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Citizen Science Water Projects in Nepal: Participant Motivations And the Impacts of Involvement

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ABSTRACT: Citizen science is blossoming in the water sciences and benefits to the scientific community are well reported. The experiences of involved citizens are less well researched, however, particularly in the Global South. To address this knowledge gap, we investigated the participant motivations of citizen science water projects in Nepal and the benefits and negative impacts of involvement. Semi-structured interviews and questionnaires were utilised with 74 participants and 15 project organisers, mainly from 5 projects. Participant responses yielded evidence of most of the commonly reported potential benefits of involvement in citizen science, including knowledge gain, increased scientific literacy, and empowerment. Not all benefits were experienced by all participants, however, and there was evidence – albeit minimal – of negative impacts, with some participants reporting the net effect of involvement as being burdensome or disappointing. Participant motivations matched those typically observed among Global North citizen scientists; most commonly, contributing to scientific research, having the opportunity to learn, and helping the community. While this study indicated that involvement in the investigated projects was mostly beneficial, further Global South citizen scientist assessments are needed to enable benefits to be maximised, negative impacts to be avoided, and motivations to be understood for improved participant targeting and retention.

KEYWORDS: Citizen science, Global South, water resources, water quality, disaster risk reduction, participant assessment, Nepal

INTRODUCTION

There is an increasing push to create more societal value from scientific knowledge through greater collaboration between scientists, authorities and the general public (Brouwer and Hessels, 2019; Groffman et al., 2010). There is thus growing advocacy for public participation in scientific research as a means to engage and empower citizens (Aceves-Bueno et al., 2015; Reed, 2008). Citizen science facilitates such participation, and its application in various fields of the water sciences is proliferating (Njue et al., 2019; Buytaert et al., 2014). The general public is increasingly involved in monitoring hydrometeorological variables and water quality and is more frequently participating in mapping and modelling exercises, often to assess vulnerabilities (Walker et al., 2021). Citizens can be involved at all stages of the scientific process; this can include developing research questions; designing methods; collecting, analysing and interpreting data; and disseminating findings (Shirk et al., 2012).

The benefits of citizen science to the scientific community are well reported; they include increasing the range and frequency of sampling or monitoring beyond what research or authority budgets allow (Danielsen et al., 2009); filling gaps in formal monitoring networks (Walker et al., 2016); facilitating the collection of data during extreme events (Le Coz et al., 2016); incorporating local and traditional knowledge into the scientific process (Gérin-Lajoie et al., 2018); and satisfying the public outreach requirements of research funders (Silvertown, 2009). The potential benefits of citizen science for the involved non-scientific community are commonly listed in water science publications; investigation of actual benefits experienced by participants, however, is less common. Walker et al. (2021) conducted a review of 544 publications concerning citizen science applications in the water sciences; it showed that only 16% of studies had assessed the benefits experienced by participants, and that 70% of those studies were from the Global North.

Studies of Global North citizen science water projects have investigated and confirmed a range of participant benefits; these include knowledge gain and increased scientific literacy (Ballard et al., 2017; Křeček et al., 2019); increased social capital (Brasier et al., 2017; Overdevest et al., 2004); behaviour change such as more environmentally friendly decision making (Egerer et al., 2018; Church et al., 2019); and empowerment in the form of the contribution of citizen science data to enforcement of environmental laws (Wilson et al., 2018; Ramirez-Andreotta et al., 2015). Global North citizen science, however, has the general aim of raising awareness in order to encourage behaviour change such as improved environmental stewardship (Edwards et al., 2018; Middleton, 2001), whereas Global South projects are often aimed at empowering citizens and improving livelihoods (Buytaert et al., 2014). Because achievement of these aims is difficult to measure (Reed, 2008), Global South citizen science research generally comprises observation – rather than investigation – of participant benefits (Walker et al., 2021). Studies have observed how citizen scientists who were monitoring groundwater levels and rainfall in India (Jadeja et al., 2018) and Ethiopia (Walker et al., 2019) became recognised as community water experts and became empowered to advise on irrigation, contamination and well maintenance. At a community-based hydrometeorological monitoring project in Burkina Faso, livelihood improvements were observed where locally gathered data was used to aid decision making on planting and livestock management for drought preparedness (WaterAid, 2015); in a project in Kenya, participatory downscaling of climate forecasts also resulted in improvements in livelihood (Kniveton et al., 2015).

The small number and limited geographical spread of the Global South examples suggests uncertainty with regard to the transferability of most of the Global North research and the achievability of its benefits. There are often fundamental differences between the Global North and the Global South in terms of the participants, recruitment, and aims of projects. Surveys have shown that Global North citizen scientists belong to a particular demographic, that is, they are predominantly white, middle-class, well-educated, wealthy, middle-aged males (Reges et al., 2016; Raddick et al., 2009); this demographic is most likely to have the available leisure time and underutilised scientific background that encourages volunteering (Haklay, 2013). Global South citizen scientists, on the other hand, are likely to belong to a very different demographic, as projects often target impoverished or hazardous areas, and because it is common for participants to be nominated by community leaders rather than volunteering (Walker et al., 2019; Regmi et al., 2019).

The negative impacts of involvement in citizen science water projects are largely unreported even though reporting such outcomes would allow others to learn from them and avoid pitfalls (Stepenuck and Green, 2015; Walker et al., 2021). Citizen science participation, especially in the form of regular monitoring, may add an additional burden to the daily lives of people who are already marginal (Resnik et al., 2015). This is less of a problem if the citizen scientist can simply stop participating, but withdrawing may be difficult if the citizen scientist was nominated for involvement by their community, as is common in Global South citizen science projects (Walker et al., 2019; Regmi et al., 2019). Other negative impacts include: disappointment due to lack of project impact, which is often due to the difference of organisers' goals from those of participants (Munnik et al., 2011); health and safety risks, particularly when monitoring river stage during floods (Gladfelter, 2018); decreased self-reliance, as when scientific support stops with the end of project funding (Malakar, 2014); disempowerment, as when certain groups have only token representation (Gaventa and Barrett, 2010) or because of the use of certain technologies (Baudoin et al., 2016); and the creation of conflict, such as when citizen science data goes against certain groups' interests (Baalbaki et al., 2019) or when there are heterogeneous financial incentives (Walker et al., 2016). While these examples demonstrate the possible negative impacts of citizen science involvement, lack of investigation and/or reporting means we do not know the extent of these issues.

Citizen scientists' motivations in the Global North are well researched; they generally include the desire to increase personal scientific knowledge, satisfy environmental concerns, meet like-minded people and/or spend time outdoors, and sometimes simply because involvement is fun (Alender, 2016; Assumpção et al., 2019; Brouwer and Hessels, 2019). Investigation of motivations benefits project organisers because it can help target and retain the most committed citizens. Hamel et al. (2018) speculated that in low-income regions of the Global South, where citizen science is often established, livelihoods commonly depend on water resources, and citizen scientists' motivations are more likely to be related to the desire to improve health and decrease risk. Our literature review, however, could identify no studies of Global South water projects that investigated participant motivations.

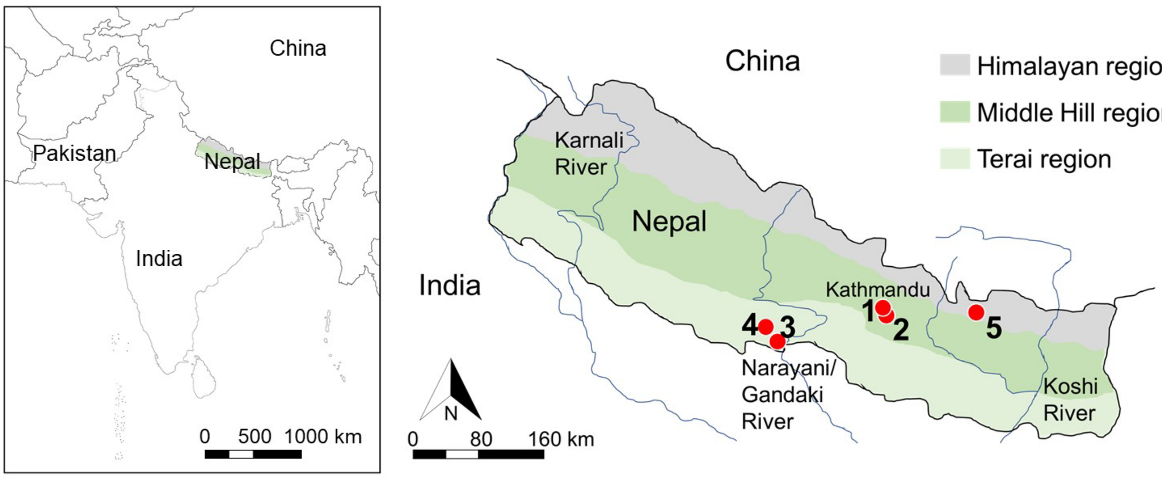
This study aimed to investigate the benefits and negative impacts experienced by participants of citizen science applications to water in Nepal; it aimed also to contribute to the sparse literature from the Global South by assessing citizen scientists' motivations. Such investigation responds to the call by

Staddon et al. (2014) for participatory projects to consider the wider unintended social impacts of their interventions.

STUDY AREA

Nepal is vulnerable to natural hazards, susceptible to climate change effects, and a large proportion of the population does not have access to safe drinking water (Gautam, 2017; Udmale et al., 2016). In addition to anthropogenic contaminants such as nitrates and pathogens (Acharya et al., 2019), over 2 million Nepalis are exposed to excessive levels of natural arsenic in groundwater, especially in the lowland Terai region (Brikowski et al., 2018). Formal hydrometeorological and water quality monitoring is sparse (Bajracharya et al., 2017; Acharya et al., 2019). This has given rise to numerous citizen science projects, which explains our selection of Nepal as the study area. Common citizen science initiatives include: community-based early warning systems (CBEWS) that monitor rainfall intensity and river stage in order to warn of impending floods (Smith et al., 2017) and landslides (Malakar, 2014); hydrometeorological monitoring which enables communities to better manage scarce water resources for irrigation (Regmi et al., 2019); water quality laboratories that sample and analyse spring water to ensure its suitability for drinking (Tosi Robinson et al., 2018); and participatory mapping to integrate local and scientific knowledge for building landslide resilience (Cieslik et al., 2019). For this research, we selected projects that address a range of water-related issues that vary in their geographical location, and thus in their socio-economics and culture and in how they were established and operated. Table 1 summarises the projects incorporated into this study and Figure 1 shows their locations.

Figure 1. Location map of incorporated projects.



Source: Authors. Note: 1 = Smartphones For Water Nepal (S4W-Nepal); 2 = Urban Environment Management Society (UEMS); 3 = Congregational Transboundary Flood Resilience (C-TBR); 4 = Kyushu University/ Environment and Public Health Organization (KU-ENPHO); 5 = Web-Based Natural Dam-Burst Flood Hazard Assessment and ForeCasting SysTem (WeACT).

Table 1. Summary of incorporated citizen science projects.

Project	Location	Focus	Aim	Model	Recruitment	Participants	Organisers	Status
Smartphones For Water Nepal (S4W-Nepal)	Kathmandu Valley	Hydrometeoro-logical monitoring	Mobilise young researchers as citizen scientists with mobile technology to bridge water data gaps Data openly available for research	Smartphone app. to record and submit manual measurements of rainfall, evaporation, river flow and stage, stone spout flow, and groundwater level in shallow wells.	Undergraduate science students targeted through university outreach events and social media campaigns	About 30 year-round; about 340 during monsoon	US/Nepali NGO	Ongoing since 2016
Urban Environment Management Society (UEMS)	Lalitpur, Kathmandu Valley	Water quality	Increase access to safe drinking water	Installation of biosand filtration or nitrate removal systems. Committees test groundwater (principally for coliform bacteria and nitrate) and treat it to be sold in 20-litre jars. Earnings pay for operation, maintenance and periodic laboratory testing.	Communities approach UEMS to request participation and decide water user committee members themselves	Committees of 7 to 13 people in about 150 communities	Nepali NGO	Ongoing since 2002
Congregational Transboundary Flood Resilience (C-TBR)	Narayani/ Gandaki River, Terai (Nepal and India)	Flooding CBEWS	Enhance the flood resilient livelihoods of vulnerable communities and increase empowerment through citizen forums	Committees receive river stage notifications from upstream gauging stations, then disseminate warnings. Committee members trained in evacuation, search and rescue, first aid and rehabilitation of those displaced by floods.	Volunteers and nominations during community meetings	Committees in 10 villages, each with about 25 members	INGO and Nepali NGOs	Ongoing since 2013
Kyushu University/ Environment and Public Health Organization (KU/ENPHO)	Nawalparasi, Terai*	Arsenic in groundwater	Build local capacity for sustainable arsenic mitigation	Committees tested and marked all wells. Committee members trained in field testing, arsenicosis identification, and awareness raising.	Volunteers and nominations during community meetings	Committees in 59 villages; total of 357 members	Japanese university, Nepali NGO	2011-2013
Web-Based Natural Dam-Burst Flood Hazard Assessment and ForeCasting SysTem (WeACT)	Downstream of Tsho Rolpa Lake†	Glacial lake outburst flood (GLOF)	Improve flood preparedness	Participatory mapping and modelling to improve resolution, incorporate risk, and develop scenarios for web-based flood forecasting models for improved decision- and policy-making.	Targeted mix of local stakeholders	Mapping: 7 to 10 people in 4 locations Modelling: About 90 people at workshops	UK and Nepali universities, INGO	Ongoing since 2018

Note: * Nawalparasi is Nepal's most arsenic-affected district (Brikowski et al., 2018); † Of Nepal's lakes, Tsho Rolpa Lake has the highest risk of glacial lake outburst flood (Bajracharya et al., 2020); INGO = international non-governmental organisation.

CITIZEN SCIENCE DEFINITION AND TYPOLOGIES

Citizen science is commonly defined as scientific activities where the general public participates to some degree in data collection, analysis and dissemination (Walker et al., 2021). The degree of citizen participation and control of a project varies. Citizen science typologies, as presented by (Shirk et al., 2012), can include: (1) contributory projects that are designed by scientists, where members of the public primarily contribute data; (2) collaborative and (3) co-created projects where the public participates in project design, analysis, interpretation and dissemination; and (4) collegial projects that are designed and implemented by non-professionals. There are rarely clear boundaries between these typologies nor between citizen science and participatory development projects. As with citizen science, there is no universally accepted definition of participatory development, though it is generally defined as the incorporation of stakeholders who influence and share control over development initiatives, decisions and resources that affect them (Mohan, 2002). There are often aspects of participatory development projects that can be considered citizen science.

Regarding the projects involved in this study, and according to the continuum described above, S4W-Nepal is considered to be contributory citizen science; WeACT, on the other hand, is referred to as collaborative because participants both contribute data and are involved in the development of a modelling tool. Those two projects explicitly incorporate citizen science for scientific research; the aim of the research being participatory development. UEMS, C-TBR and KU/ENPHO, on the other hand, are participatory development projects within which there are aspects of collaborative citizen science such as sampling of water and analysis of water samples, and participatory inundation mapping.

METHODS

Research design

This study was designed to: 1) elicit the benefits and negative impacts of involvement in citizen science projects, 2) test for the possible benefits and negative impacts identified through literature review, and 3) determine motivations for participation in citizen science. Citizen scientists were our primary concern, though we also assessed the personal benefits and negative impacts experienced by citizen science organisers.

Certain benefits can be objectively assessed; participants' acquisition of new knowledge and skills can be assessed using specific tests (Křeček et al., 2019), and decreases in risk can be quantified according to the percentage of households that used early warnings to save livestock and relocate food storage (Hassan and Shah-Jr, 2008). As stated by Bremer et al. (2019), however, in social and political interventions like citizen science, reliance on participants' subjective appraisal is more realistic than adopting an objective position; also, qualitative analyses are the most effective way to evaluate changes in attitudes and practices that are expressed in culturally rich, place-specific ways. Face-to-face semi-structured interviews were thus the preferred assessment method; they enabled in-depth discussions, which produced lengthy responses for analysis. To further increase the assessment reach, questionnaires were delivered online, by email, or by hand for later collection. Although questionnaires did not allow for prompting of the interviewee to gain more detailed information, completing the questionnaire in their own time may have enabled greater consideration of experienced benefits and negative impacts.

Questions were formulated so as to encourage participants to describe what they considered to be the benefits and negative impacts of involvement; questionnaires also evaluated what participants may have been less aware of, that is, increased scientific literacy or decreased self-reliance. Questions were trialled with Nepali project organisers and selected citizen scientists, and then revised in preparation for use at project sites. Table 2 shows how the assessments were conducted.

Table 2. Assessment summary.

Category	Simplified queries	Question types	Benefits potentially revealed	Negative impacts potentially revealed
Information on the project	Whose idea was it? Degree and type of citizen scientist involvement? Aims? Data use? Most significant hazards in the area? Vulnerable groups? Project suggestions? *Feedback received?* *Feedback desired?*	Open-ended	Democratisation of science Public engagement Raised awareness Knowledge gain Scientific literacy Incorporation of local and traditional knowledge	Decentralised monitoring and risk Mismatch in organisers' and participants' goals Disempowerment Disappointment due to no impact
Information on role	How long in the role?		Motivational benefits	Burdensome Health and safety issues Demotivational impacts
	What monitored or assessed/how/frequency?	Short answer		
	Time and effort expended?	Likert scale		
Benefits	Is it a positive experience? What are the benefits?	Open-ended		
	Whole community benefits?		Any personal and community benefits	Disempowerment
	Less illness/danger?	Likert scale	Improved health/decreased risk	Decreased self-reliance
	Learned a lot? Learned what?	Likert scale/ open-ended	Raised awareness/knowledge gain	Increased sensitisation to hazards
	What else would like to learn? *Use learning in everyday life? How?*	Likert scale/ open-ended	Scientific literacy Behaviour change	
	Who learning shared with? How?	Multi-choice/ short answer		Conflict creation
	Trust with other citizen scientists? Organisers?	Likert scale	Increased social capital Development of mutual trust	
	Better connected to authorities? Which and how? What impacts?	Likert scale/ open-ended	Empowerment	Disempowerment
	Project impacts political decision making? What impacts on what issues?	Likert scale/ open-ended		
	Any new technology, finances, infrastructure?	Open-ended	Increased resource capital	
Negative impacts	Any negative or disappointing aspects?	Open-ended		Any negative impacts
Motivations	*Initial motivation to get involved?*	Open-ended	Motivational benefits	
	Current motivation to stay involved?		Empowerment Behaviour change	
	Any financial incentives?			Financial incentive issues
	Enthusiasm to continue?	Likert scale		Demotivational impacts
	Aware of anyone who quit? For what reasons?	Open-ended		Any negative impacts
Demographics	Gender, age, education level, occupation	Multi-choice	Empowerment	Disempowerment

Note: Underlined text = organiser query; italics = participant query; otherwise = query for both.

Data collection

Interviews were conducted with project organisers in Nepal, UK and Japan in November and December 2019 (Table 3). The organisers represented five current and three former projects and were generally part of a multi-partner team.

Table 3. Participant and organiser surveys quantity and method.

	Participants		Organisers	
Project	No.	Method	No.	Method
S4W-Nepal	4 22	Semi-structured interview Online questionnaire	2	Semi-structured interview
UEMS	3	Semi-structured interview	2	Semi-structured interview
C-TBR	32 6	Semi-structured group interview Paper questionnaire‡	2	Semi-structured interview
KU/ENPHO	5	Semi-structured interview	2	Semi-structured interview
WeACT	2	Email questionnaire	3	Semi-structured interview
Other*	†		4	Semi-structured interview
Total	45 responses from 74 participants‡		11 responses from 15 organisers§	

Note: * Other citizen science projects concerned: 1) hydrometeorological monitoring for improved water management and irrigation planning; 2) participatory hydrological, geological and vulnerability assessment for landslide risk reduction; and 3) rainfall and river stage monitoring for flooding CBEWS. † The citizen scientists were inaccessible during this research project; ‡ Each of three group interviews produced one response; § Four of the interviews were with a pair of organisers and produced one response each.

Participant interviews were conducted in Nepal in February 2020. Participants were randomly sampled according to availability; some were visited at home and others at their place of work. Interviews lasted 20 to 45 minutes, depending on the level of detail provided in the responses. Interviews were conducted in English, Nepali or Bhojpuri by, or with, project field staff who were known to the communities, with responses translated into English for analysis.

Interviews were preferentially conducted with individual citizen scientists; group interviews, however, were conducted with the C-TBR project at the suggestion of the community disaster management committees (CDMCs). Additional paper questionnaires were provided and later collected from individual members of other CDMCs to ensure that individual voices were not excluded by these group interviews.

The availability of participants for interviews proved problematic; an online questionnaire was therefore utilised to reach more citizen scientists. In the end, this method could only be used with S4W-Nepal, the only project that required smartphones and internet for collecting and sending data. Citizen scientists were emailed the online questionnaire link and could access it on closed social media groups. The online questionnaire was adapted for areas with weaker internet and limited smartphone usage where it was distributed by email. This procedure could ultimately only be utilised for the WeACT project. Questionnaires were conducted in February and June, 2020.

Analysis

Analysis of interview and questionnaire responses was initially inductive, with the aim of identifying any possible benefits, negative impacts and motivations. Subsequently, the analysis was deductive: evidence for the benefits and negative impacts identified by the literature review was coded within the responses.

The coded evidence for each benefit and negative impact for each interview/questionnaire was graded 'none' when there was no evidence, and 'modest' or 'substantial' based on the amount and type of evidence provided. What constituted modest and substantial evidence differed for each benefit and negative impact; this is described in the results section of the paper. Likert scale responses that specifically targeted a possible benefit were given less weight than evidence from open-ended questions. Assessment of certain benefits and negative impacts required comparison of citizen scientists' and organisers' responses, or consideration of organisers' responses alone, as also described in the results section. To reduce additional subjectivity stemming from the authors' own reading of the responses, the assessment was peer reviewed by co-authors to achieve a consensus model of validation.

Limitations

Participants who had negative experiences may have ended their involvement and thus not been contacted, meaning the results may be skewed in favour of those who had positive experiences. To lessen this limitation, participants were asked if they knew of anyone who had ended their involvement, and if they knew their reasons for quitting. These queries revealed negative impacts of participation, even if not experienced by the respondent.

The research design led to participation by disproportionately large numbers of people from certain groups, especially urban-dwelling students aged 16 to 25. This may have skewed results concerning, for example, the most common motivations for involvement. This paper, however, aims to present the range – rather than proportions – of motivations, benefits and negative impacts.

The study relied on project staff and respondents to provide information on the groups involved in their projects and to indicate whether any groups were excluded. Independent assessment of the range of stakeholders at each project location was beyond the scope of this study.

The presence of project staff during interviews could generate bias if participants thus amplified or invented benefits, assuming that is what the project staff want to hear. The reverse could also be true, with negative impacts amplified or invented in order to invoke greater intervention. Anonymous online, email and paper questionnaires may have negated these response biases.

RESULTS

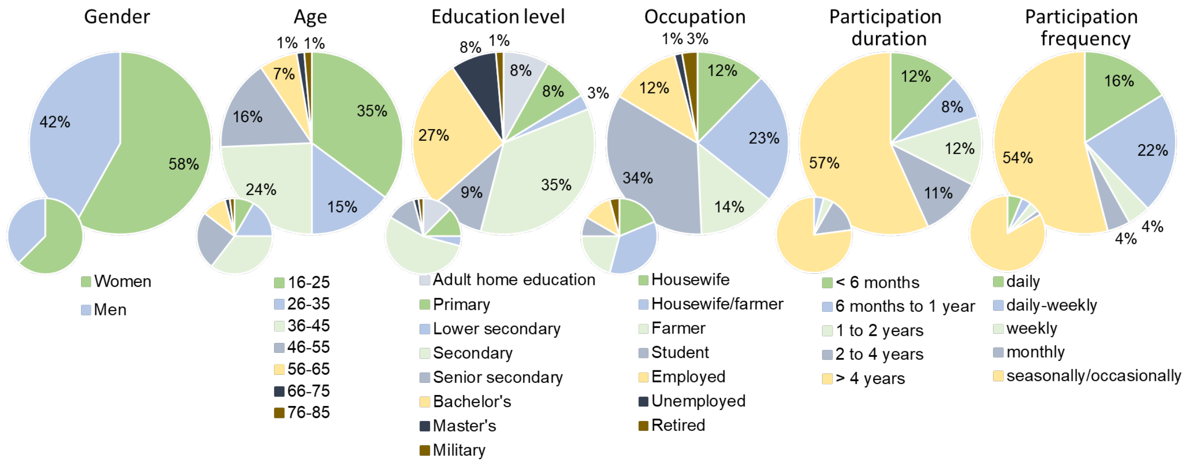
Demographics

Because we sampled only a portion of each project's total participants, we cannot analyse the overall demographics of participation. Figure 2, however, enables comment on participant diversity because there was no attempt to stratify participants; respondents were those who decided to complete the questionnaire or were available for an interview. Participants clearly comprised a diverse range of ages, education levels and occupations, as well as duration and frequency of involvement.

Motivations

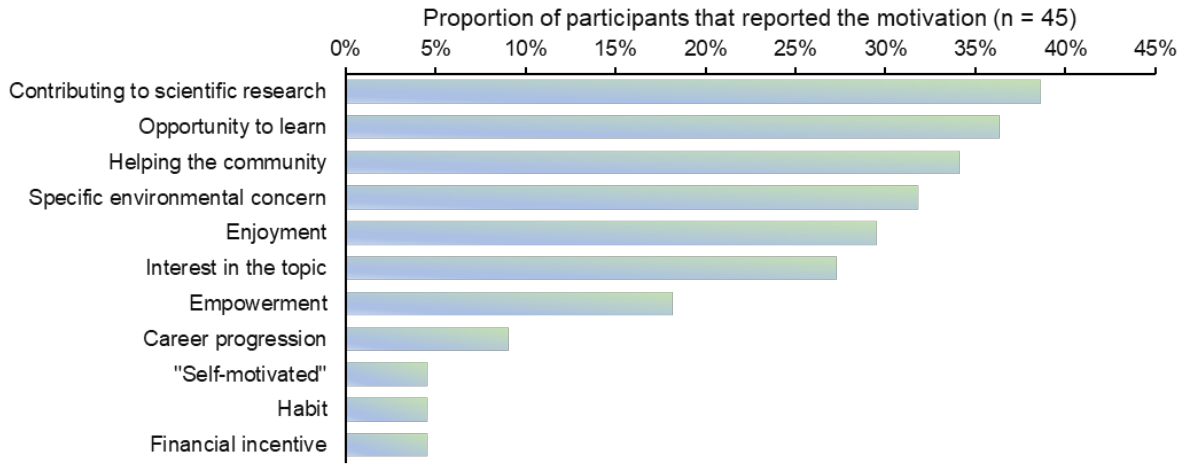
Participants were asked about their motivations for involvement, and motivations were also identified in responses to other queries. Themes were developed inductively and collaboratively among researchers (Figure 3). Most participants mentioned multiple motivations, or motivations that could be categorised into multiple themes; one respondent, for example, revealed several motivations in the process of stating that, "I felt it was nice to be part of this project [enjoyment] and increase knowledge [opportunity to learn] and to educate community about arsenic [helping the community]" (Respondent 43, KU/ENPHO).

Figure 2. Participant demographics.



Note: The larger pie charts show participants of all projects (n = 74), while the smaller pie charts (n = 48) exclude the S4W-Nepal participants; these were predominantly a homogenous group of bachelor's and master's students, 16 to 25 years old.

Figure 3. Participant motivations.



The most common motivation was being able to 'contribute to scientific research', which was noted by 39% of participants; this motivation, however, was exclusive to S4W-Nepal participants. The fact that most S4W-Nepal citizen scientists are university environmental science students is likely a significant factor in this motivation, and many responses illustrated an appreciation of the need for data for research:

> The long-term need of hydrological data motivates me to become a citizen scientist. The daily monitoring of these data would help to understand the rainfall pattern, water quality, water scarcity, and ecological status of freshwater systems as a whole, which will be beneficial for future predictions to combat natural and anthropogenic induced disasters (Respondent 15, S4W-Nepal).

'Opportunity to learn' was a motivation for 36% of participants. Participants' responses noted the opportunities to gain new specific knowledge and skills or simply the general opportunity for learning. One respondent stated, that, "I became a citizen scientist to get knowledge and be aware about data collection" (Respondent 4, S4W-Nepal); another gave their motivation as, "to learn more about groundwater and understand impact on health" (Respondent 40, KU/ENPHO).

The most common motivation put forward by respondents from projects other than S4W-Nepal was 'helping the community'; this was noted by 34% of participants. Reported as a general desire to contribute to their community or to be able to provide education or a specific service, one respondent stated that it was, "[the] safety of the community and helping people in need [that] motivates me" (Respondent 33, C-TBR). Another commented that, "I have been a community health promoter for many years and thus wanted to avail safe water to the community" (Respondent 29, UEMS).

The fourth most common motivation was a 'specific environmental concern' (32% of participants); these concerns included water resources, water quality, natural hazards and the environment. One participant responded that, "My initial motivation was the concern regarding water resources" (Respondent 16, S4W-Nepal); another identified a specific concern in saying that, "There is a water problem. A pipeline is here but there is no water, so we were collecting tanker water for 12 years, but we know it isn't safe" (Respondent 27, UEMS). Yet another said that, "Seeing the present condition of the environment, I want to help the earth to become a better place to live" (Respondent 6, S4W-Nepal).

'Enjoyment' was a motivation for 30% of participants, although one UEMS participant remarked that it was inappropriate to say they enjoyed it because they were providing a vital service.

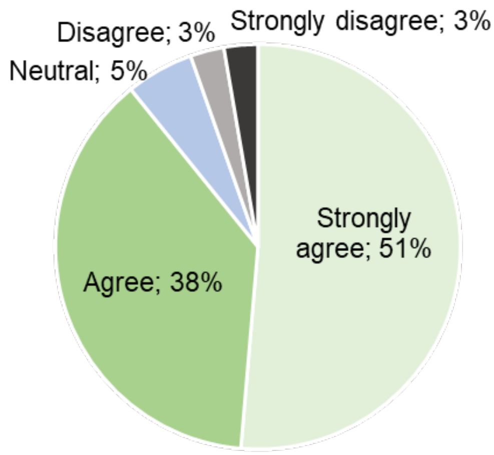
'Having an interest in the topic' was the next most common motivation (27% of participants), though only for S4W-Nepal participants. For some, the interest was in citizen science as much as in a particular water issue. One respondent said that, "Being an environmental science student, it was quite interesting to know more about the water-related issues. Most importantly, citizen science approach is what fascinated me" (Respondent 12, S4W-Nepal).

'Empowerment' was a motivation for 18% of participants. Within the theme of empowerment were motivations relating to increased social capital. As one respondent said, "I am able to raise voice for my rights and authority … for social respect and recognition" (Respondent 34, C-TBR); another gave as a motivation, "To increase my familiarity in the community … to meet and to know community leaders" (Respondent 40, KU/ENPHO). Confirmation of empowerment as an important motivation was reported by a project organiser, who said that, "There used to be a lot of competition to be a volunteer due to the social recognition; people go to them when they want problems solved" (Organiser 4, UEMS). Most responses, as those presented above, related to personal empowerment. C-TBR participants, however, also spoke of community empowerment as a motivation in the form of community self-sufficiency when facing natural hazards.

Further motivations were 'career progression' (9% of participants), followed by 'self-motivated' and 'habit and financial incentives', each of which was noted by 5% of respondents. During face-to-face interviews, 'self-motivated' was a common response, and prompting for further detail elicited various motivations that were categorised elsewhere. The expression was seemingly used as a synonym for intrinsic motivation, that is, not motivated by a financial or reward-type incentive. While the travel and maintenance expenses of C-TBR and KU/ENPHO participants were covered during training, only two of the interviewed participants (both from S4W-Nepal) received financial incentives for their regular citizen science tasks; this was in the form of mobile phone credit, which primarily paid for monitoring data submission. Notably, a third S4W-Nepal participant who had initially been motivated by the financial incentive no longer received the mobile phone credit, stating that they were now motivated by "data generation", that is, 'contributing to scientific research'.

Finally, a Likert scale question queried how enthusiastic participants were to continue involvement. Figure 4 shows the overwhelming enthusiasm to continue; this is reassuring because many of the participants were nominated for involvement rather than volunteering, and it is also encouraging because some participants had been involved in projects that had since ended.

Figure 4. Participant responses to the statement, "I am enthusiastic to continue my involvement with the project".



Benefits

The identified benefits of involvement in citizen science are presented in Table 4. What constituted modest or substantial evidence within the participants' and organisers' responses is subsequently described.

Table 4. Summary of participant benefits across all projects.

Benefit	Evidence
Public engagement	Substantial
Democratisation of science	Modest to substantial
Raised awareness	Modest to substantial
Knowledge gain	Modest to substantial
Increased scientific literacy	Modest to substantial
Incorporation of local, traditional or indigenous knowledge	None or substantial
Development of mutual trust, confidence and respect between science, authorities and the public	Modest to substantial
Increased social capital	Modest to substantial
Behaviour change	None to substantial
Empowerment	None to substantial
Increased resource capital	Modest to substantial
Improved environment	None
Improved health	None or substantial
Decreased risk	None to substantial

Public engagement: Our assessment considered involvement of more than 100 participants to be substantial evidence of public engagement. This number was arbitrarily selected, though all projects involved significantly greater than 100 participants (Table 1).

Democratisation of science: We considered the degree of involvement, control and scientific input on the part of the participants. The C-TBR project provided modest evidence because participants no longer monitor river stage themselves, nor do they make decisions on evacuation; rather, they utilise their training and act upon automatic monitoring and early warning. Other projects provided substantial evidence because, for example, UEMS and KU/ENPHO participants autonomously conducted groundwater sampling and analysis, made decisions on water treatment or well abandonment, and disseminated findings.

Raised awareness and knowledge gain: These benefits are considered together because of overlapping evidence. The mention of learning or of having raised awareness of water-related issues that had been addressed by a project was considered to be modest evidence, while specific examples of new knowledge or skills, and evidence of raising awareness among peers, were considered to constitute substantial evidence. Evidence was often provided in response to an initial question that asked whether involvement had been a positive experience and what benefits it had brought. One respondent stated that, "Yes, I am happy being in the project. I have increased knowledge on flood early warning and disaster risk reduction. I have got to know about improved agricultural practices also" (Respondent 33, C-TBR). Another's response was, "Yes. Awareness of arsenic in groundwater, impacts of arsenic on health, how to make and maintain a biosand filter, how to keep myself safe, capability of speaking in front of community and recognition in community" (Respondent 42, KU/ENPHO).

Increased scientific literacy: We assessed multiple responses to a number of questions, including: how learning was applied in participants' everyday lives; whether there was anything additional they would like to learn; what additional feedback they would like to receive; and whether they thought any part of the project should be done differently. Most participants offered substantial evidence of increased scientific literacy. According to one participant, "We installed our own carbon filter [autonomously] to try and improve taste. We would like to try reverse osmosis" (Respondent 29, UEMS). Another respondent said that, "Engaging myself in such projects enhanced my abilities to act against the disaster in a responsible way, yes I have been using this" (Respondent 44, WeACT).

Incorporation of local, traditional or indigenous knowledge: The C-TBR and WeACT projects sought out the local knowledge of past flooding events and local topography that is missing from digital elevation models (DEMs), using this to generate maps and hydrological models.

Development of mutual trust, confidence and respect between science, authorities and the public: Likert scale responses as to whether there was trust and respect among participants and between organisers and participants were almost always 'agree'. Regarding trust and respect in the relationships between authorities and the public, however, there was substantial evidence only within KU/ENPHO responses. There, the high levels of mutual trust and respect were elucidated through comments about the sharing of data with local and district government officials and about newly formed partnerships for safe water provision, as subsequently described.

Increased social capital: We assessed responses concerning: with whom and how new learning was shared; mutual trust and respect; behaviour change resulting in greater community participation and expanded community; whether participants were now better connected to authorities; and motivations for involvement. Evidence of increased social capital included: "I share [what I learn] with everyone I deal with (Respondent 25, S4W-Nepal); "Our community is united for flood response" (Respondent 33, C-TBR); "[We conducted] awareness programmes in primary and government schools aiming to get children to convince their parents, and awareness programmes in other communities" (Respondent 42, KU/ENPHO).

Behaviour change: When only a generic behaviour change was mentioned, it was considered to be modest evidence, while specific examples of impactful behaviour change were considered substantial evidence. Responses revealed that behaviour change generally resulted from increased human capital. According to one respondent, "I always use safe water because I'm familiar with every well. I still only use non-arsenic wells" (Respondent 40, KU/ENPHO). Another stated that, "I have confidence that water is safe, so I drink direct from filtered water. Also, I now have good hygiene practice" (Respondent 27, UEMS). In many cases, behaviour change contributed to improved livelihoods. One respondent, referring to the benefit of educating others on wise water use, said that, "I teach them to use water wisely" (Respondent 11, S4W-Nepal); another stated that, "I tend to not waste water unnecessarily and make people in my circle aware" (Respondent 12, S4W-Nepal). Yet another participant commented that an additional personal behaviour change benefit was that, "I measure the rainfall data at 9 am every day, and this has made me punctual in my behaviour" (Respondent 25, S4W-Nepal).

Empowerment: Evidence of behaviour change and better connections to people and institutions in positions of power (that is, increased political capital) was considered to be modest evidence of empowerment, whereas a consequent influence on policy-making or on livelihood was considered to be substantial evidence. One respondent, for example, said that, "[I am better connected to] local government. They come to see the water resources I monitor and I give an explanation of the project" (Respondent 3, S4W-Nepal); another stated that, "I have a personal relationship with local government authorities now. Visits from the Chief District Officer and others take place so I know them personally now" (Respondent 33, C-TBR). There was evidence of increased human and social capital, which had empowered citizens to participate in decision- and policy-making. According to one participant,

> I learnt about arsenic in groundwater, I previously didn't know. Now I know the groundwater is bad and brings diseases and now has solutions. I developed the ability to speak up in meetings. Also, social recognition as I became familiar in the community and was nominated to be president of the tank and infrastructure committee. It took two years to bring tank infrastructure and I did a lot of homework (Respondent 43, KU/ENPHO).

This quote demonstrates community empowerment, as was also revealed by all five KU/ENPHO interviewees. When the project ended in 2013, their committees, which had been responsible for testing wells and raising awareness of arsenic in groundwater, did not disband; instead, they evolved to raise money to provide credit to community members in strife and to pressure local government to provide a safe water supply. One respondent said that, "I and the public are aware of arsenic contamination and could push the ward office and local political leaders to build a water tank and a deep borehole" (Respondent 40, KU/ENPHO). There were also examples of personal empowerment, with a participant saying that, "After being associated with the project, I have become chairperson of a municipal-level women's network and chairperson of the committee of an agriculture cooperative. I have become chairperson of the CDMC and I am happy to lead" (Respondent 38, C-TBR).

Increased resource capital: Provision of monitoring equipment and financial incentives was considered to be modest evidence of increased resource capital, whereas new infrastructure was rated as substantial evidence. The projects providing substantial evidence included: UEMS with the provision of biofiltration systems; C-TBR with sirens, life-saving equipment, raised shelters and emergency funds; and KU/ENPHO with deep boreholes, raised storage tanks, and piped water supply. In the latter case, this infrastructure was not part of the KU/ENPHO project but was a later result of committees lobbying for improved water supply.

Improved environment: No evidence was identified; this was not an aim of any project.

Improved health: Likert scale questions assessed improvements in health and decreased risk. Where there was strong agreement, participants generally also noted this in other responses as being a chief benefit of their project. When first asked if their involvement had been a positive experience and what benefits it had brought, UEMS participants gave responses such as, "Yes, waterborne diseases decreased in the community" (Respondent 27, UEMS), and "Yes, because it brings safe water to the community for a minimum price" (Respondent 29, UEMS). Participants of UEMS and KU/ENPHO projects that focused on water quality provided substantial evidence of improved health in their responses.

Decreased risk: Assessment of decreased risk was applicable for projects that focused on a water issue with a high level of immediacy. Substantial evidence was provided by participants of projects with a constant hazard of poor water quality or a seasonal hazard of flooding. One respondent stated, for example, that, "There used to be a lot of fear but it is now reduced. It feels like it is a safer place and we have a shelter house" (Respondent 30, C-TBR). Another said that, "People have access to flood information … people don't need to wake up in the middle of the night if they are worried about the river level because we will wake them up" (Respondent 31, C-TBR). Yet another told us that, "Previously we used unsafe water, now we are safe from water disease" (Respondent 42, KU/ENPHO).

Negative impacts

The question was asked, "Are there any negative or disappointing aspects of being a citizen scientist? If yes, what?" In their responses, 59% of participants (77% of S4W-Nepal participants) answered 'no'; however, the assessment did provide some evidence of negative impacts. These are summarised in Table 5.

Table 5. Summary of participant negative impacts across all projects.

Negative impact	Evidence
Burdensome	None to substantial
Health and safety	None
Decreased self-reliance	None to modest
Increased sensitisation	None (1 modest)
Disempowerment: Exclusion	None
Disempowerment: Technology	None (1 substantial)
Data privacy	None to modest
Conflict creation	None to modest
Decentralising monitoring	None to modest
Decentralising risk	None to substantial
Goals mismatch	None to modest
Disappointment due to no impact	None to modest
Financial incentive issues	None to modest
Demotivational impacts: Time-consuming, boring, difficult	None to modest

Burdensome: To assess whether participation was a burden, Likert scale questions queried the time and perceived effort involved in participation. Significant commitment of time and effort, together with mentions of being over-burdened, was considered to be substantial evidence. There was variation in evidence among participants within projects even when they had similar roles and thus similar time and effort commitments. Apparently, what was considered 'burdensome' was unique to each individual and could be due to personal feelings or circumstances. Poorer citizens who receive daily wages, for example, may suffer from attending lengthy meetings and training sessions. Examples alluding to burdensome participation included, "It is hard work, also because of water quality report preparation" (Respondent 27, UEMS), and "Sometimes the duration of the [training] program is short, but I have to travel a long distance to attend it" (Respondent 35, C-TBR).

Health and safety issues: No evidence was identified.

Decreased self-reliance: There was little evidence of decreased self-reliance, the exceptions being three participants who requested greater involvement by project organisers in order to enforce measures beneficial to community safety.

Increased sensitisation to a hazard: A potential negative impact of raising awareness is its possible encouragement of a community's excessive preoccupation with a hazard. Although a project organiser noted that their project may cause increased sensitisation to a hazard, only one participant mentioned this effect, and not negatively so. In response to the question, "Are there any negative or disappointing aspects of being a citizen scientist?", they responded that one aspect of being a citizen scientist was, "Increased sensitisation to river level, but this is a good thing. Now we are always more curious about river level" (Respondent 30, C-TBR).

Disempowerment (exclusion): Disempowerment through exclusion can occur where existing power structures are reinforced by the exclusion of certain groups from the participatory process (Reed, 2008). We identified no evidence of such disempowerment, and participants informed us that all stakeholder groups were involved in the projects.

Disempowerment (technology): Disempowerment can occur where certain groups do not, or cannot, use or afford necessary technologies such as smartphones, computers, the internet, or certain social media (Baudoin et al., 2016). There was no evidence of this from these participants, though an S4W-Nepal participant mentioned a friend who had to stop their involvement due to a non-functioning smartphone.

Data privacy: No examples of data privacy violations were reported. This is a potential issue, however, if personal information can be gleaned from collected data (Zheng et al., 2018); it could be an issue only for S4W-Nepal participants, who use smartphones for recording and uploading data.

Conflict creation: There was little evidence of conflict creation, though one respondent did say that the project had, "Raised awareness in the community but didn't provide a solution, therefore, the community criticised me and requested a solution from me" (Respondent 39, KU/ENPHO); another stated that the, "Community were critical of the arsenic mitigation committee because we were buying parts and making biosand filters to sell to other communities but the community thought we were getting parts for free and making money" (Respondent 42, KU/ENPHO). A third respondent said that, "Men are not supportive of women. Men buy water from other sources because they don't trust this water quality test and [they] say taste isn't as good" (Respondent 27, UEMS). The latter response, from a water committee run by a women's group, caused us to specifically look for this conflict during other interviews; however, we did not encounter it.

Decentralising monitoring and passing on the onus to the general public: Citizen science is often promoted as a solution to declining formal hydroclimate monitoring networks (Walker et al., 2016; Njue et al., 2019). Authorities may relinquish responsibility for monitoring for cost-saving purposes, and may pass the burden to the public (Chan et al., 2017). C-TBR and S4W-Nepal scored 'none' because the CBEWS is informed by formal river stage and rainfall monitoring that is performed by the Department of Hydrology and Meteorology (DHM), and because S4W-Nepal's monitoring complements low-density formal monitoring. There was modest evidence with UEMS, KU/ENPHO and WeACT, because it was arguable that such vital monitoring should be conducted by a national authority.

Decentralising risk and passing on the onus to the general public: Going beyond passing on to the public the burden of monitoring, governments may relinquish care of their citizens to the citizens themselves. Well-meaning interventions like CBEWS – which are aimed at increasing communities' resilience – can, in the name of empowerment, unintentionally naturalise vulnerability and can individualise responsibility for self-security; indeed, such interventions can provide an excuse for government neglect of marginalised citizens (Gladfelter, 2018). With C-TBR there was substantial evidence of decentralising risk and passing on the onus to the general public because the DHM send an automated flood warning, but subsequent procedures such as sounding the alarm, evacuation, search and rescue, and rehabilitation are primarily the responsibility of the community. Regarding UEMS and KU/ENPHO, even though the onus is on the community for safe water provision, there was modest evidence of occasional government support. In the case of UEMS, this was in the form of, for example, funding for a jar washing machine, and for KU/ENPHO there were examples of government provision of safe water supply.

Goals mismatch: Potential issues caused by a mismatch of goals were chiefly assessed through comparing organisers' responses with those of participants concerning project aims. Participants of most projects offered no evidence of goals mismatch. An exception was KU/ENPHO, which provided modest evidence of mismatch, as several participants spoke of how the identification of contaminated wells, and raising awareness of arsenic health issues and mitigation measures, was insufficient and there should have been a subsequent goal of safe water provision. In regard to this, one respondent stated that, "There was awareness raising but not continued support. Should have been continuation, i.e. solutions" (Respondent 43, KU/ENPHO).

Disappointment due to no impact: Most participants provided no evidence of this, though an exception was a perceived lack of personal benefits. As one participant commented, "Well, to be honest, there is no change in me because it's a very normal task which can be done by even people of little knowledge. So, for the bachelor's student like me there is no benefit for me, I guess" (Respondent 12, S4W-Nepal).

Financial incentive issues: Few of the projects involved financial incentives, therefore there was almost no evidence of related issues.

Demotivational impacts: Common demotivators for participation in citizen science, such as tasks being boring, time-consuming or difficult (Assumpção et al., 2019; Gérin-Lajoie et al., 2018) were offered on a multi-choice list, alongside motivations. Participants were asked to select words on the list that described their role and were also allowed to suggest additional words. While the common demotivators were rarely selected, participants occasionally stated synonyms elsewhere; they said, for example, that, "It was interesting at the start but continuing the same job for a longer period has been monotonous" (Respondent 14, S4W-Nepal), and, "It's boring to take the data but it's making an impact so it's important too" (Respondent 18, S4W-Nepal). An unanticipated demotivator was mentioned by two S4W-Nepal participants, though their dissatisfaction actually reflected enthusiasm for the project and concern over data gaps; one of these participants said to us that, "Sometimes when I am out for some days, there might be data inconsistency which might affect the overall data of my location" (Respondent 12, S4W-Nepal).

Benefits for professional participants of involvement in citizen science

During 10 of 11 organiser interviews, professional participants noted increased social capital as being a benefit. It is noted that they were specifically queried about their relationships with communities that were involved in citizen science. A common response was how, after initially being quite cold, relationships with communities had improved with time and in the course of project successes; organisers were in some cases initially seen as "aliens" or "money distributors". When organisers were queried about the personal benefits to them of involvement in citizen science, increased social capital was again identified in 55% of responses. In addition to the development of mutual respect and understanding with communities, several organisers – like many citizen scientists – mentioned community recognition as a benefit, one organiser commenting that "the community values you" (Organiser 4, UEMS). Building professional networks was noted as a benefit that was a by-product of the interest in citizen science from the media, government, and overseas organisations and researchers. According to one respondent, "We feel really happy when people appreciate our work and want to collaborate with us" (Organiser 8, S4W-Nepal).

Among organisers interviewed, 64% provided examples of knowledge gain through co-producing knowledge with communities and benefitting from their local knowledge. One organiser remarked that, "we always learn something every time we visit the community" (Organiser 4, UEMS). A specific skill gained through working with citizen scientists was referred to by one organiser, who commented that, "my confidence level on intercommunication skill has considerably developed" (Organiser 15, UEMS).

Negative impacts for professional participants of involvement in citizen science

A specific query about negative or disappointing aspects of involvement was put to organisers, with negative impacts identified in 64% of interviews. The negative impacts were applicable to any project involving stakeholder engagement. In five interviews, difficulties in managing community expectations were noted, with one organiser stating that, "Community and government are demanding, but there are no funding resources to meet these demands. We are here to complement government work, but they are expecting something from us" (Organiser 4, UEMS). An academic organiser claimed that it was common for NGOs to promise too much, or to later exaggerate the benefits that had been achieved. Organisers from a local NGO, on the other hand, lamented that when overseas academic partners did not deliver, they were left accountable to the communities. This potential disappointment due to community expectations being left unfulfilled could lead to damage of trust and confidence. Several organisers therefore noted the importance of stressing to members of the community that: 1) some projects had research aims, as opposed to having the goal of providing the new infrastructure that communities often desired; and 2) projects were finite, and explanations should thus be given as to how projects linked to other initiatives.

DISCUSSION

Participant motivations

An important finding of this research is the similarity of the motivations of citizen scientists to those determined from previous studies. Previous assessments of motivations to participate in citizen science water projects were all conducted in the Global North and involved volunteers who research shows belong predominantly to a particular demographic, that is to say, white, middle class, well-educated, wealthy, middle-aged males (Reges et al., 2016; Raddick et al., 2009). In contrast, the projects covered by our research involved diverse participant demographics (Figure 2) and included people who were nominated for participation, as well as volunteers. The most common motivations for the Nepali participants (Figure 3), however, match findings from the Global North. Alender (2016) surveyed 271 volunteers from 8 US water quality monitoring organisations, and found that the strongest motivators were 'helping the environment or community', and 'contributing to scientific knowledge'. Church et al. (2019), in their survey of US water quality monitoring participants, found the main motivations to be 'having a specific environmental concern', and the 'opportunity to learn'. 'Learning' was also the key motivator identified by Storey et al. (2016) regarding stream water quality monitoring in New Zealand; respondents also cited 'interactions with the local council' as a motivation because they felt the council had a genuine interest in their results. This corresponds to the 'empowerment' motivation identified in this research. Participation leading to 'increased political capital' was similarly reported as a motivation by Overdevest et al. (2004) for another US stream water quality monitoring project. Alongside 'contributing to scientific research' and 'acquiring new knowledge', 'enjoyment' was also a prime motivation for participation in a tap water quality monitoring project in the Netherlands. This was noted as well by Assumpção et al. (2019) for a hydrological monitoring programme in Greece and Romania.

Notably, 'enjoyment' was also a common motivation for Nepali participants, despite the official project aims of decreased risk and improved health; the Global North examples, by contrast, had scientific research aims and participation was considered to be a leisure activity.

Participants' gender, age, education level and occupation were poorer predictors of motivation than were the aims of the project in which participants were involved. The motivations of 'contributing to scientific research' and 'interest in the topic' were exclusive to S4W-Nepal with its aims of producing data for scientific research. S4W-Nepal citizen scientists were predominantly bachelor's and master's students aged 16 to 25. This demographic existed among participants of other projects that had aims of improved health and decreased risk; however, the prevalent motivations for involvement in those projects – 'opportunity to learn', 'helping the community' and 'having a specific environmental concern' – were predominant for all demographics.

Several US studies reported how citizen scientists were intrinsically motivated when there was a known water-related hazard, especially if it could affect the health of themselves and their families; in such cases, financial incentives were unnecessary (Jakositz et al., 2020; Ramirez-Andreotta et al., 2015). Similarly, Sy et al. (2018) stated that people's motivations in flooding-related citizen science projects are self-evident because it is about their livelihoods; they therefore have a personal interest in participating because they feel their contribution is useful for themselves and their community. Evidence from the Nepali projects supports these earlier findings as the projects generally targeted an immediate water-related hazard and participants were intrinsically motivated by concerns for their community, with few receiving external incentives. In the case of S4W-Nepal, however, while our research analysed citizen scientists' appraisals, Davids et al. (2019) assessed the data contribution by 154 citizen scientists during the 2018 monsoons. Findings indicated that paid S4W-Nepal citizen scientists took significantly more rainfall measurements per week than did volunteers, and that financial incentives were an effective means of motivating participants in rural areas that were beyond the reach of the typically urban-dwelling science students.

Participants offer a cost-effective way to increase the range and quantity of data collection and contribute to analysis, interpretation and dissemination; they are not free labour, however, as financial and human resources are required to recruit, train, supervise and retain participants and to recognise their accomplishments (Alender, 2016). Understanding participants' motivations and factoring these into project design will help project organisers reduce recruitment and retention costs and maximise the benefits derived from involvement in citizen science (Raddick et al., 2009; Shirk et al., 2012).

Impacts of involvement

This research shows that, for Nepali participants, almost all the commonly stated potential benefits of involvement in citizen science are occurring. As with motivations, patterns of benefits were identifiable by comparing participants from particular projects rather than from particular demographics. S4W-Nepal participants, however, were predominantly bachelor's and master's environmental science students 16 to 25 years old, whose responses showed that they already had knowledge of water-related issues and already possessed a high level of scientific literacy. Consequently, S4W-Nepal citizen scientists mostly provided modest evidence of increased human capital (raised awareness, knowledge gain, increased scientific literacy), whereas other projects' participants offered substantial evidence. Brouwer and Hessels (2019), reporting on water quality monitoring in the Netherlands, also saw greater increases in human capital for citizen scientists with lower education levels. Predictably, increased social capital was identified most strongly in projects where participants were members of committees (UEMS, C-TBR, KU/ENPHO). Evidence within responses suggested that these committees, along with community workshops, facilitated social learning, thus building both human and social capital. There was also more evidence of empowerment from these projects because participants were visible to, and working for, their communities. The UEMS, C-TBR, KU/ENPHO and WeACT projects – with aims of improved health and decreased risk – offered the greatest evidence of behaviour change resulting from increased human and social capital. Empowerment had also commonly led to increased political and resource capital. Participants of these projects thus perceived substantial benefits in terms of decreased risk and improved health. This sequence of benefits was identified by Bremer et al. (2019), who assessed the impact of citizen science on community climate change adaptation in Bangladesh. Interviews following a year of monitoring revealed large increases in citizen scientists' human capital with regard to understanding of local rainfall; this was learning that they applied in adaptive practices and local leadership. They also reported large increases in social capital and moderate increases in political capital, with some evidence of citizen science being used to support public adaptation decision making.

Although most participants reported no negative or disappointing aspects of involvement, there was infrequent evidence that involvement could be burdensome or boring, that it was disappointing due to lack of impact, had created conflicts, or that there was a mismatch between the goals of participants and those of organisers. Other studies that recognised these negative impacts observed that they caused participants to reduce or stop their involvement, with younger participants being most easily demotivated (Gérin-Lajoie et al., 2018; Brasier et al., 2017). Negative impacts were minimal across projects and demographics, however, and Figure 4 shows that there was overwhelming enthusiasm to continue participation. There is a suggestion that what is perceived as a negative impact is largely personal and is unrelated to a participant's gender, age, education level, occupation, duration or frequency of involvement, or project aims. Many Global North studies have lamented a lack of diversity among participants; they recognise the potential for continued marginalisation of certain groups in society, while citizen science should in fact be an opportunity for bringing people together (Chase and Levine, 2018; Woelfle-Erskine, 2017). Participant demographics (Figure 2) imply that the citizen science projects in Nepal do not suffer from a lack of diversity and the consequent potential disempowerment. This supports the recommendation of Brouwer and Hessels (2019) that recruitment methods other than the scattergun approach of mass media advertising can be employed to help attain a more diverse sample of participants.

In any assessment of the benefits and negative impacts experienced by participants, one cannot straightforwardly separate the impact of involvement in citizen science from the impact of a project of which citizen science is a part, as in the case of participatory development projects. This separation is unnecessary for a project like UEMS, where the citizen science task of testing water quality and applying the necessary treatments results in immediate livelihood benefits in the form of consumption of safe water. Even though the act of data collection still produces benefits such as raised awareness and increased scientific literacy, citizen scientists involved in projects with aims of scientific research may not get to appreciate livelihood benefits unless the research is subsequently acted upon. As shown by the KU/ENPHO project, the legacy of citizen science can bring about livelihood benefits years after a project has ended. Initially, the C-TBR project involved manual river stage monitoring, which then become automated. C-TBR communities were also previously involved in participatory inundation mapping for risk analysis and development of evacuation plans. The project continues with a reduced citizen science aspect, though current benefits may also be considered a legacy of citizen science. This research shows, as suggested by Gharesifard et al. (2019), that there is value in investigating the legacy of citizen science, not only when the project ends but long after.

The need for participant research

There were significant differences in organisers' and participants' responses to queries about the benefits and negative impacts of involvement. While important benefits were correctly predicted by organisers, many other benefits were not, and there were few similarities regarding negative impacts. These discrepancies could have adverse effects on project management and participant satisfaction if organisers unwittingly persist with unpopular practices or make unnecessary changes. Several organisers speculated, for example, that there were no negative impacts for participants; other organisers thought that participants were annoyed at frequent contact, yet many participants requested more contact. Most organisers believed that participation could unrealistically raise communities' expectations; however, there was little evidence from participants that this had led to disappointment. Some organisers lamented that communities awaited the next project rather than seeking government support, while other organisers suggested that communities expected government support and were disappointed when it was not forthcoming; neither of these issues was raised by participants. Clearly, awareness of pertinent benefits and negative impacts can only be achieved through participant assessment; steps can then be taken to maximise benefits and avoid negative impacts.

The assessment also garnered useful feedback that is currently being acted upon by project organisers. Many participants requested more feedback, remarking that they would like to learn more about data analysis and how data are subsequently used. This opens up an opportunity for organisers to educate and utilise citizen scientists and move them up 'Arnstein's ladder of participation' (Arnstein, 1969). Other useful feedback included requests for events to bring citizen scientists together, technical training on how equipment works (rather than only on how to use it), and smartphone apps rather than manual methods.

In addition to considering impacts on the public, the impacts on professionals should not be overlooked in the designing of mutually beneficial citizen science projects. This assessment is a reminder that professional scientists and project organisers are also citizens who experience certain personal benefits and negative impacts of their involvement in citizen science.

The identified benefits and negative impacts, and the motivations for involvement, contribute to the sparse literature concerning Global South citizen scientists involved in water projects. While other Global South studies have observed many of these benefits, rarely have participants been consulted to provide evidence of their occurrence (Walker et al., 2021). This study showcases the usefulness of participant assessment in ensuring that motivations are satisfied, benefits are mutual, negative impacts are nullified, current projects are improved, and future projects are better designed.

The political nature of citizen science projects

Two projects targeted disaster risk reduction, C-TBR and WeACT. Participants spoke of the heightened flood risk for those compelled to live on marginal land such as flood-prone riverbanks and for those who have poorer support networks to aid in coping and recovery. The disaster literature theorises the criticality of socio-economic and political status for how natural hazards are experienced (see, for example, Bolin and Kurtz (2018); Tierney (2007)). The sharing of knowledge and experiences by traditionally marginalised ethnic groups and castes that have participated in these Nepali projects confirmed the unevenness of exposure and vulnerability. Two projects strived for safe water provision, UEMS and KU/ENPHO. Participant responses supported the hydrosocial theory that achieving a safe water supply requires disenfranchised communities to gain control of decision making over their water (see, for example, Budds and Sultana (2013)). Development was enabled by an increase in human, social and political capital, and by the provision of technology, sometimes by government.

Within the incorporated projects, there was substantial participation by ethnic groups that are considered indigenous and/or marginalised. The projects in the Terai incorporate Madhesi and Tharu people; C-TBR has a mandate for at least 40% of participants to be Dalit or indigenous; UEMS works exclusively with the indigenous Newar, and the WeACT project involves various ethnic groups with a high proportion of indigenous Sherpa. In addition to the participatory nature of the projects enabling integration of different knowledge systems, the identified increased political capital supports research which suggests that citizen science could contribute to empowerment of such marginalised groups (see, for example, Wilson et al. (2018); Gérin-Lajoie et al. (2018)). Similarly, Figure 2 shows significant participation by groups that are traditionally disempowered, including women, youth, those with less education, and farmers. Many of these respondents spoke of how involvement in the projects had led to increased human, social and political capital, suggesting that citizen science could be a means of reshaping social power relations. Contributing to this reshaping is the democratisation of scientific knowledge and data. Participants and their communities, as opposed to local and district governments, are now the (informal and formal) knowledge holders concerning water resources and the environment with its inherent natural hazards.

All of the projects involved in this study were funded by international donors. Local and district-level governments were generally invited to project workshops, especially at the planning and onset stages. There is evidence that as the presence of the projects grew, local and district governments again became involved and, in some cases, contributed funding. What the incorporated projects mean to the donors and to government was not analysed. We acknowledge that such water-related development interventions are inherently political; it was, however, beyond the scope of this study to conduct a critical assessment of each project which considered how it might be naturalising causes of inequality and/or pursuing control of water resources and risk (see Budds and Sultana (2013)).

CONCLUSIONS

There is abundant research on the benefits of citizen science to water professionals; little research, however, has been conducted on the benefits and negative impacts for citizens. Through analysis of participant interviews and questionnaires, this research shows that citizen science water projects in Nepal have led to multiple personal and community benefits for those involved. Participants with lower levels of education provided most evidence of increased human capital and, predictably, participants operating in committees provided the strongest evidence of increased social capital. Substantial evidence of empowerment – such as community recognition, adopting leadership roles, and increased political capital – was provided by committee members who worked with, and for, their communities. Participant responses showed that these benefits had led to behaviour change; this behaviour change, combined with increased resource capital such as water access, treatment technologies, and flood early warning systems, meant that, in the opinion of their participants, the projects' aims of decreasing risk and improving health had been achieved.

There was infrequent evidence of negative impacts such as involvement being burdensome, disappointment over no impact, and the generation of occasional conflict. The identified negative impacts were distributed across projects and demographics; this suggested that negative impacts were more likely to be personal or isolated, and were seemingly unrelated to the characteristics of a particular project or group of people. Further investigation is recommended to assess if any of the negative impacts are in fact more widespread.

Most previous research on participants in citizen science applications to water were focused on Global North projects, while this study contributes to the sparse research from the Global South. Motivations of Global South citizen scientists, in particular, have rarely been investigated. Results of this investigation indicate that the motivations that were predominantly reported by Nepali participants were akin to those of their Global North contemporaries, that is, contributing to scientific research, the opportunity to learn, and helping the community. This finding is significant because Nepali citizen science – and perhaps generally Global South citizen science with its alternative recruitment methods – has a more diverse range of participants.

Knowledge gain and increased social capital were the most-reported benefits of involvement in citizen science by professional participants (project organisers). The most frequently mentioned negative impact for professionals was the difficulty of managing participants' expectations; however, scant evidence was provided by the citizen scientists of disappointment due to unfulfilled expectations. This is one of many examples of a discrepancy between what organisers perceived were negative impacts for participants, and what participants themselves reported; such discrepancies were also found between perceived and reported benefits.

Further assessments of the experiences and motivations of Global South citizen scientists are warranted; this will help ensure that both professionals and citizens maximise the benefits of the increasingly global expansion of citizen participation in the water sciences. Project organisers can use participant feedback to improve citizen scientists' experiences and better achieve project aims. Ethically, it is important to ensure that participants are not negatively impacted by their involvement; this contributes to a "politics of accountability" for those who promote such participatory programmes (Staddon et al., 2014).

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