Science of the Total Environment 619–620 (2018) 1133–1142

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Formal and informal environmental sensing data and integration potential: Perceptions of citizens and experts

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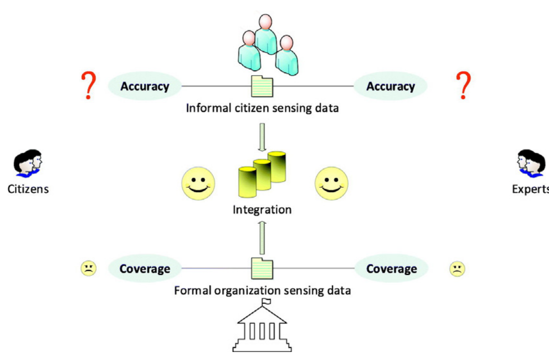
HIGHLIGHTS

- Citizens' and experts' perceptions of formal and informal environmental sensing data and integration potential are compared.
- The accuracy of informal environmental sensing data is largely unknown among citizens and experts.
- Integration of formal and informal environmental sensing data could improve data quality.
- Informal environmental sensing data are expected to complement formal data, but are still far from meeting this potential.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 10 August 2017
Received in revised form 18 October 2017
Accepted 27 October 2017
Available online xxxx

Editor: Simon Pollard

Keywords:
Citizen science
Sensor
Questionnaire
Data quality
Data integration

ABSTRACT

Environmental sensing data provide crucial information for environment-related decision-making. Formal data are provided by official environmental institutes. Beyond those, however, there is a growing body of so-called informal sensing data, which are contributed by citizens using low-cost sensors. How good are these informal data, and how might they be applied, next to formal environmental sensing data? Could both types of sensing data be gainfully integrated? This paper presents the results of an online survey investigating perceptions within citizen science communities, environmental institutes and their networks of formal and informal environmental sensing data. The results show that citizens and experts had different views of formal and informal environmental sensing data, particularly on measurement frequency and the data information provision power. However, there was agreement, too, for example, on the accuracy of formal environmental sensing data. Furthermore, both agreed that the integration of formal and informal environmental sensing data offered potential for improvements on several aspects, particularly spatial coverage, data quantity and measurement frequency. Interestingly, the accuracy of informal environmental sensing data was largely unknown to both experts and citizens. This suggests the need for further investigation of informal environmental sensing data and the potential for its effective integration with formal environmental sensing data, if hurdles like standardisation can be overcome.

1. Introduction

Environmental issues cannot be tackled without environmental data. These data are often produced by official institutions, which

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https://doi.org/10.1016/j.scitotenv.2017.10.329
0048-9697/

provide formal sensing data from which valuable information can be derived about the state of the environment (Artiola et al., 2004; Schnebele et al., 2014). Nowadays, however, more and more environmental data are being produced by so-called "citizen science", using low-cost sensors as monitoring instruments. These data are known as informal environmental sensing data (Kamel Boulos et al., 2011; Kooistra et al., 2009).

Though citizens have long been involved in science, the term citizen science is still new and evolving. There is as yet no wide consensus about the definition, as underlined in a paper by members of the European Citizen Science Association (ECSA), the Citizen Science Association (CSA) and the Australian Citizen Science Association (ACSA) (Eitzel et al., 2017). The current paper defines citizen science as including not only communities but also individuals performing scientific activities ranging from posing research questions to finding answers with or without the involvement of professional scientists (Bonney et al., 2016; Haklay, 2013; Lewenstein, 2016; See et al., 2016).

Traditionally, most data collection has been done by professional scientists within projects, based on the questions that these projects posed. To implement projects, scientists usually rely on funding and cooperation, which however, typically stop after funding ends (Jalbert and Kinchy, 2016). Citizen environmental sensing is generally more loosely organised. It involves citizens' monitoring of the environment using sensors enabled by advancements in information and communication technologies (ICTs) (Kamel Boulos et al., 2011). Examples are smart phones and the "internet of things". Open source movements are another key aspect in citizen environmental sensing campaigns. These allow citizens to establish networks, or communities, from the local to the global level, and collect data as never done before. Using open hardware and software, citizens can even make their own tools (Carton and Ache, 2017; Hemmi and Graham, 2014; Jiang et al., 2016). These new technologies and movements are being observed by policymakers and scientists as well, spurring them to think differently about how citizen data can be utilised for improved policymaking – for more effective and efficient social impact.

Hemmi and Graham (2014) compared a bottom-up open citizen science with a closed expert-oriented approach in tackling the radiation monitoring problem after the Fukushima Daiichi accident. Their findings emphasise the merit of open citizen science, which was found to be more successful than closed expert-oriented approaches (Hemmi and Graham, 2014). The main reason for this success was the use of open data, as opposed to closed data. Data openness enabled faster evolution of the data creation and use cycle. In this case, open source and open community platforms attracted a diversity of experts and numerous citizens to contribute trustworthy open data at low cost (Hemmi and Graham, 2014). D'Hondt et al. (2013) did a citizen science experiment about noise monitoring and claimed that citizen noise monitoring (informal) can achieve the same accuracy as standard noise monitoring (formal) if implemented properly. A one-year experiment conducted in Paris by Aumond et al. (2017) concluded also the usefulness of (informal) urban noise measuring using mobile phone. The air pollution monitoring case study conducted in Antwerp, however, considered (informal) mobile monitoring as useful in respect of spatial trend identification but also indicate the challenges of collecting sufficient data and proper data analysis (Van den Van den Bossche et al., 2016).

Bell et al. (2015) conducted research on data quality from citizen weather stations. They observed, however, that significant instrument biases may appear in the data. Analogous research on informal citizen environmental data has been conducted in other fields as well: climate and atmospheric sciences (Muller et al., 2015), air quality (Borrego et al., 2016; Mead et al., 2013; Weissert et al., 2017), water (Little et al., 2016) and noise pollution (Maisonneuve et al., 2010). These studies have discussed or compared various aspects of formal and informal sensing data, for instance, accuracy and accessibility.

Research on experts' and citizens' perceptions of formal and informal sensing data, and possibilities for integrating the two, has been limited up to now. Perceptions, however, here defined as the way "something is regarded, understood, or interpreted" (Oxford Dictionaries, 2017), influence not only the development of environmental sensing technology but also the applications of the data produced. To understand the perceptions from experts and citizens is crucial for citizen environmental science. The experts may not have the same perceptions as described by Minkman et al. (2017) about experts' perceptions on citizen science in water resource management. Furthermore, there might be contrasting perceptions between experts and citizens which lead to conflicts, distrust and tensions rather than collaboration as Weng (2015) concluded in an ecological restoration case study.

For implementation of citizen science projects, especially co-created citizen science, it is important to understand the different perceptions of citizens and experts regarding formal and informal data sources and the potential for integrating the two, as this can raise awareness of obstacles, influence how produced data are used, help to find solutions for problems and mark how changes and shifts happens. The current research investigated perceptions of citizen scientists and experts on formal and informal environmental sensing data and the potential for their integration. To our knowledge, no such study has been done before in terms of the citizen environmental sensing topic and the method.

This paper is organised in five sections. After this introduction, Section 2 elaborates on the survey method used. Section 3 describes and analyses survey results. Section 4 discusses these results, together with other associated research findings and limitations. Finally, Section 5 presents the conclusions.

2. Method

2.1. Online survey questionnaire

A survey questionnaire was designed for the purpose of collecting experts' and citizen scientists' perceptions of formal and informal sensing data. The survey was administered online and targeted experts and citizens from selected environmental organisations and citizen communities. Fig. 1 presents the conceptual design underlying the survey. Thus, citizen and expert respondents answered questions about both formal and informal environmental sensing data. Each also gave their opinions about the potential for integrating the two data types to address environmental concerns.

The perception aspects investigated were derived in part from (Hemmi and Graham, 2014; Lewis and Edwards, 2016; Mead et al., 2013; Muller et al., 2015; Veregin, 1999) (Fig. 2), and formulated in part by the authors. For instance, according to Veregin (1999), data quality components include accuracy, precision or resolution, consistency and completeness. Accuracy, consistency and completeness were directly selected. However, instead of using precision or resolution, calibration and coverage were used. Due to the particularities of citizen sensing, other aspects selected were calibration, maintenance and training and support (Mead et al., 2013). Social aspects, like trust, privacy and public awareness, were also considered important. For instance, after the Fukushima Daiichi accident, distrust was a main reason why citizens began a citizen environmental sensing community (Hemmi and Graham, 2014).

Of course, there are other important aspects as well, especially in relation to specific disciplines. We did not include more however, to prevent the questionnaire from becoming too complex, particularly for citizen respondents. For instance, the geo-information science and remote sensing community divide data accuracy further into spatial, temporal and thematic categories. Perception aspects range from quality of the data to continuity of data collection.

The perception aspects selected for use in our questionnaire were subsequently developed into questions to create the online survey (see Fig. 2 and Appendix).