas convenient for data collection. In the following stages, after selecting the monitoring locations, the research proceeds to establish the measuring structures by painting water level gauges on the works and assuming the presumptive elevations for each location or using the available water level gauges at the waterworks.

Simultaneously, the research team will invite participants. At this stage, we develop a questionnaire to identify the local people's concerns about water resources and their expectations and motivation to participate in the project. The survey participants' personal information will also be processed and analyzed by age, education level to determine the potential participants. Interviewing and selecting participants

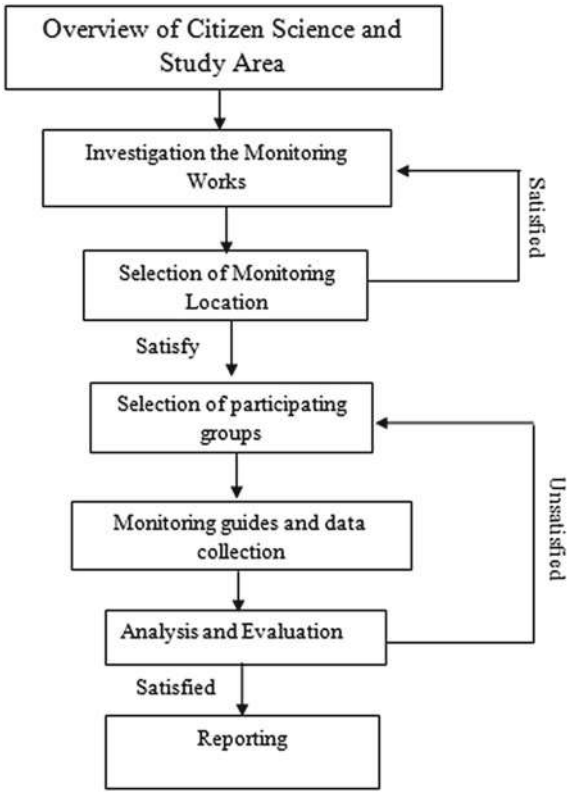


Fig. 55.2 The key stages of SC project on water level monitoring on the Nhue River

is conducted in three periods (December 10, 2015, March 12, 2016, and April 24, 2016) to attract more participants in the project and improve the suitable participants' approach.

In the following stage, we guide participants on observing and sending data at the monitoring stations. The study also depends on the actual situation to choose an appropriate communication method with the participants via SMS messages, social networks, etc.

Afterward, water level obtained from participants will be compared with the water level at some existing monitoring stations on the river section. Thereby, it helps check and detect erroneous data and promptly respond to the participants to improve in the next observations.

The final step is after verifying and assessing the suitability of the data, the water level data will be published widespread so that all participants can follow, or other peoples can access the data for the research, assessment, or management of water resources.

55.3 Results and Discussion

55.3.1 Selecting and Constructing CS Observation Points

To choose the appropriate monitoring stations, research was conducted to investigate existing monitoring stations and constructions along the Nhue River to install staff gauges to reduce tasks. Monitoring stations should be accessible to everyone and must not be harmful to participants during the observing process. Several water level monitoring works were currently installed by Nhue River Irrigation Development Investment Co., Ltd to operate drainage and irrigation systems on the Nhue River, such as Lien Mac 1, 2 sluices, Dong Bong 1, 2 pumping stations, and Ha Dong sluice, etc. The Nhue River separates urban and sub-urban areas of Hanoi. There are, therefore, many bridges across the river like Noi, Dien, Nhue, Ha Dong bridges. Three stations are chosen: Lien Mac sluice No.2, Noi bridge, Dong Bong No.1 pumping stations to implement the CS project. The locations of CS observations in water resource monitoring is shown in Fig. 55.1 and Fig. 55.3.

These selected stations are located on a straight branch, which meets the station designing standards, while these areas are of crowded residents and can avoid tracks and busy streets at highways and main avenues. Lien Mac No. 2 sluice is a control structure integrated traffic bridge, which combines with Lien Mac No 1 sluice to control flood from Red River for Ha Noi. Lien Mac No 2 sluice gates normally open to transfer water from Red River to Nhue River for irrigation purposes. A small bridge was designed to operate and maintain structures on the top of the sluice gate where participants can stand there to monitor the water level. Noi Bridge is far from Lien Mac No sluice more than 2 km toward downstream, with two bridges to serve traveling, a smaller and lower one for pedestrians, bicycles, and scooters. We installed a staff gauge on a pier of the remaining bridge, while a vertical datum was assumed at pile cap level (Fig. 55.3.a, b). Dong Bong No1 pumping station is an outlet of My Dinh urban area's combined drainage system, consisting of complex constructions to drain into Nhue River such as pumping and culverts. Staff gauges were installed

(a) Constructing a staff gauge on the Noi Bridge pier

(b) Noi Bridge

(c) Lien Mac No. 2 sluice

(d) Dong Bong No.1 pumping station

Fig. 55.3 The views and staff gauges of pilot areas on the Nhue River

on the culvert, hidden when the valve gate is heightened to drain water into the Nhue River (Fig. 55.3.d).

55.3.2 Participants in CS

The interview took place in three phases in the monitoring stations and surrounding areas, which lasted one day for each period (December 10, 2015; March 3 and April 24, 2016). The first three authors interviewed 69 people, and the number of respondents per phase was 19, 9, and 45, respectively. After finishing each phase, the research reformulated the questionnaire form to reduce redundant questions and match the actual situations. The information of the interviewer was announced to be anonymous to get honest responses.

Third-four of the interviewers agreed to join the CS project with some appealing reasons such as environment protection, research supporting, and their curiosity about CS. The 25% of people interviewed disagree to join the project; most of them are the elders being afraid of health conditions and technical skills to join projects. However, one of them is keen to share their knowledge of the river, which they witnessed. There are three age groups taking part in interviews, including 18–34, 35–60, and 60–75 year olds. The 69% of interviewers were 18–34 year-olds, mainly students studying at the study area universities. Two remaining groups only occupied one-third of the response, sharing 22% and 9%, respectively (Fig. 55.4).

The participants agreeing to join the project graduated with bachelor's degrees and high school with 59%, 33%, respectively, and less than 15% only study secondary and primary school.

The participation recruitment processes were divided into different periods. Figure 55.5 demonstrated the percentage of the number of interviewees joining the

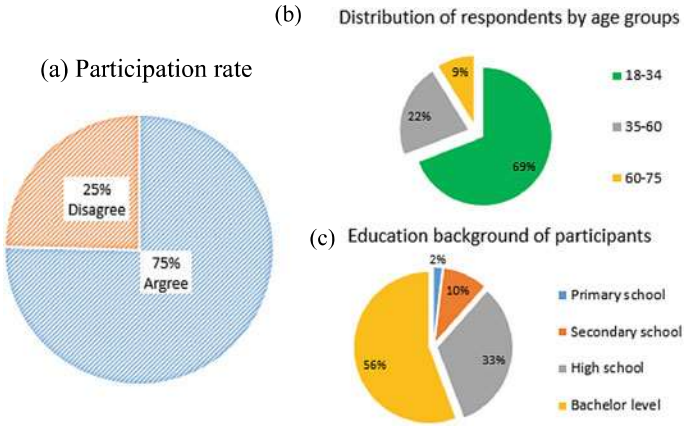


Fig. 55.4 The agreement rate and demographic of the participant in CS research

Table 55.1 The rate of participants preferring data collection methods and frequent monitoring contribution

Commitment of monitoring frequency	Percentage (%)	Data collecting method	Percentage (%)
Twice day	20.0	Photo	81.0
Once a day	35.0	SMS	2.4
2–4 time/ week	37.5	Email	4.8
Once a week	7.5	Notebook	11.9

project gradually increased. These results showed the efficiency of improvement of questionnaires and chose more appropriate persons.

55.3.3 Data Collecting and Sending Methods

The survey results about the data collecting method and participant's commitment on monitoring frequency are given in Table 55.1. A monitoring frequency question was performed to ask the commitment of participation spending their time on monitoring activities. During surveying periods, most participants (more than 70%) believed that they can monitor water level every day; 20% of participants committed to monitor twice a day. Regarding the data collecting method, 81.0% were photo-taking, 11.9% used hard report, and 7.2% constituted both Email and SMS. Currently, Smart-phones are commonly for people. Therefore, most participants preferred taking the photo to collect water level values instead of using notes. Besides, they can take advantage of social networks such as (Facebook, Zalo a social media platform developed by a Vietnamese technology company) to share and send data.

The research used the social network, a public Facebook page (the source of the Facebook page: https://www.facebook.com/groups/233323730344680/) as a data collection aggregation platform. This approach can avoid service fees to maintain like a private website. Besides, it can access many people and is convenient to use. After collecting water level by taking the photo, the participant can upload its photo in the group with some short information, including location, time and value of measurement, and notes.

55.3.4 Evaluating Water Level Obtained from CS

The Lien Mac No. 2 sluice, Noi Bridge, and Dong Bong No. 1 pumping station were chosen to implement citizen-based observations.

At Noi bridge point, thanks to convenient transportation and a high student density; there was more than 104 observations from March to November 2016. The

community- monitored water level at Noi Bridge is shown in Fig. 55.7a reflecting flow regime in flood and dry seasons with a flood season from May to October. The dry season was frequently monitored because this time coincided with the surveying campaign, accounting for 76% of the recorded value. Recorded water level ranging from −2 m to 1 m, is relative water level compared with the Noi Bridge's pile cap level. The water level at Noi Bridge has been updated in the group since then, but occasionally.

The two remaining stations are in remote areas. There were about ten citizen-based observations for each Lien Mac 2 sluice and Dong Bong 1 pumping station in 2016. The later station's staff gauge will be hidden by the sluice gate when it is opened to drain water for the urban area. The participant can use an alternative way to estimate the water level position with some stable points there such as the embankment toe, the embankment peak, etc.

To estimate the accuracy of water level from CS, water level obtained from CS compared to formal observations of existing monitoring works such as Lien Mac 2 sluice and Dong Bong 1 pumping station. Due to the time limitation, research collected only water level of Lien Mac 2 sluice published on the Website of Day River Irrigation Development Investment Co., Ltd, is considered reference values. In the paper's scope, the water level obtained from CS at Lien Mac 2 sluice and Noi Bridge was compared with reference values. The community-based versus formal water level on the Nhue River is shown in Fig. 55.8.

At the Lien Mac 2 sluice, although there were nine recorded values from CS from 24th April to 5th May 2016, the water level trend of the two methods is the same. The error ranges from 0.02 m to 0.61 m, the mean error was 0.15 m. Unfortunately, there is only nine values overlapping between the formal and the community water level data. Therefore, research will not consider the correlations with formal sources (Fig. 55.8).

In general, the water level at Noi bridge has the same trend as Lien Mac 2 sluice, especially in the dry season. The correlation coefficient (R) is 0.95, which indicates two datasets are closely relative. The flow significantly fluctuates in flood season, while citizen-based observations were intermittent. Therefore, some recorded values

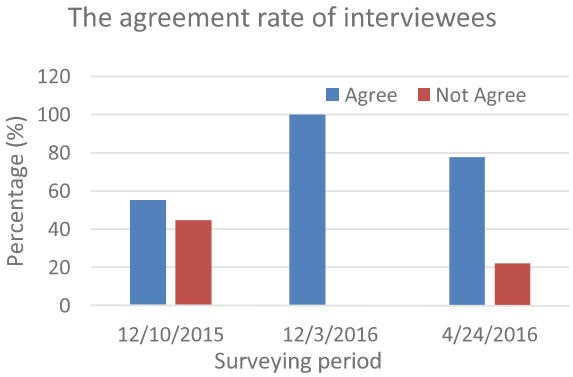
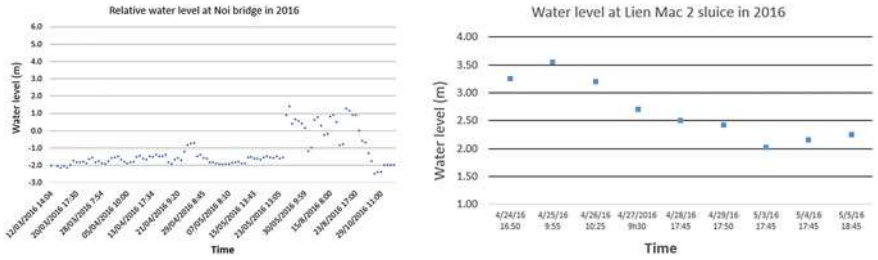


Fig. 55.5 The agreement rate of interviewees joining CS project

Collecting data | Uploading data on the social network

Fig. 55.6 Photographs of (left to right) the water level monitoring by photo-taking (a) and uploading data on the social network (b)



(a) Noi Bridge (b) Lien Mac No.2 sluice

Fig. 55.7 Water level from community-based monitoring on the Nhue River

did not match the reference value trend (for instance: flood in the end of May). The datum level of the Noi Bridge station has not been transmitted according to the national datum level (VN 2000). Therefore, there is a large gap between a citizen-based station and a traditional station although two stations are located in a short river section (Fig. 55.8). The research will not consider the error between data pairs of two sets of data.

55.3.5 Reporting and Exploiting Water Level Values from CS

Monitoring data from the community is aggregated and displayed in the process line for the whole monitoring period. The 2016 Noi Bridge water level monitoring results were aggregated and shared on the group's fan page. Some members are interested in the result and asked to have access to data for research.

In 2016, Tran et al. used water level obtained from CS in this project to explore the contribution of CS and modeling in water resources monitoring and controlling.

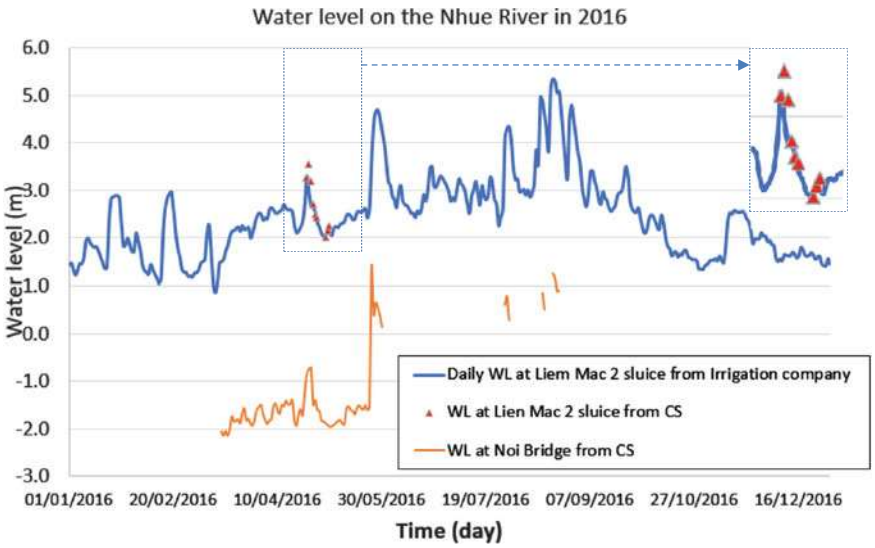


Fig. 55.8 The community-based versus formal water level on the Nhue River

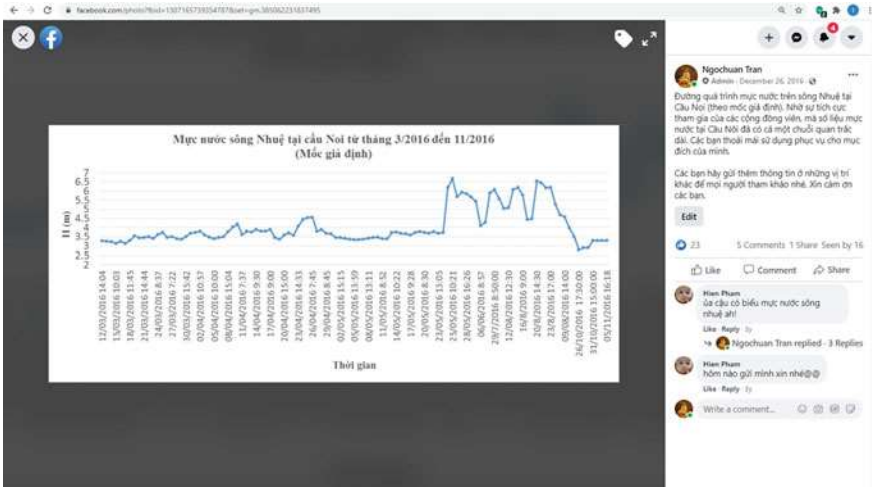


Fig. 55.9 The water level from CS model displaying on group's fan page

The work highlights that citizens can provide timely observation, which reflects natural phenomena such as storms, wastewater discharge, etc. At the same time, modeling can estimate water level along the river, from that datum level of citizen-based monitoring can be determined (Tran et al. 2016). This issue is still a limitation of CS on water resource monitoring when researchers only consider relative water

level (Etter et al. 2020; Starkey et al. 2017; Walker et al. 2016), while water level relative to national datum reference can help stakeholders to use it easily.

55.4 Conclusions

The CS on water resources monitoring in the Nhue River was demonstrated and water level was collected by the local community at Lien Mac No.2 sluice, Noi Bridge, and Dong Bong No.1 pumping station. The major conclusions are mentioned below:

1. CS project on water resource monitoring underwent seven main stages: investigating, surveying, recruiting participants, monitoring guidance, analysing data to publish, and using data for different purposes. The measurement location selection was a crucial factor in the project's success. In addition, the station should be located in a population density area.
2. Most of the participants are young generation aging from 18 to 35. They are familiar with smartphone and social networks usages, a pillow in developing citizen projects to collect and transmit data. They are enough time and health to join the CS project, and pioneers to disseminate CS to other classes.
3. Citizen-based water level monitoring was conducted by images that will be uploaded on social networks. The water levels obtained from the CS on the Nhue River are as good as the conventional approach. The correlation coefficient is relatively high.

Our research organized that CS projects need to be maintained regularly to attract the attention of people. The motivation of enthusiasm of participants has been decreasing over time. Although they committed to collect data every day or every two days, the community-based water level is intermittent for flood reasons after finishing survey campaigns. In order to motivate the participants, a clear and simple data collection method is necessary, like AKVO flow, ODK Collect apps (Davids et al. 2019). The correlation equation of water level among measurement locations can be considered in the future to extend missed data.

In developing countries citizen science is quite alien. It can be applied in other aspects of water resources management such as land use, and water quality monitoring to promote the development of CS. The citizens can understand the role and significance of water resources monitoring and supervision, especially areas that are faced with the problems related to water recourse when they join CS projects.

Acknowledgements This work was supported by the MK27 project under CGIAR Research Program on Water, Land and Ecosystems in the Greater Mekong, funded in part by the Australian Government. The authors are thankful to Mariette van Tilburg and Maurits Ertsen of Civil Engineering and Geosciences Faculty of TUDelft and this book editor's reviewer for their comments and suggestions. We sincerely thank all citizen scientists who volunteered in this project for their whole-hearted support and devotion. The first author gratefully acknowledges a scholarship grant of Catholic Academic Exchange Service (KAAD) during doctoral research period at University of Rostock.

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