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Author(s): Maria Palacin-Silva[1)], Ahmed Seffah[1)], Kari Heikkinen[1)], Jari Porras[1)], Timo Pyhälahti[2)], Yrjö Sucksdorff[2)], Saku Anttila[2)], Hanna Alasalmi[2)], Eeva Bruun[2)], Sofia Junttila[2)]
1) Lappeenranta University of Technology
2) Finnish Environment Institute

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ABSTRACT

Citizen science has rapidly spread in the last decades around the world as a genuine interactive and inclusive opportunity for engaging citizens in the continuous collection of data relevant for science, governance, businesses, communal living and individual concerns. The present–day abundance of ICT technologies has caused the proliferation of two data collection methods in this field: participatory (user-centric) and opportunistic (device-centric). As a result, citizen observatories have become big data systems, with large scale volumes of data that come and go to millions of users.; about any social or environmental phenomenon (e.g. transit, air or weather) and comes in different formats (e.g. XML, Plain Text, CSV) and through different platforms (e.g. websites, mobile apps, sensor networks).

This study reviewed the last 10 years of citizen science literature through a systematic literature review. This study identified 108 citizen observatories, which were deeply studied and clustered to identify global and European trends in environmental applications, practices, engagement techniques and technology uses. Challenges and recommendations from the literature in the field were classified to understand the common present and future path for the discipline. Furthermore, a survey and interviews were applied to stakeholders in Finland to gain broader understanding of the field country–wise. This study, provides the first comprehensive insight of the broad scale of contemporary ICT enabled citizen observatories in social and environmental dimensions.

Keywords: citizen science, citizen observatories, ICT, data, environment, Finland

TIIVISTELMÄ

Kansalaistiede on nopeasti levinnyt viime vuosikymmeninä aidoksi sekä interaktiiviseksi että osallistavaksi tavaksi ottaa kansalaiset mukaan jatkuvaan datankeruuseen, joita voidaan hyödyntää niin tieteessä, hallinnossa, liiketoiminnassa ja yhteisöissä. Nykypäivän tieto-ja viestintätekniikka on nostanut esiin kaksi merkittävää datankeruumenetelmää; osallistuva (käyttäjäkeskeinen) ja opportunistinen (laitekeskeinen). Tämän seurauksena, kansalaisobservaatiot ovat tulleet suuren datamäärän keskuksiksi, jossa ja jonne voidaan siirtää paljon dataa käyttäjiltä; lähes tulkoon mistä sosiaalisesta tai ympäristöllisestä ilmiöstä (esim. liikenne, ilmanlaatu tai sää) erilaisissa tietotyypeissä ja joita voidaan käyttää eri alustoilla (esim. Web-sivut, mobiilisovellukset, sensoriverkot).

Tämä systemaattinen kirjallisuustutkimus tarkasteli viimeiseltä kymmeneltä vuodelta kansalaistiedettä. Tutkimus tunnisti 108 kansalaisobservaatiota, jotka luokiteltiin niin Eurooppalaisten kuin maailmankin eri kehityssuuntausten (ympäristösovellutukset, käytännöt, kansalaisten aktivointi, teknologiat) mukaisesti. Löydetyt haasteet ja suositukset luokiteltiin myös, jotta voitaisiin ymmärtää kansalaistieteen nykytila ja tulevaisuus. Osa tutkimuksesta sisälsi kysely- ja haastattelututkimuksen sidosryhmille Suomessa, jotta voitaisiin saada laaja ymmärrys kansalaistieteestä ja sen tilasta erityisesti Suomessa. Tämä tutkimus kokosi ensimmäisen kattavan ja laajan kokonaisuuden tieto-ja viestintätekniikan hyödyntämisestä kansalaisobservaatioissa ja sen sosiaalisissa ja ympäristöllisissä ulottuvuuksissa.

Avainsanat: kansalaistiede, kansalaishavainnointi, tieto-ja viestintätekniikka, data, ympäristö, Suomi

SAMMANDRAG

Amatörforskning har spridits raskt under de senaste årtiondena runt jorden som ett genuin möjlighet att på ett interaktivt och inkluderande sätt engagera medborgare i en kontinuerlig insamling av data för vetenskapliga, styrande, affärsrelaterade och individuella ändamål. Dagens rikedom av IKT-teknologier har hjälpt spridningen av 2 datainsamlingsmetoder inom området: deltagande (användarecentrerade) och opportunistiska (enhetscentrerade). Some ett resultat av detta har medborgarobservationer blivit stora data-system, med stor-skaliga volymer av data som kommer och går till miljontals användare. Observationerna handlar om alla slags sociala eller miljö-relaterade fenomen (t.ex. genomresor, luft och väder) och kan komma i olika format (t.ex. XML, oformatterad text, CSV) och genom olika platformer (t.ex. webbsidor, mobil-appar, nätverk av sensorer). Den här studien gick igenom de senaste 10 åren av litteratur kring amatörforskning genom en systematisk litteraturstudie.

Studien identifierade 108 amatörforskingsområden, vilka studerades och grupperades för att identifiera trender på global och europeisk nivå inom miljö-relaterade tillämpningar, praxis, sätt att engagera folk och hur olika teknologier används. Utmaningar och rekommendationer från literaturen från litteraturen klassifierades för att förstå den gemensamma trenden, nuvarande och framtida, inom ämnet. Utöver det, så genomfördes en undersökning och intervjuer med intressenter i Finland för att få en bredare förståelse av ämnet inom landet. Studien ger en första omfattande inblick inom de sociala och miljö-relaterade aspekterna inom samtida IKT-baserade amatörforskingsområden.

Nyckelord: amatörforskning, amatörforskingsområden, IKT, data, miljö, Finland

PREFACE

What is the role of citizen observatories in environmental monitoring around the world? Who are running observatories? What are the trends in the way observatories are used? These were key questions in the development of this report.

Citizen observatories have become ubiquitous around the world, allowing observations of a large set of phenomenon from environment, city planning to personal health. Technologies advancement are tightly related with the field growth because, they have supported different levels of citizen's involvement (from passive involvement: installing sensors, to active involvement: learning and classifying observations). Citizen observatories in the 21st century represent the largest opportunity for mass collaboration and global monitoring with little infrastructure needed.

The Authors, Lappeenranta.

CONTENTS

1 Introduction

The term ‘‘citizen science’’ has taken on several different meanings since it was coined by Irwin, A [1] – as scientific citizenship which foregrounds the necessity of opening up science and science policy processes to the public –. And then by Bonney in the 1990s – as public-participation engagement and science communication projects – [1–3].

A decade ago this field was seen as the future of genuine interactive and inclusive science engagement [2,4,5]. Nowadays, citizen science aims to integrate professional scientists and engaged laypeople (citizens) in the conduct of research [6–11] – such as data gathering, classification and dissemination – in a wide range of fields (e.g. ‘volunteered geographic information’ and ‘crowdsourcing geospatial data’ by geographers and ‘people–centric sensing’ and ‘participatory sensing’ by computer scientists)[12]. Information and communication technologies (ICT) are the leading factor in the recent spread of this phenomenon [13], which has reached the visions of [4,5,14] by becoming widely spread around the world, to influence and engage massive audiences, projects such as eBird and Galaxyzoo, have not only recruited millions of observers but have helped genuine scientific discoveries which have been largely documented [15,16]. Citizen observatories have also become key in the development of the information perspective in a smart city (Figure 1) because, the observatories effectively support participatory governance, allowing citizens to become monitoring and changing agents in their own environment [17].

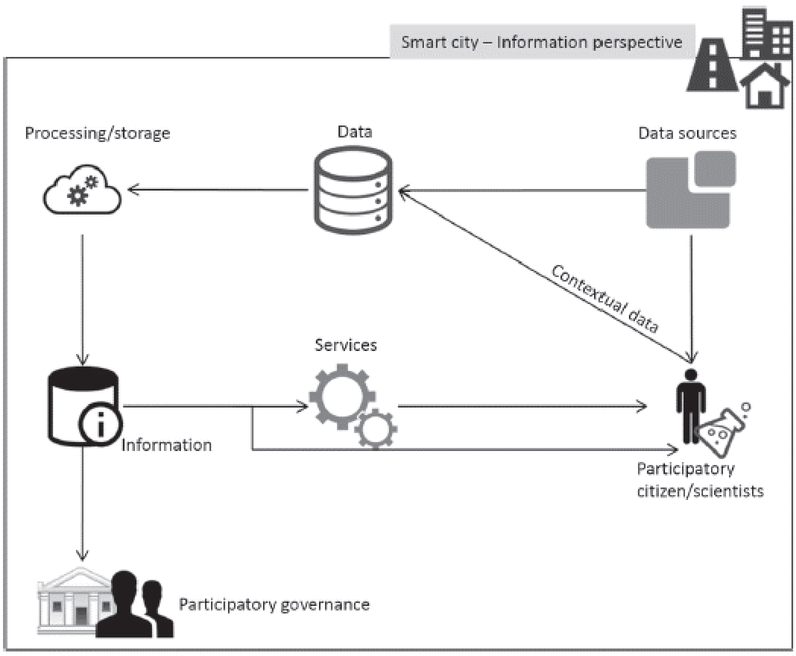

Figure 1: Smart cities – Information Perspective: The dependencies between citizens, data, ICT tools, utilization and provisioning of municipal services in order to support participatory governance. Source: [17]

Citizen science also opens several opportunities to bring citizens together with decision makers and researchers to jointly address common concerns. European Commission has a concrete vision in this field: "science for the people, by the people" under their “Digital Agenda for Europe 2020”. This agenda supports, through multiple funds, projects running all over Europe in the field of digital and scientific practice enabled by ICT, in particular by high performance computing, networking infrastructures, large–scale data facilities and social media.

The rise in social computing (based on social production and mass collaboration) has facilitated a shift from consumer cultures (specialized in producing finished artifacts to be consumed passively) to cultures of participation (in which all people are provided with the means to participate and to contribute actively in personally meaningful problems) [18]. Participation approaches have progressed through a series of phases [19,20] from awareness raising in the 1960s, incorporation of local perspectives in the 1970s, recognition of local knowledge in the 1980s, participation as a norm as part of the sustainable development agenda of the 1990s to empowerment of citizens to directly effect on the sustainable development from their local environments. However, with the proliferation of sensor and actuator networks in the urban environment there are increased opportunities for data collection through sensors. Therefore, there are two data collection methods [4]:

- *Participatory data collection:* Users are actively involved in the collection process by deciding on the spot when to report data (user-centric data collection).a
- *Opportunistic data collection*: Sensor sampling occurs whenever the state of the device (e.g., geographic location) matches the application's requirements described in a sensing task (device-centric data collection).

The present–day abundance of raw data streams and information constitutes part of what has come to be called Big Data. Every short message service (SMS) sent via mobile phones, every email, and each seemingly insignificant daily transaction we make, collectively contribute single pieces of information to an immense global data cloud. In an attempt to aptly describe this wealth of data, Richard S. Wurman uses the example of the New York Times newspaper to highlight that an average weekday edition contains more information than a 17th century person was likely to come across in an entire lifetime [21].

In this context, citizen observatories have become big data systems due to their data–intensive nature – their existence relies in the need to observe and monitor a phenomenon –, citizen observatories deal with large scale volumes of data that come and go to millions of users. That data can be about any social or environmental phenomenon (transit, air or weather, among others) and comes in different formats (XML, Plain Text, CSV, etc.) and through different platforms (websites, mobile apps, sensor networks, etc.). In addition, the data comes from people (participatory sensing) or sensors (opportunistic sensing) in real time and intends to show the current state of a phenomenon of common interest.

This study reviewed the last 10 years of citizen science literature through a systematic literature review. Identifying 108 citizen observatories, which were deeply studied and clustered to identify global and European trends (presented in chapter I) in efforts, modern engagement techniques, technology uses, and practices. In addition, challenges and recommendations from the literature in the field were classified to understand the common present and future path for the discipline. This study, provides the first comprehensive examination of the broad scale of contemporary ICT enabled citizen observatories in social and environmental dimensions. In addition, a survey and interviews were applied to key stakeholders in Finland to gain broader understanding of the field country–wise (presented in chapter II).

2 Research Methods

This report is result of the use of three data collection methods: a systematic literature review, a survey and interviews. The systematic literature review was used to gather global and European information of the topic. On the other hand, the survey and interviews were targeted to key stakeholders in Finland.

The research questions of this study are:

RQ1: What are the trends in citizen observatories in the world?
RQ2: What are the practices in citizen observatories in the world?
RQ3: What are the current and past initiatives in citizen observatories in Finland and Europe?
RQ4: What are the current and past initiatives in citizen observatories in environmental observation in Finland and Europe?
RQ5: How to engage citizen?

2.1 Systematic literature review

The research process followed the guidelines by [22–25].The aim of a systematic literature review is establishing the state of evidence of a subject (other goals like classification are also mentioned). In this case the goals of the review is to assess the state of the art of citizen observatories, so this study is categorized as secondary literature review. The systematic literature review followed the process by [22] presented in Figure 2.

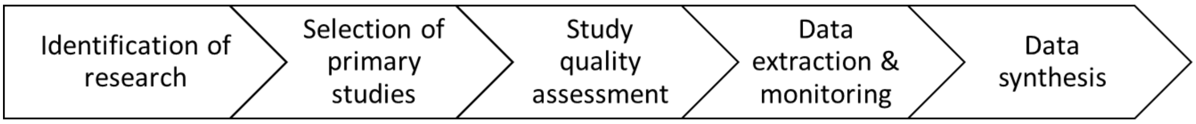

Figure 2: Stages of conducting a systematic literature review. Source: Based on [22]

Search process

The search design and procedure follow the guidelines in [22]. The review research questions were the ones enumerated in the beginning of this section. The search process is based on an automated searches on the following digital libraries:

- IEEE Digital Library http://ieeexplore.ieee.org
- ACM Digital Library http://dl.acm.org
- Sciencedirect / Scopus www.sciencedirect.com
- Web of Science www.webofknowledge.com
- Springer Link www.link.springer.com

2.1.1 Inclusion criteria

The following criteria were chosen in order to select the relevant publications to answer our research questions:

- Publication in the last 10 years (1/1/2004 – 31/06/2015)
- Books, papers, technical reports
- Explicit mention of citizen observatories or repositories
- Relevance with respect to research questions

2.1.2 Exclusion criteria

- Studies without empirical findings or examples
- Available only in abstract of power point
- Environment term used in the sense of a system environment and not nature

Two search strings were used:

Search String A: citizen* AND observ* OR repository* AND environment
Search String B: citizen* AND engagement* AND environ AND observ*

The overall number of results per query is listed in Table 1. All results were ordered "by relevance". From the results, we considered the first 100 results of each data base. In total, this study reviewed 828 publications. The summary of results included and relevant are listed in Table 2. An included result is a study that met the inclusion criteria of the study, a relevant result is a study which served for detailed data collection and statistical analysis, this use is explained below in the subsection "Data Analysis".

Table 1: Number of results per database

Database	Date	Results Q1	Results Q2
IEEE Digital Library	27.7.2015	1981	7275
ACM Digital Library	28.7.2015	13	347
Sciencedirect	28.7.2015	2589	4339
Web of Science	28.7.2015	6689	15
Springer Link	28.7.2015	39980	5079

Table 2: Relevant/Included/Found Results Comparison

	IEEE Digital Library	ACM Digital Library	Science direct	Web of Science	Springer Link
Q1+Q2 (Relevant/Included/Found)	18/46/200	18/55/113	19/41/200	3/18/115	12/38/200

Article Selection

- The researchers execute the search on each database and save references in plain text files
- The principal researcher (Maria Palacin Silva) reads all titles and abstracts and checks the inclusion and exclusion criteria for each entry
- The principal researcher classifies the papers and articles according to type, research approach relevance and domain
- The expert reviewer (Ahmed Seffah) reassesses the classification of relevance and inclusion/exclusion.
- The principal researcher reads each entry marked as relevant and extracts statistics for analysis.

Data Analysis

The data has been tabulated to show:

- The databases and numbers of query results
- Listed by database for included publications:
    - Author, title, country, date, keywords
    - Publication type and research approach

Each paper/entry was read and every observatory mentioned in each study was further reviewed to answer the research questions of this study.

- Data collected per citizen observatory in each paper:
    - (RQ1,RQ3,RQ4) Project title, environmental focus, participation model, domain, focus–domain, country, description, type of data measured, year of start, activeness, contact, website
    - (RQ1,RQ5) Stakeholder, activities description, techniques to engage
    - (RQ1) IT platform, description, application type, goal, services use, detail IT infrastructure, social media
    - (RQ1,RQ2) Problem or limitation, cause, solution proposed
    - (RQ2,RQ5) Best practice, process
    - (RQ1,RQ2) Recommendations
    - (RQ1,RQ2) Standard in use, description, issuing institution, website

2.2 Survey design

The research process followed the guidelines by [26]. The aim of a survey is to serve as a data collection method from a standardized sample of individuals to describe, compare, or explain individual and social knowledge, feelings, values, preferences, and behavior. Probabilistic random sampling methods described by [26] were used. Table 3 summarizes all the methods and details used for the data collection.

Table 3: Survey design

Method	Detail
Survey method	Online
Design method	Cross–sectional
Number of sample groups	1
Number of survey sections	3
Time duration	4 weeks (20.10.2015– 16.11.2015)
Selection method	Random sampling
Sample requirements	Person who has worked with a citizen observatory in Finland
Survey administration	Via webropol tool from Lappeenranta University of Technology (LUT)
Processing the data	Data is automatically entered from survey to database via webropol
Survey distribution	Invitations to fill the survey to a random sample: 1) Via Emails, 2) Via Twitter. Invitation to fill the survey to key stakeholders pointed by SYKE.
Answers collected	12
Reach (Times form opened)	491

The selected design method was the cross–sectional defined by [26] because data was collected only at a single point of time. The survey design followed a structured organization in order to approach the RQ2, RQ3, and RQ4 (Table 4). The data analysis is presented in chapter II. It includes descriptive statistics with averages, summaries and cross tabulations. Finally, the applied survey is located in Appendix I.

Table 4: Survey questions design

Section	**Aim**	**Research Question**	**Number of questions**	**Questions design**
Basic Information (I)	Gather background information.	RQ3, RQ4	1	Open–ended question
Aspects of Data Collection and Analysis (II)	Gather information about the type of data that is collected, practices and data issues and uses.	RQ2, RQ3, RQ4	9	Multiple choice question Open–ended question Closed question Interval scare question
Challenges and Future Perspectives (III)	Gather information about the main challenges, achievements and future expectations related to their citizen observatories.	RQ3, RQ4	4	Multiple choice question Open–ended question Open question

2.3 Interviews design

The interviews study followed the guidelines by [27]. The aim of an interview is to understand describe central themes in the life of the subjects. The type of interview used, was general interview guide approach, this approach intends to ensure that the same information is collected from each interviewee.

Forty–two individuals from 28 organizations (appointed the Finnish Environment Institute as relevant in Finland) were contacted. Seven individuals agreed to be interviewed. The interviews were designed (Table 5), to last an average of 30 minutes. The data analysis is presented in chapter II.

Finally, the interview design is located in appendix II and the processed interview answers are in appendix XVII.

Table 5: Interview design

Section	Goal	Research Question	Type of Questions
Informed Consent	Explain the purpose of the interview and address terms of confidentiality		
Section 1: Data Collection	Understand what kind of crowdsourced citizen observation data do you gather and how do you gather it?	RQ3,RQ4	Background/demographics Knowledge
Section 2: Location and Motivation of citizens	Understand how you recruit and motivate your citizen observers.	RQ3,RQ4, RQ5	Behaviors
Section 3: Challenges and Success Stories	Understand your success and your biggest challenges.	RQ3,RQ4	Behaviors Feelings
Extra: Perspectives of what is going on in Finland with citizen observatories	Learn about perspectives and expectations about the future of citizen observatories.	RQ3,RQ4	Opinions/values

3 Trends in the World and Europe: Past, Present and Future

Citizen observatories have been used in a wide range of areas around the world since the 20th century – such as ornithology, astronomy, biology, biodiversity monitoring, and city management among others–. These can transform the relations between citizens, businesses, governments and other organizations. Yet, there are no standards that specify in which ways data should be collected, aggregated (from various formats) and analyzed (to deduce useful information) to be interoperable and open. Citizen observatories have vital characteristics, such as the following that have been appointed by [18,28]:

a) A citizen observatory should involve citizens as active partners in environmental monitoring and decision–making, since this is central for protecting and enhancing our environment;
b) Environmentally-focused observatories should target an array of natural resources and/or a range of environmental components;
c) Generally, the involvement of citizens has multiple purposes, with education and raising public awareness being the most common objectives;
d) There is value in citizen observatory as a way to bring community groups together. citizen observatory, like other forms of civic engagement, can build social capital within the community;
e) Evaluation of the effectiveness of a citizen observatory as well as of the public involvement decision–making is needed.

This chapter found 108 observatories (40 of which are European), through a systematic literature review. The found citizen observatories were studied in depth to identify trends in the focuses, engagement techniques, technology uses, practices, stakeholders, standards, limitations and recommendations.

Key findings in the chapter:

- Remarkably, 69% of the identified world observatories have an environmental goal which involves species, water, streams, snow, sea, biodiversity, air, spectrum and global monitoring.
    - Most of the European observatories (up to 80%) have been collecting environmental information – about species, biodiversity, air and spectrum, water, streams, snow, sea, precipitations, climate change–
- The three domains that have most of the citizen observatories applications are: city management (25%), species (23%) and water, streams snow and sea monitoring (18%) projects.
    - The top three focus area of European citizen observatories are: species monitoring, biodiversity monitoring and air and spectrum monitoring.
- USA, UK and Canada are the leaders in citizen observatories and environmental citizen observatories in the world.
    - Within Europe, United Kingdom is by far the most active country in this field with 47.5% of the total citizen's observatories in the continent, being followed by Ireland and Netherlands with 7.5% observatories each.
- The most common model for data collection is the participatory, in which citizens are actively involved as data providers.
    - Among European citizen observatories the most common practice is to gather their data using participatory data collection methods.

- There is a raise since 2000s in observatories using opportunistic data collection methods, such as automatic background data collection.
- The top three stakeholders for citizen observatories are:
    - Citizen: This group (represents 58% of the total), is mainly providing raw data (34%), installing sensors or apps that collect background information (9%), deploying their own observatories according to their interest (6%) and, its focus of all the types of observatories.
    - Academy and government: This cluster (represents 22% of the total), is providing data (4%), installing sensors or apps that collect data (4%), deploying their own observatories (2%), and using information from observatories for decision making, research and development (12%). The observatories that involve this type of stakeholder are: city management observatories, tools for citizen observatories, species monitoring and air and spectrum monitoring projects.
    - Nature enthusiasts: This stakeholder's group (represents 10% of the total), is providing data (6%), installing sensors and apps to collect background information (2%) and, using the data for decision making (2%). information from observatories for decision making, research and development (12%). The observatories that involve this type of stakeholder are: biodiversity monitoring, species monitoring, water, streams, snow and sea observatories and city management observatories.
- The most used techniques for engagement are:
    - Present Data Benefit: This technique was the most common among citizen observatories. It aims to promote discussions with stakeholders, to highlight the direct benefit data can bring for them such as: better roads and cities, improvement in their environment –air, water, pollution, etc. and a better channel for participating in local governance.
    - Citizens Interest based monitoring: This category, included techniques that allow citizens to set up and manage their own concern observatory.
    - Unify observatories with recreational activities: This group of techniques included to use recreational activities, competitions, learning games and, art campaigns that raise emotional feelings among the stakeholders, while they submit observations.
- There is a clear trend of digitalization of the observations submission, which translates into the popular use of web (38%), mobile (23%) and both (2%) technologies to collect data. On the other hand, the least common technologies are: dedicated games (2%), phone–based (3%) – using Interactive voice response known as IVR – and public displays (5%).Remarkably, 69% of the identified world observatories have an environmental goal which involves species, water, streams, snow, sea, biodiversity, air, spectrum and global monitoring.
- The common problems and limitations of citizen observatories are caused by: user practices, standardization issues, limited knowledge, limited resources, narrow focus, privacy issues, need for recognition of contributions, centralized data, data accessibility problems, data analysis and technology.
- Common practices among observatories include: co–creation, data aggregation, environmental campaign in public spaces, feedback from observations, gamification, identify stakeholders and their motivations, interest based observatories, involve decision makers, measure motivation, observatory component based, open data for engagement, opportunistic data collection, participatory data collection, provide technology, provide training material, real time visualization, set common protocols for observers.

3.1 Statistical results

The statistics presented in this section, are result of the analysis of 108 citizen observatories around the world and their: focuses, engagement techniques, technologies, practices, stakeholders, standards, limitations and recommendations. Special emphasis is put on the European and environmentally-focused observatories. The data source for these analyses can be found in appendix V to XIV.

Major domains and applications of citizen observatories

Our study classified the identified (108) observatories into eight categories according to their focus (Figure 3):

1. **City management (21):** Grouped observatories that support decision makers managing city's issues such as: transportation, bicycle routes, land usage, energy consumption, surroundings classification, environmental conditions, traffic and parking monitoring, citizen needs and perceptions.
2. **Species monitoring (25):** Involving single species monitoring projects – such as insects, bats, birds, butterflies, sea species, and game animals –.
3. **Water, streams, snow, sea (19):** Observatories that are collecting data about water quality, precipitations, streams, lakes, snow, ice and sea environments.
4. **Biodiversity monitoring (13):** Observatories that focused on monitoring biodiversity, flora, forests, mountains, biosphere and trees.
5. **Air and spectrum monitoring (11):** Observatories that gather data about air quality, noise, sounds and radiation.
6. **Tools for citizen observatories (14):** Involving tools that are useful for creation or integration of citizen observatories, such as: configurable citizen observatories (plug and play tools), image classification components and sensors monitoring components.
7. **Global monitoring (3):** Astronomy and climate change observatories that monitor global trends.
8. **Disasters monitoring (2):** Observatories that are looking at earthquake monitoring and early detection.

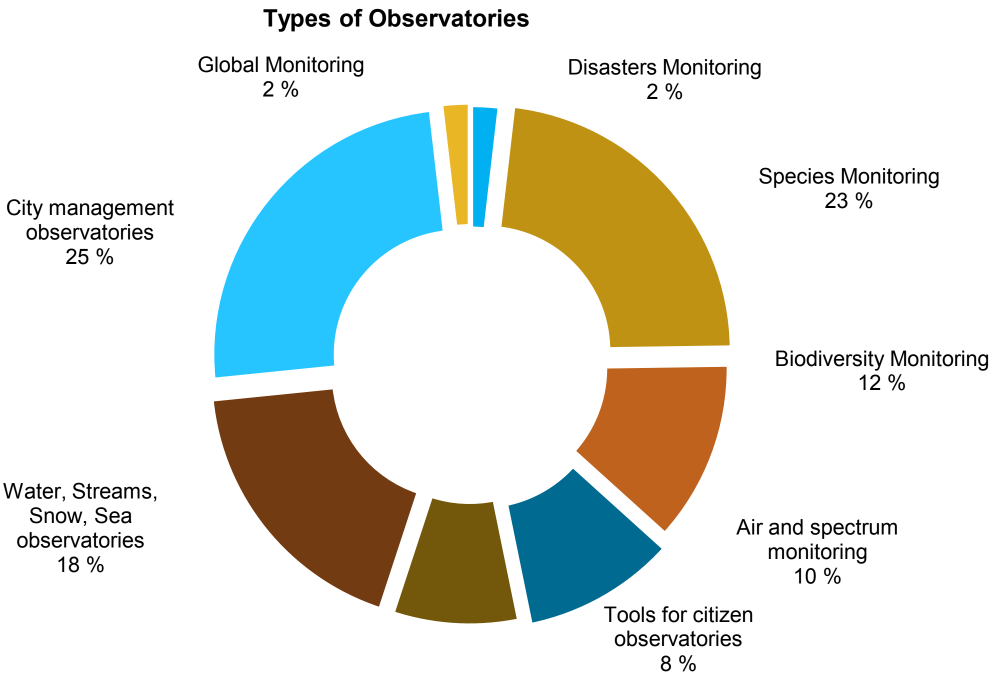

Figure 3: Types of citizen observatories

Globally the geographic reach of a citizen observatories can go from local (in a specific country and city) to worldwide (with features that adapt for global needs). The (Figure 4) resumes the distribution of citizen observatories by location and type. 13% of the total observatories has a global reach and has been defined under the location of "worldwide" with strong focus on: tools for citizen observatories (creation or integration), city management and species monitoring. 5%, of the total observatories has a European reach and has been defined under the location of "Europe" with strong focus on air, spectrum and biodiversity monitoring. On the other hand, the three most active countries hosting citizen observatories are:

1. **United States:** Hosting 38% of observatories focusing especially on: water quality, cities management and species monitoring.
2. **United Kingdom:** Having the 16% of the total observatories, where the most common types of observatories are for: species monitoring, biodiversity monitoring and city management.
3. **Canada:** With 8% of the total identified observatories, having special focus for: water, streams, snow, sea observatories, species and biodiversity monitoring.

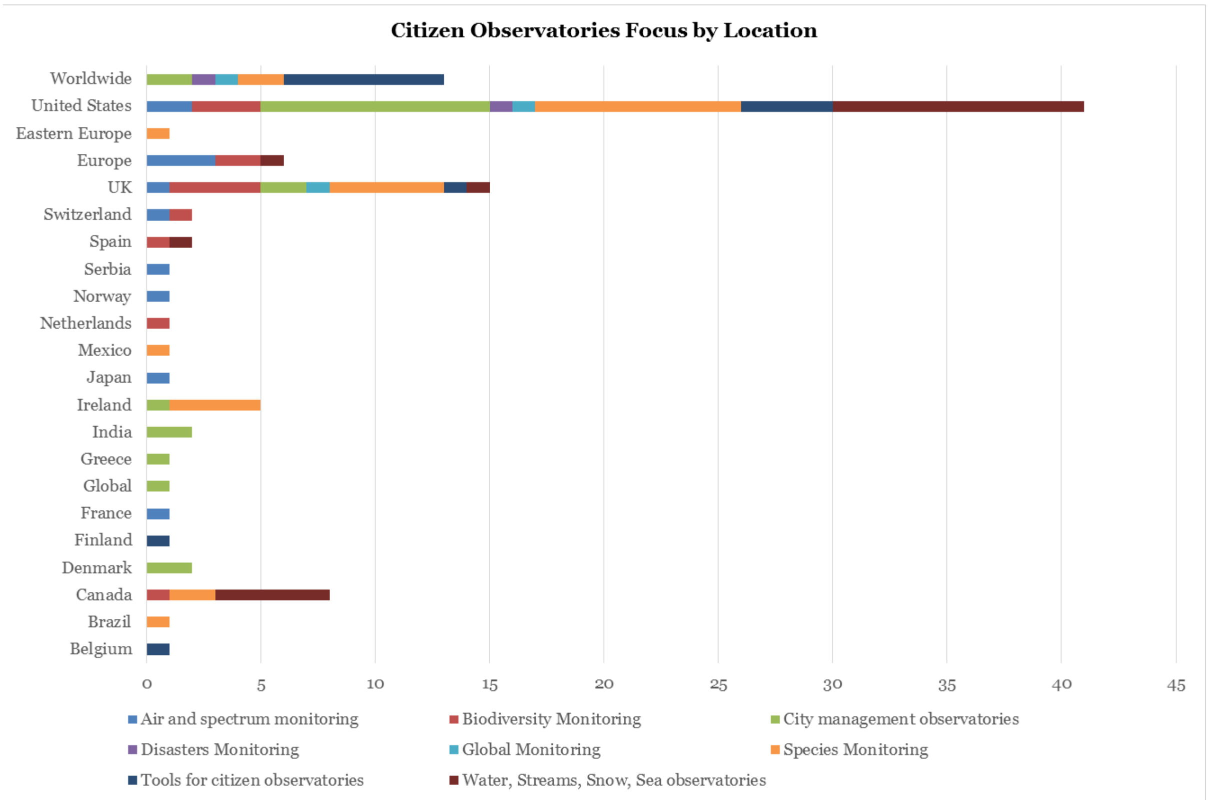

Figure 4: Citizen Observatories' distribution by location and type.

Also through the systematic literature review, this chapter identified 40 citizen observatories in Europe. These observatories have started since 1966 and have had a peak in 2012 with 6 new observatories launched during that year (Figure 5).

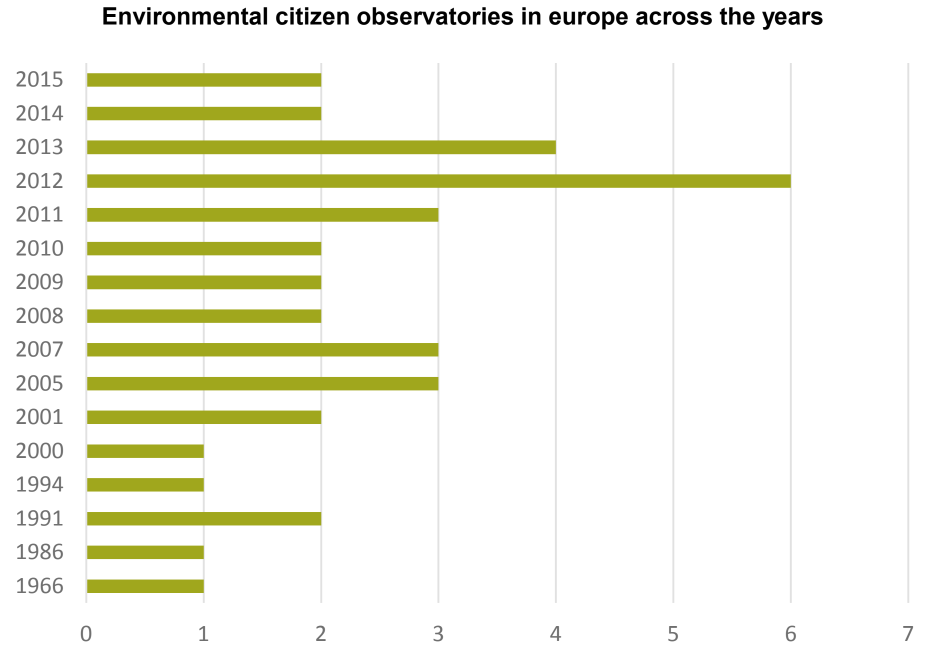

Figure 5: Citizen Observatories in Europe – years of start

The focus area of the European citizen observatories is environmental monitoring (Figure 6) with special interest in **species monitoring** (9) – e.g. birds, bats, butterflies and bumblebees – **biodiversity monitoring** (9) –e.g. mountains, forests, biodiversity and biosphere – **air and spectrum monitoring** (8) – air quality, pollution and sound – **water, streams, snow, sea monitoring** (4) – e.g. sea, water quality, aquatic species, precipitations – and, **global monitoring** (1) – climate change – also, other areas have been developed such as **tools for citizen observatories** (2)– e.g. automatic classification and configurable citizen observatories– and, **city management monitoring** (7) – e.g. Smart transportation, energy consumption, mobility issues, urban issues management and environmental campaigns and conditions–.

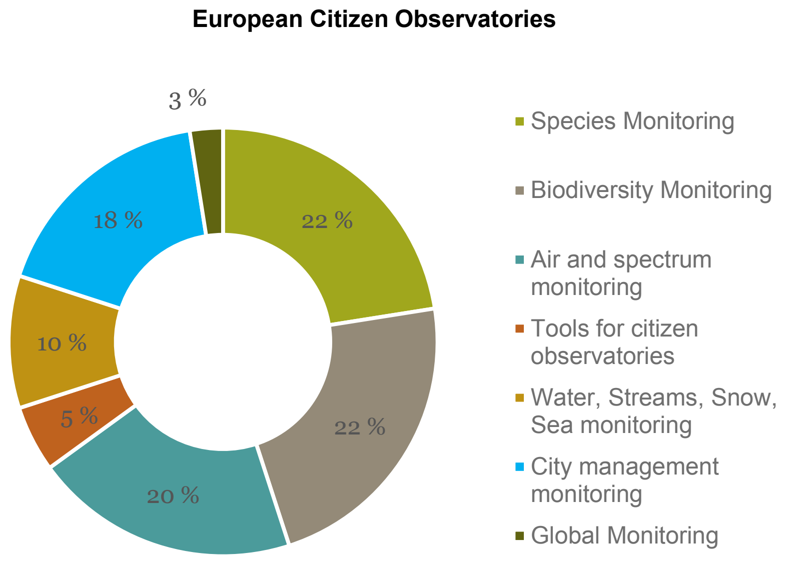

Figure 6: Citizen Observatories focus areas in Europe

Over 16 countries in Europe are actively involved running some type of environmental citizen observatory (Table 6); United Kingdom is by far the most active country in this field with 38% of the total citizens observatories in the continent, being followed by Ireland with 13% of observatories and, Spain, Switzerland and, Denmark with 5% each. However, there is a 15% of citizen observatories that are not strictly connected to one country but rather to the whole Europe.

Table 12: Citizen Observatories in Europe – countries distribution by percentages (%)

Country	%
Belgium	3 %
Denmark	5 %
Finland	3 %
France	3 %
Greece	3 %
Ireland	13 %
Netherlands	3 %
Norway	3 %
Serbia	3 %
Spain	5 %
Switzerland	5 %
UK	38 %
Eastern Europe	3 %
Europe	15 %

Citizen science projects have been shown to enable large–scale data collection, increase scientific literacy, and monitor environmental quality [29], as either people–centric or environment–centric sensing. People–centric applications mainly focus on documenting activities (e.g., sport experiences) and understanding the behavior of individuals (e.g., eating disorders). In contrast, environment–centric sensing apps collect environmental parameters (e.g., air quality or noise pollution) [30].In addition, citizen–contributed data has high resolution and requires low calibration in contrast to official databases (low resolution, high calibration) [31].

There are two modern data collection models used by citizen observatories around the world: a) The participatory model, in which users are actively involved in the collection process and, b) the opportunistic model, where sensor sampling occurs whenever the state of the device (e.g. geographic location) matches the application's requirements described in a sensing task, without the knowledge of the individual using the mobile device [4]. These two models were used to classify the identified observatories (108) of this chapter (Figure 7).

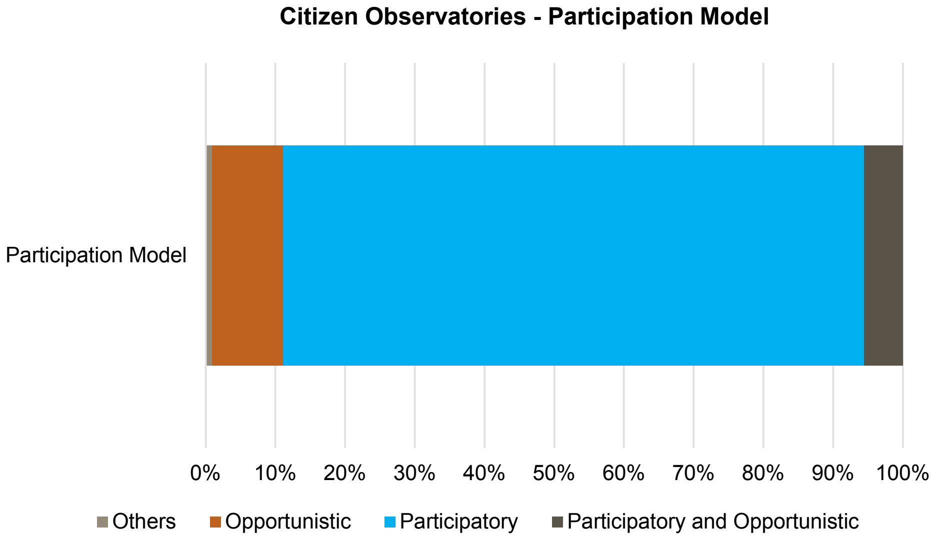

Figure 7: Citizen Observatories' by participation model

In overall, the most used model for data collection is participatory (83%), which according to Figure 8 has been used since 1900 and has become widely spread since 1960s and continues growing, while the opportunistic model is less common (10%) but, has been growing since 2000s and it is expected to continue growing while the mobile technologies development keep developing. However, it is also feasible for citizen observatories combine these two approaches, the 6% of the identified observatories work under this approach which has emerged after 2005 and seems to be increasing.

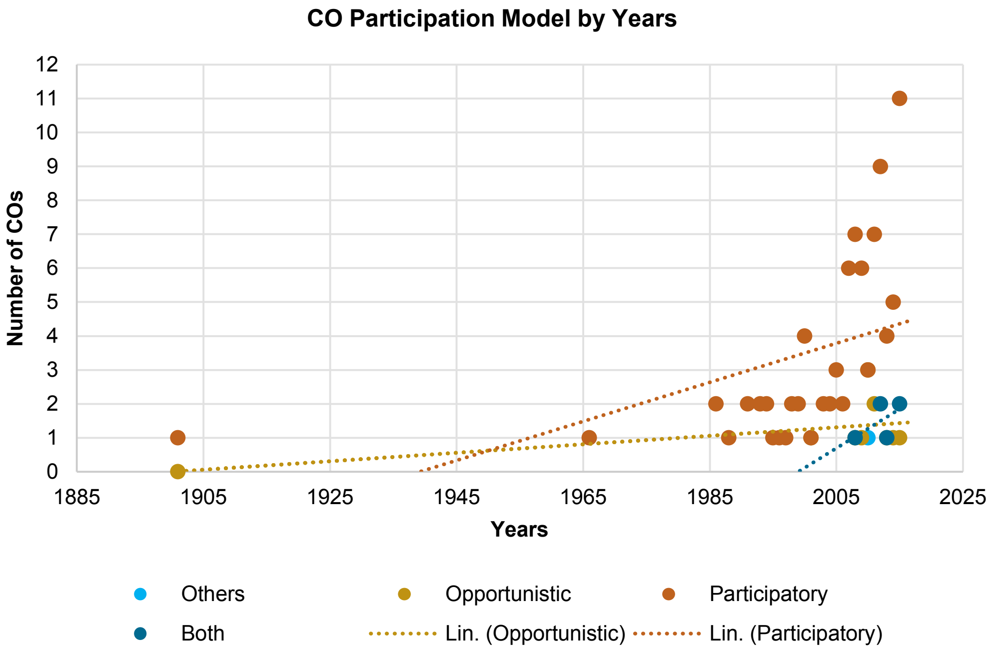

Figure 8: Participation models by citizen observatories starting year

Within Europe, the citizen observatories characterize for being of the type community–based monitoring. The monitoring activities under this type of monitoring include many different types of assessments of ecosystems such as: 1) status assessment (i.e., population monitoring), 2) impact assessment (i.e., effect of pollution), or 3) adaptive management (i.e., managing based on monitoring) [32]. Also, among

European citizen observatories the most common practice is to gather their data using participatory data collection methods (Figure 9).

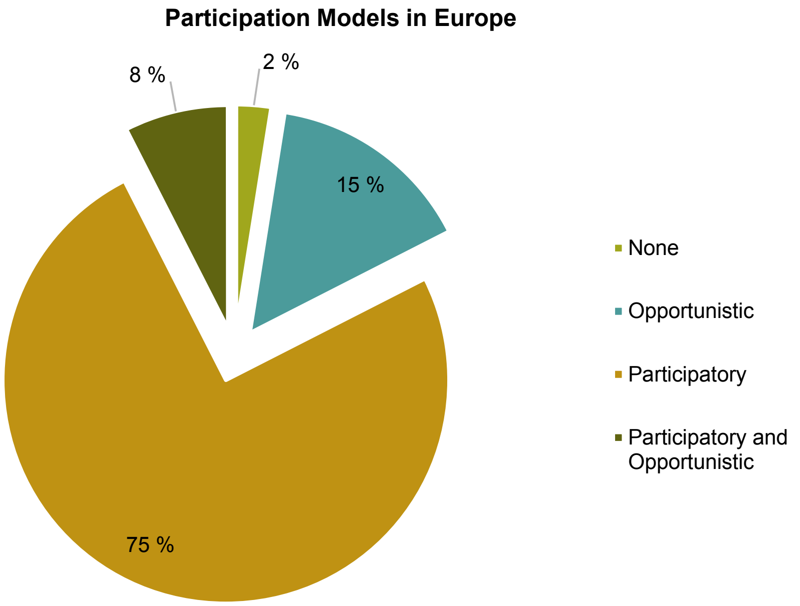

Figure 9: Citizen Observatories in Europe – participatory practices

Nonetheless, citizen observatories need to address the following dimensions: collection (huge amounts of data), aggregation (of data in various formats) and analysis (to deduce useful information). Addressing these challenges require a multipronged approach involving standardization of data formats, data harmonization mechanisms, computational processing and storage infrastructure and mechanisms to ascertain contextual relevance of the data with its consumers [17]. While it is true that the large amounts of data captured by sensors provide a "ground truth" base and though new tools and systems offer the power to capture more data, human collaboration, analysis and stewardship are required to extract useful information [33].

The citizen scientists that contribute with the citizen observatory projects, normally collect data but they may also help refine project design, analyze data, or disseminate findings; and co–creating projects, in which projects are co–designed by scientists and volunteers [29]. However, a citizen science project must consider multiple stakeholders that not only collect and use data but also support the project such as researchers and government.

Also, the citizen observatories present the potential for considerable improvements in terms of social innovations. Their features can enable a two–way communication paradigm between citizens and decision makers, potentially resulting in profound changes to existing governmental management processes [12].

This chapter clustered the stakeholders of the identified observatories according to their occupation in five categories: **citizen, academy and government, nature enthusiasts, families plus specific individuals** and **developers.**

Also, the activities these stakeholders perform were clustered in four types –according to the goal of the activity–, such as: **provide data, install sensor/app and let them collect background data, deploy a private citizen observatory campaign,** and **get training and do classifications.**

Figure 10 and 11 summarize the stakeholder groups by their main activities, and which type of observatories are involving which cluster of stakeholders:

1. **Citizen:** This group (represents 58% of the total), is mainly providing raw data (34%), installing sensors or apps that collect background information (9%), deploying their own observatories according to their interest (6%) and, its focus of all the types of observatories (Figure 6).
2. **Academy and government:** This cluster (represents 22% of the total), is providing data (4%), installing sensors or apps that collect data (4%), deploying their own observatories (2%), and using information from observatories for decision making, research and development (12%). The observatories that involve this type of stakeholder are (Figure 6): city management observatories, tools for citizen observatories, species monitoring and air and spectrum monitoring projects.
3. **Nature enthusiasts:** This stakeholder's group (represents 10% of the total), is providing data (6%), installing sensors and apps to collect background information (2%) and, using the data for decision making (2%). information from observatories for decision making, research and development (12%). The observatories that involve this type of stakeholder are (Figure 6): biodiversity monitoring, species monitoring, water, streams, snow and sea observatories and city management observatories.
4. **Families plus specific individuals:** This stakeholder's cluster (represents 10% of the total), is providing data (4%), installing sensors and apps that collect background information (4%), using the information for personal decision making and research (4%). The observatories that involve this type of stakeholder are (Figure 6): city management observatories, biodiversity monitoring and air and spectrum monitoring observatories.
5. **Developers:** This group (represents 2% of the total), is mostly using the data for research and development (2%) and the observatories that have involved them are the air and spectrum monitoring observatories.

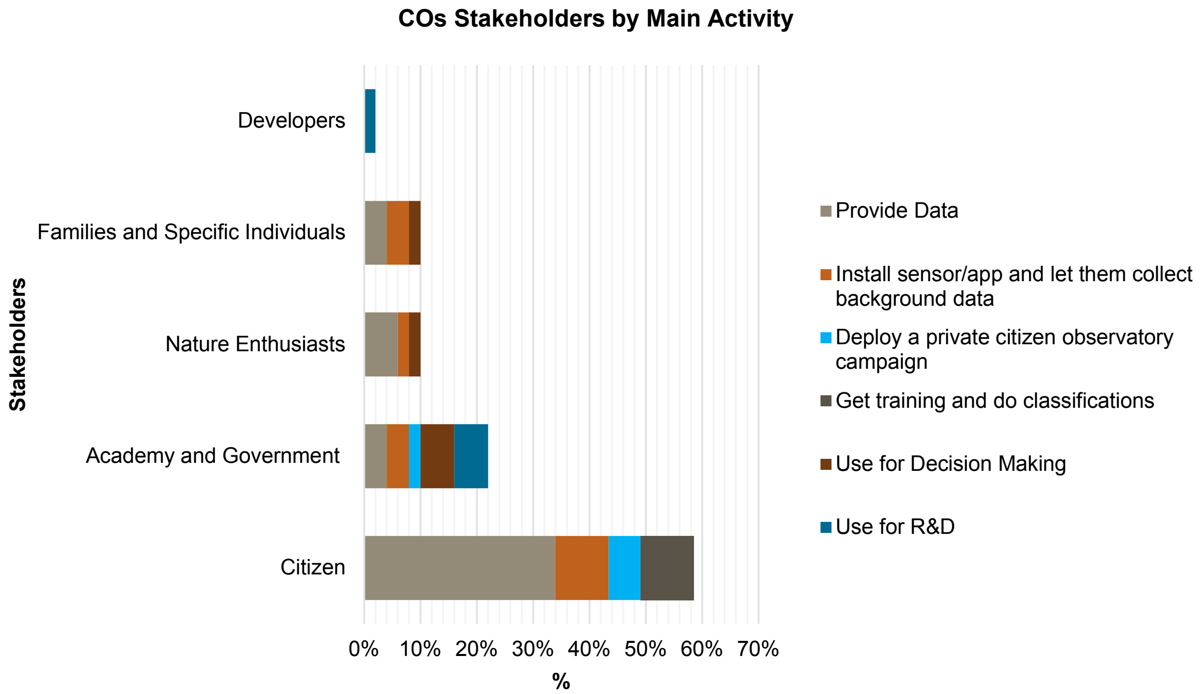

Figure 10: Citizen Observatories' stakeholders by main activity

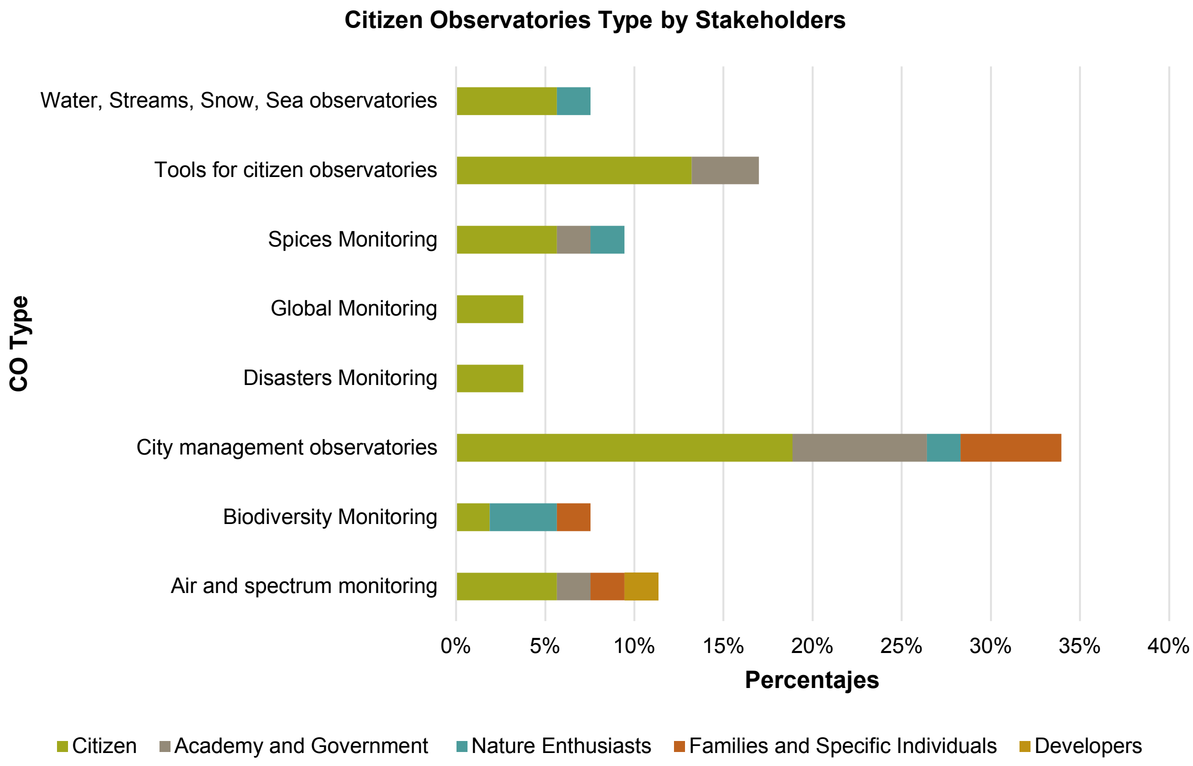

Figure 11: Citizen Observatories' type by stakeholder

In overall, the types of data that stakeholders have been reporting for citizen observatories (Figure 12) is mainly data about **measurements (74)** via their mobile devices, special devices or their own recordings, **opinions (7)** about set topics or proposing topics and, **both (27)** through classifications and ideas for new observatories.

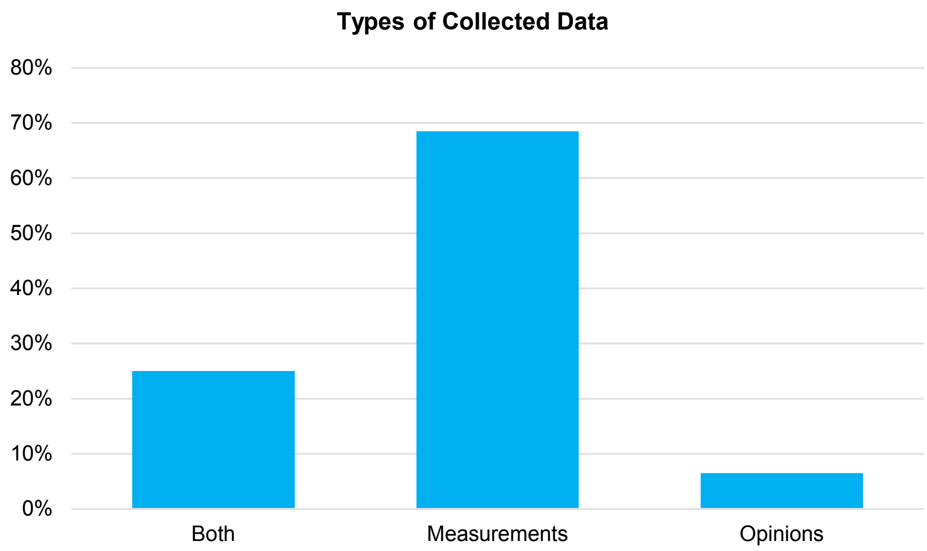

Figure 12: Types of collected data

There is a rise in social computing (based on social production and mass collaboration) that has facilitated a shift from consumer cultures to cultures of participation (in which all people are provided with the means to participate and to contribute actively in personally meaningful problems) [34].

Social computing (is the intersection of social behavior and computational systems) provides a new opportunity for citizens to reach out and change their world. HCI (Human Computing Interaction) researchers have begun to investigate on how social computing can increase citizen engagement and participation with government. In addition, researchers have recently begun to investigate how social computing can support planning activities around urban infrastructure, giving citizens a greater voice in the planning process that reshapes their world [35].

Furthermore, the citizen observatories present the potential for considerable improvements in terms of social innovations (as result of social computing). However, it is important to define what the social innovation in question consists of, to what extent it is being attained and under what conditions, and how it can be fostered [12].

In this context, citizen observatories are social computing applications that actively involve mass collaboration under common goals. This chapter, clustered the ways stakeholders are currently being engaged by the studied citizen observatories to perform citizen science activities under seven clusters (Table 7):

1. **Be an exceptional citizen:** This cluster grouped techniques that award the activeness of a particular citizen as an observer with social recognition in their communities, TV or schools/work places.
2. **Citizens Interest based monitoring:** This category included techniques that allow citizens to set up and manage their own concern observatory.
3. **Gamification Strategies:** This cluster grouped the gamified techniques that involve to incorporate game elements into their applications such as puzzles, avatars, competitions or story lines.
4. **Partnership:** The main focus of this cluster, are techniques that empower city managers to install sensors and apps in their cities, to collect background data about different concern issues.
5. **Present Data Benefit:** This cluster was the most common among citizen observatories and embraces the discussion with stakeholders, to present them the benefit of the data they will provide, for themselves such as: better roads and cities, better knowledge about the status of the environment –air, water, pollution, etc. – around their areas, solve their issues and, share their opinion about city concerns.
6. **Save Money:** This category focused on creating monetary saving for the users, due to their activeness using a particular observatory. It is a key to keep the users updated about of how much has been saved because of their actions.
7. **Unify observatories with recreational activities:** This group of techniques included to use recreational activities, competitions, learning games and, art campaigns that raise emotional feelings among the stakeholders, while they submit observations.

Table 7: Citizen Observatories – Techniques to engage

Technique to Engage	Source
Be an exceptional citizen	(6%) of Observatory Projects
Citizens Interest based monitoring	(19%) of Observatory Projects
Gamification Strategies	(6%) of Observatory Projects
Partnership	(2%) of Observatory Projects
Present Data Benefit	(53%) of Observatory Projects
Save Money	(2%) of Observatory Projects
Unify observatories with recreational activities	(13%) of Observatory Projects

The fabric of contemporary cities increasingly incorporates ubiquitous networks of sensing and actuation devices. These systems allow for an unprecedented understanding of numerous aspects, relating to the urban environment itself and the processes that take place in it. Environmental conditions, air quality, occupancy levels, energy consumption, electricity usage, traffic flows, public transport frequency, noise levels, water management are among the few indicators that can nowadays be observed and, subsequently, controlled by such devices. In addition, every obtained observation synchronously constitutes a set of geo–located data, reflecting a minuscule piece of information about the city dynamics [36].

Pervasive computing (ICT existing everywhere) can ultimately engage millions of people in mass participation to environmental campaigns, raising awareness of environmental issues, supporting education, activism and democracy, and delivering environmental data on a scale never before possible [37].

This chapter, analyzed the technologies that are currently used to build citizen observatories (Figure 13). There is a clear trend of digitalization of the observations submission, which translates into the popular use of web (25), mobile (15) and both (1) technologies to collect data, which is followed by a strong use of sensors (5) and sensors plus mobile apps or web platforms (2). Finally, the least common technologies are: dedicated games (1), phone–based (2) – using Interactive voice response known as IVR – and public displays (3).

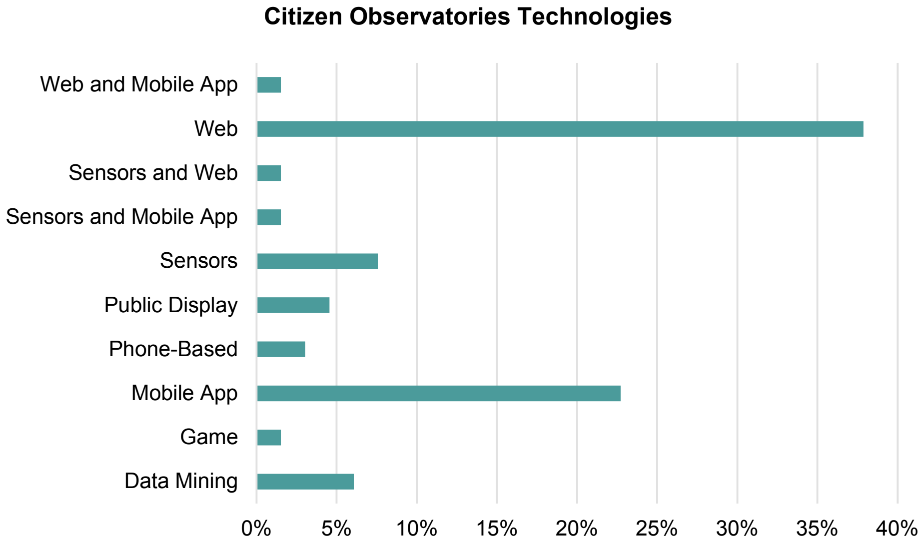

Figure 13: Citizen Observatories' by technology use

In addition, only 21% of the studied citizen observatories offer some services which anyone can use to analyze, reuse and redistribute. The social media use (Figure 14) to inform and communicate with observers, citizen observatories seem to prefer Facebook, Twitter and G+ for increasing their visibility. Yet, the citizen observatories are also present on Instagram, sound cloud, YouTube, RSS, Github and some even have their own web store.

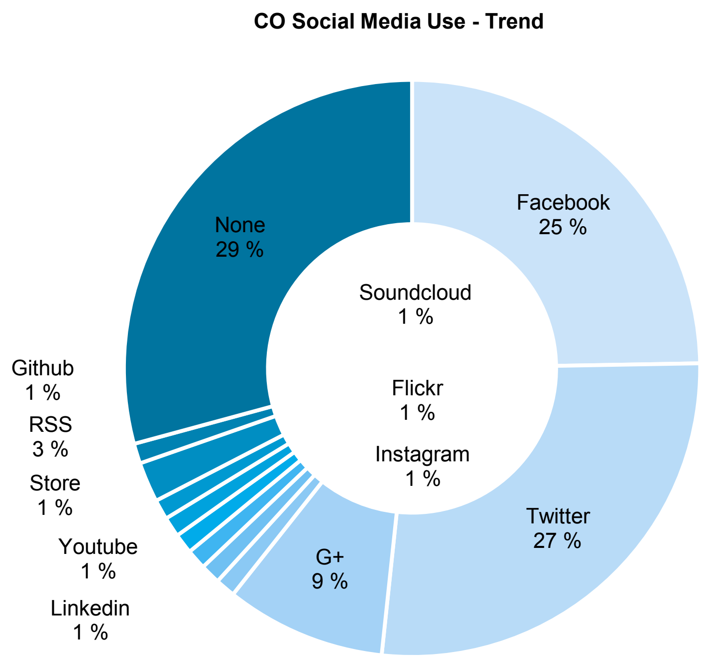

Figure 14: Citizen Observatories' by social media use

The advances in computational storage and processing capacities have not only allowed for a finer granularity of the available information sets, but have also given the opportunity to synchronously analyze data of different types; besides that, these data sets are largely referenced in space and time, while reflecting human activities as well as monitoring city–related conditions and events the actual time during which they occur. Subsequently, they constitute invaluable sources for deriving an understanding about urban dynamics [36].

But, what technologies in particular are used for building modern citizen observatories? This chapter analyzed the web platforms of observatories using the service of BuiltWith, which is service that counts with a website profiler tool that allowed us to find out what websites are built with. The size of the font (in Figure 15) is proportional to the relevance of certain tool in the field.

Figure 15: Citizen Observatories' word cloud of technical tools

3.2 Environmental observatories commonalities and goals

Thanks to the Internet, crowdsourcing is expanding its reach and establishing itself as a cheap and viable alternative for scientific work that was previously restricted to the limited capacity of professional teams [30].

This chapter classified the identified (108) observatories into two categories according to their purpose: environmental and non–environmental (Figure 16). Remarkably, 75 of the identified world observatories have an environmental goal which involves species, water, streams, snow, sea, biodiversity, air, spectrum and global monitoring. Consequently, there are 33 observatories that are classified as non–environmental and involve city management observatories, disaster monitoring and tools for building/integrating citizen observatories.

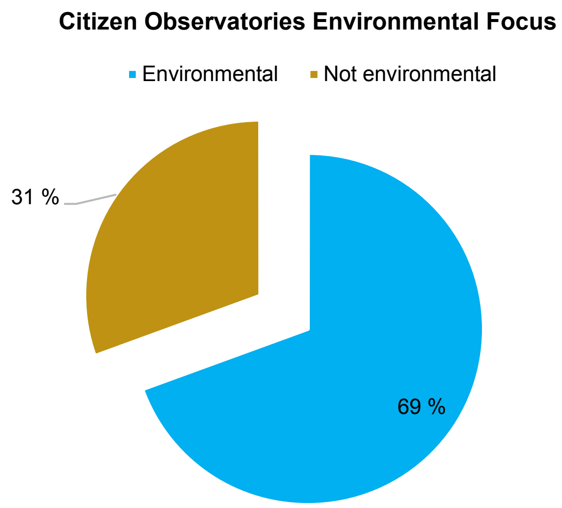

Figure 16: Citizen Observatories' environmental focus

Within Europe, 80% of the identified observatories have been collecting environmental information – about species, biodiversity, air and spectrum, water, streams, snow, sea, precipitations, climate change– and the remaining 20% have had focus on: cities management, tools for create and improve citizen observatories (Figure 17).

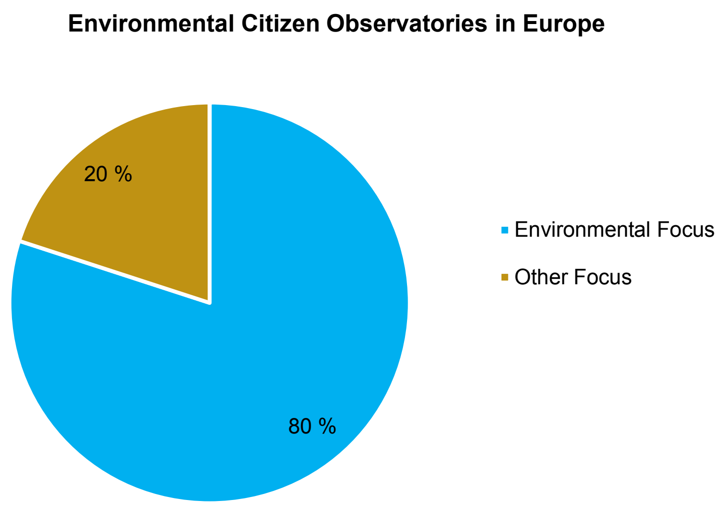

Figure 17: Citizen Observatories in Europe – environmental monitoring

The geographic reach of an environmentally focus citizen observatories as for the non–environmental can go from local to global. The figure 18 resumes the distribution of citizen observatories by location and type. The 5% of the total observatories has a global reach and has been defined under the location of "worldwide" with strong focus on species monitoring. While 7% of the total environmental observatories has a European reach and has been defined under the location of "Europe" with strong focus on air, spectrum (range of wavelengths of radiation) and biodiversity monitoring. On the other hand, the three most active countries hosting environmental citizen observatories are:

1. **United States:** Hosting 37% of observatories focusing especially on water quality and species monitoring.
2. **United Kingdom:** Having the 23% of the total observatories, where the most common types of observatories are for species monitoring and biodiversity monitoring.
3. **Canada:** With 11% of the total identified observatories, having special focus for: water, streams, snow, sea observatories, species and biodiversity monitoring.

Collecting environmental data using observatories has been done since 1900 (Figure 19), and has grown rapidly since 1960s. Non–environmental observatories have appeared only after the millennium (2000). However, both types of observatories are on the rise, though apparently environmental focused observatories have a faster growing rate. Then again, the participatory model (which involves actively people) is the most used by environmental citizen observatories (Figure 20).

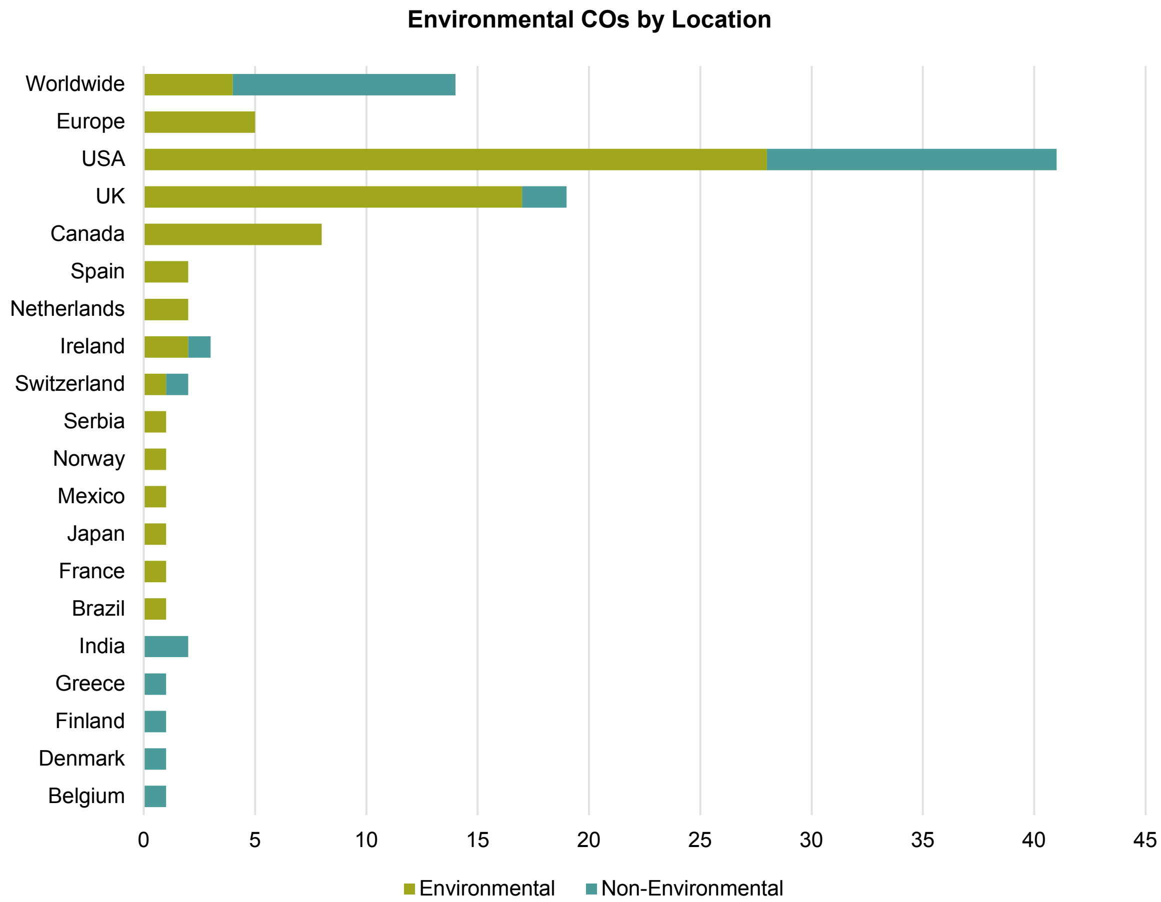

Figure 18: Citizen Observatories with environmental focus by location

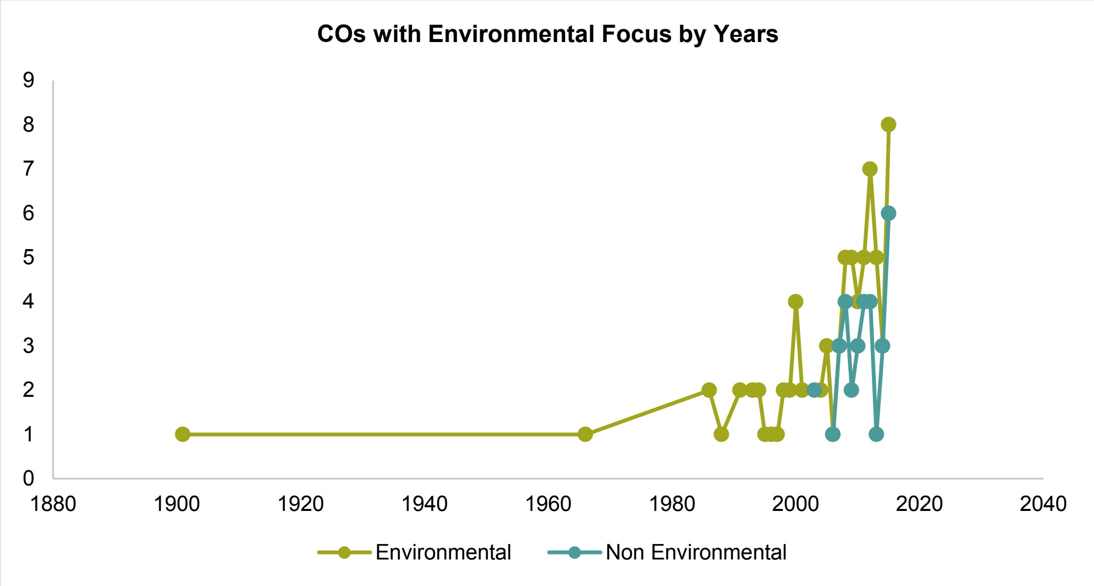

Figure 19: Citizen Observatories with Environmental Focus by Start Year

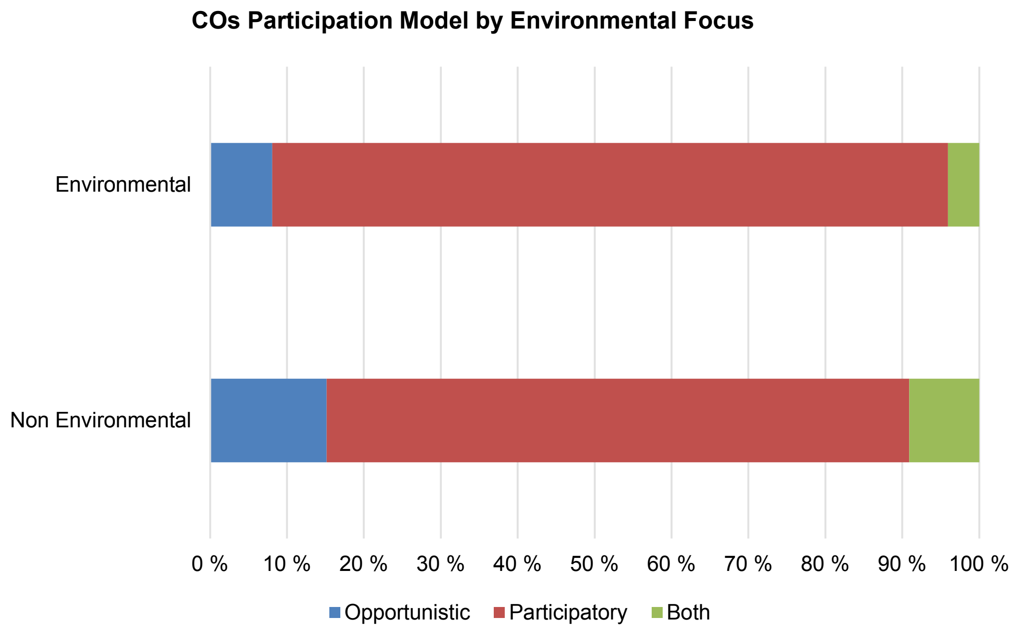

Figure 20: Environmental Citizen Observatories by Participation Model

3.3 Who are running citizen observatories around the world?

A citizen observatory can be used for multiple fields and involve several types of stakeholders but, also it can be run by various types of organizations from universities, charities, companies, consortiums, government institutions, private pioneers (initiatives), NGOs to research institutes (Figure 21).

The most common runner of citizen observatories found by this study are, private pioneers (citizens, consortiums, societies, foundations, networks) through **initiatives (34)** that have as main focus a particular type of observatory. Private pioneers were followed by: **Universities (28)** which operate with their research units handling COs, c**onsortiums (13)** that refer to multidisciplinary joint initiatives started by different types of organizations which are supported by regional grants and networks, **government (13)** through local authorities, national commissions/institutions, research units and projects, **companies (12)** that run business or research units around the COs topic, **research institutes (4)** that are highly focused on observations of different fields, **NGOs(2)** which run a particular citizen observatory as their cause (and generate revenues), and **charities (2)** that are sustained by multidisciplinary institutions.

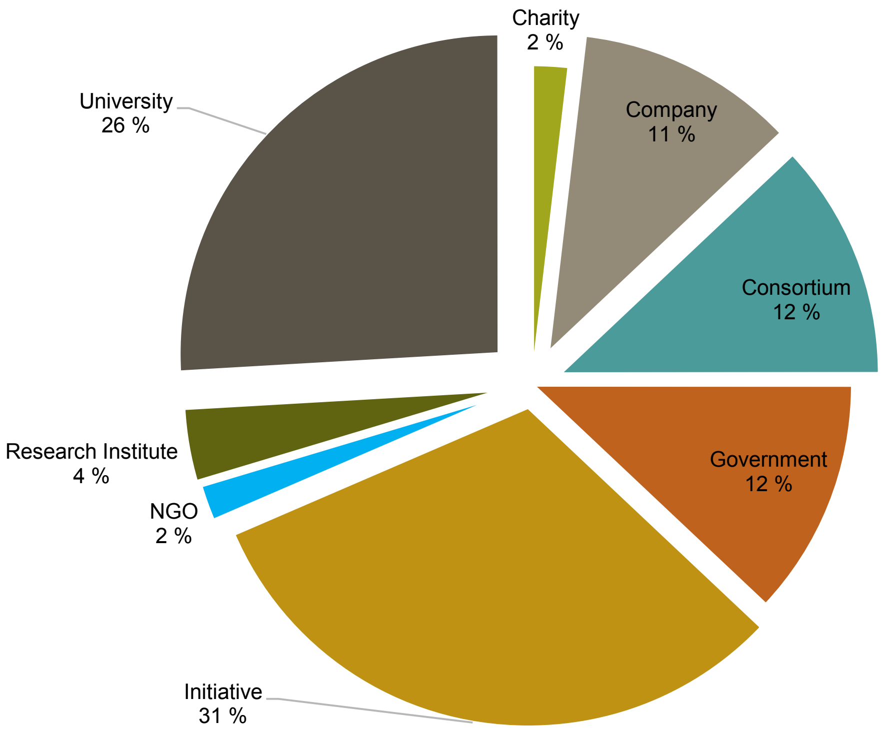

Figure 21: Institutions running citizen observatories worldwide

3.4 Challenges, opportunities, best practices and recommendations

Given the ubiquity of mobile devices and the high density of people especially in urban areas, where nearly half of the planet's population resides [38]. Citizen science can achieve an unprecedented level of coverage in both space and time for observing events of interest [39]. Although, there are differences in the monitoring across different parts of the world, there is a large number of observatories which share features, practices, and challenges within the two aspects of citizen science: community–based monitoring and community–based management [32].

This chapter, classified the reported challenges and limitations from the identified citizen observatories (108) in 9 categories (Figure 22), which are the following:

1. **User Practices (15):** The target stakeholders, are not always ready for start contributing with a citizen observatory. The figure 23, is a word cloud elaborated with the reported issues by the studied observatories.
2. **Data Aggregation Issues (7):** This problem, is faced by the observatories that have multiple data formats and data structures which have to be used to extract joint information.

3. **Technology (5):** This challenge refers to: issues with devices' size, weight and reliability, power consumption limitations, calibration and configuration constraints, lack of systematic methods to reject false and spam observations.
4. **Standardization (4):** This challenge involves: the lack of reusable methods or frameworks for creating new observatories, the lack of standards for inter–communication among observatories, semantic discrepancies, and lack of systematic evaluations.
5. **Limited Knowledge (3)**: Several observatories face issues because of the lack of knowledge about how to build practically a citizen observatory. Specially, a lack of IT knowledge.
6. **Limited Resources (3):** All resources in this world are limited and the development of a citizen observatory tends to have limited resources that are mostly spent during the setting up phases, thus there is a common need for extra resources to keep the monitoring up and well maintained.
7. **Privacy Issues (1):** Understanding the concerns of stakeholder's regarding the ownership and use of their data is important. Adequate technologies should be used to capture this opinions.
8. **Recognition of Contribution (1):** There is a need for social fairness when it comes to citizen observatories, which need to properly acknowledge the contributions and support of observers.
9. **Data Accessibility (1):** This limitation includes projects that have reported that: making data available in a transparent way to the relevant stakeholders is fundamental. However, making raw data available is not sufficient, stakeholders should be able to access, explore and analyze relevant information (extracted from raw data) in a simple and transparent fashion.

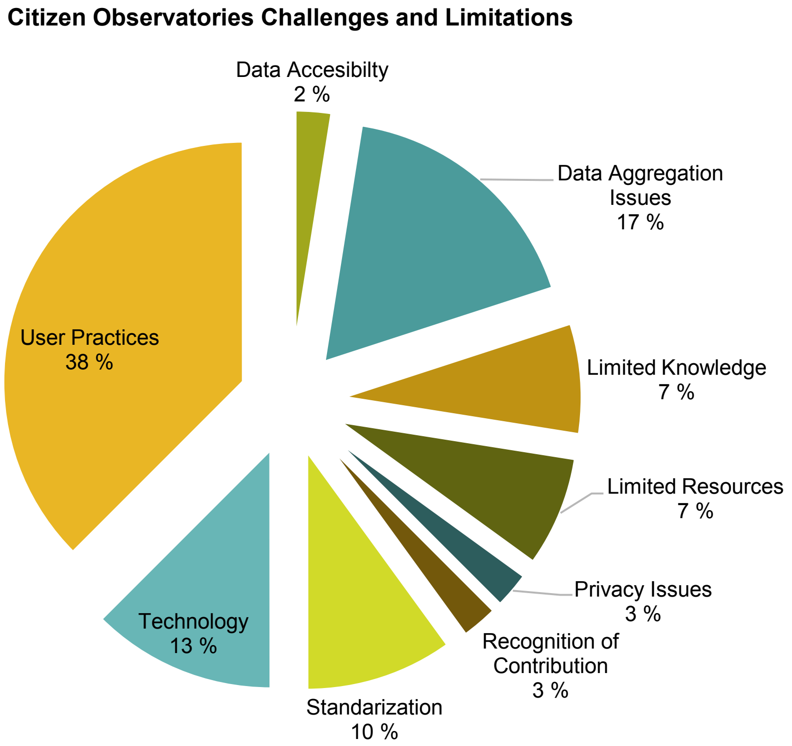

Figure 22: Common challenges and limitations among citizen observatories

Figure 23: Common problems and limitations among citizen observatories word cloud

When it comes to practices, 54 best practices were found from the available information of the identified (108) citizen observatories, common practices were found, which allowed to group them into 17 clusters: **co–creation, data aggregation, environmental campaign in public spaces, feedback from observations, gamification, identify stakeholders and their motivations, interest based observatories, involve decision makers, measure motivation, observatory component based, open data for engagement, opportunistic data collection, participatory data collection, provide technology, provide training material, real time visualization, set common protocols for observers.** Figure 24, presents the most used and least used practices, it also highlights the relation between the found practices and the means they use; Technology intensive practices, are practices that have been created to facilitate the collection, analysis and dissemination of data. The public engagement practices, aim to combine strategies to locate and motivate observers.

The top 2 most common practices among citizen observatories are: 1) co–creation practices which involve co–create solutions with citizens through direct communication with the stakeholders and highlight to their opinions and interests and, 2) feedback from observations is needed to keep observers engaged. When a record is submitted, the observer should receive an informative response which can include for example: the uses that will be given to his data, tips to keep observing or extra observing challenges (game element).

The least common practices are: 1) data aggregation –meaning integration of different data sets with the collected data–, 2) interest based observatories –that allow stakeholders to set up their own observatory according to their concerns–, 3) involve decision makers –meaning the creation of a two–way communication channel between citizens and government using citizen observatories– and 4) measurements of motivation –measuring the motivation of volunteers to understand what factors drive participation–.

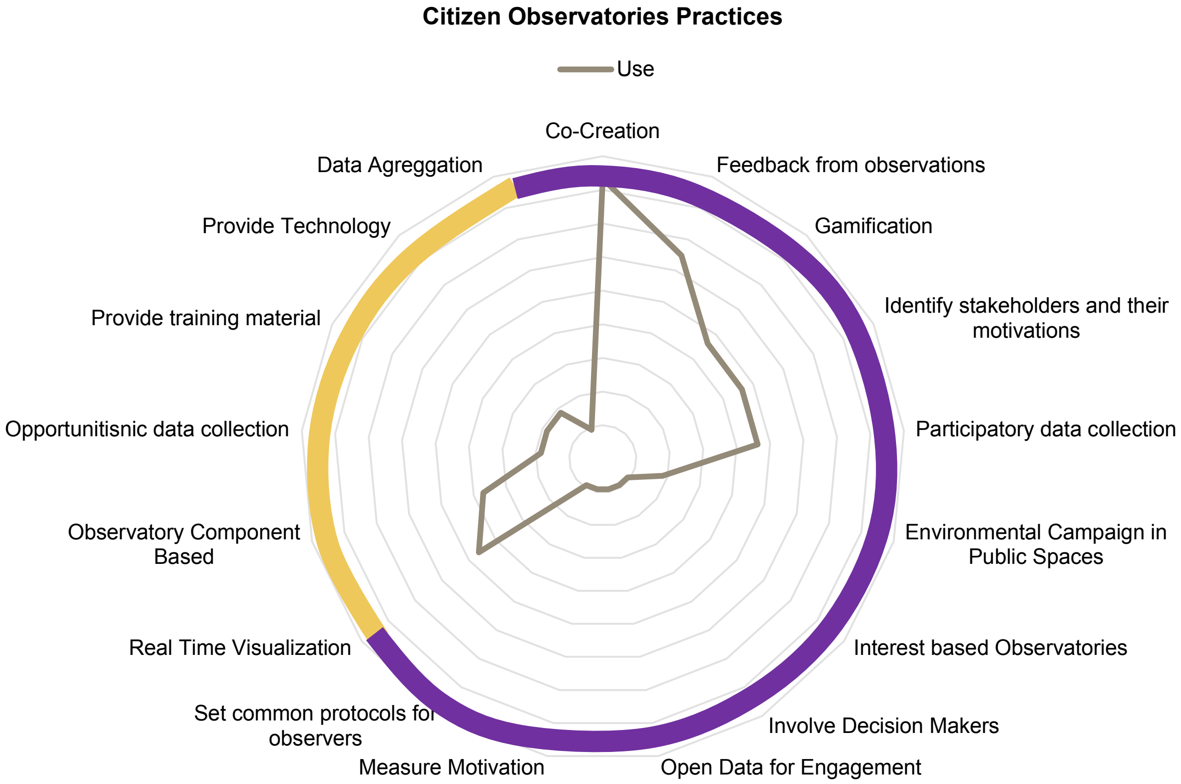

Figure 24: clusters of common practices among citizen observatories (yellow: technology intensive practices, purple: public engagement practices)

The identified practices were cross related with the citizen observatories' participation model (Figure 25). The participatory model was the most common with 61% of the practices being part of an observatory using it, followed by the opportunistic model with 20% and, a mix of both of 19%.

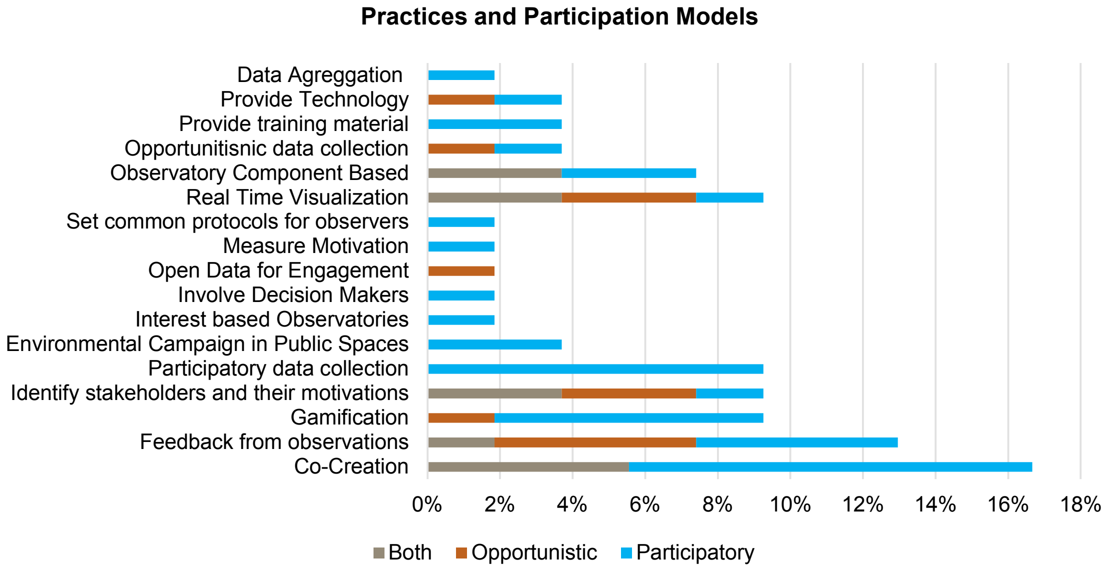

Figure 25: Practices and participation models

Finally, 68 recommendations and future perspectives were found from the available information of the identified (108) citizen observatories. Those were grouped into the following 6 clusters (Figure 26):

1. **Data Collection (29):** This group of recommendations and future perspectives include advices about ways to gather citizen observations, from whom, how and why?
2. **Engagement (21):** This cluster, groups advices about how and why to engage certain stakeholders? What types of stakeholders can feel more comfortable doing what?
3. **Data Visualization (6):** This collection, gathers the recommendations and future perspectives about interfaces, technologies, and techniques to create visually engaging applications.
4. **Standards (5):** This group, gather advices avenues within standards for citizen observatories.
5. **Data Analysis (4):** This cluster, brings together advices about requirements for performing data analysis of observatories based systems.
6. **ICT management (3):** This collection, gathers the recommendations and future perspectives about what issues to have into account when selecting or managing technologies for citizen observatories.

The full summaries of the recommendations and future perspectives can be found in appendix XIII.

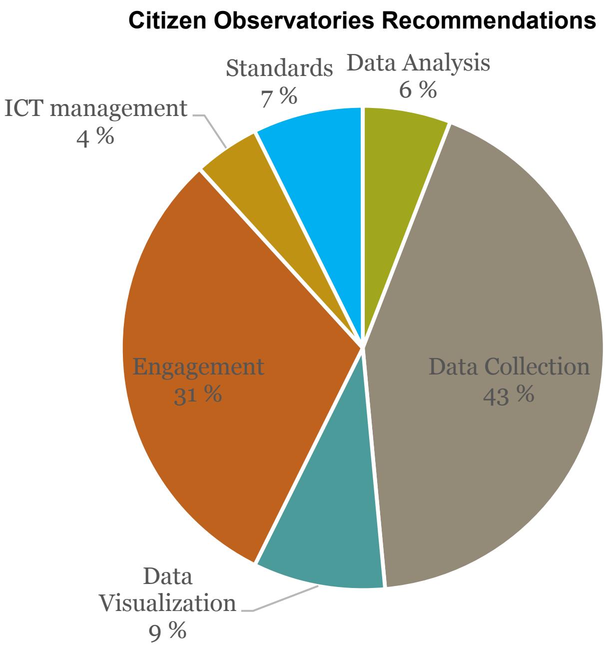

Figure 26: Recommendations and future perspectives from citizen observatories

3.5 Standards, networks and initiatives

Citizen observatories need to address the following dimensions: collection (big amounts of data), aggregation (of data sets in various formats) and analysis (to deduce useful information). Addressing these challenges require a multipronged approach involving standardization, of at least: processes, methods, data formats and metadata harmonization [17].

Standardized frameworks can help reconcile many of the challenges to citizen observatories [32]:

- Identify stakeholders (including governance analysis, consultation and outreach, identification of champions, partnership development, and selection of organizational structure.
- Identify skills and resources (including fundraising and securing adequate future funding skills assessment, capacity building.
- Create a communication plan (including achieving influence, feeding back results and management recommendations.

This chapter, recorded the standards, initiatives and networks that were reported by the identified (108) observatories and articles reviewed in the systematic literature review. As result, 25 initiatives, international agreements, networks and standards were found (Figure 27):

1. **Initiatives (9):** Among these initiatives, the three most remarkable for citizen observatories are: 1) EnvO which is an environmental ontology, 2) WISER which is a European project for water bodies monitoring that have elaborated a water framework directive–compliant assessment system for lakes, transitional and coastal waters and, 3)HarmBio COST which is an European COST action that aims to harmonize the current biodiversity models and datasets in order to improve the reliability of environmental monitoring.

2. **International agreements(6):** Among international agreement, the three most remarkable for citizen observatories are: 1) the open government partnership which involves 66 countries, aims to engage nations making their governments more open accountable and responsible to citizens through open data, 2) the Australian citizen science toolbox that provides detailed and practical methods to actively engage citizens and, 3) the Malmo eDeclaration on the joint eGovernment strategy which focus on prioritization of citizen participation into the government goals.

3. **Networks(3):** Among the networks, the three most remarkable for citizen observatories are: 1) The GEO BON, which is closely cooperating with regional biodiversity observation networks (i.e. Arctic BON, EU BON, Asia–Pacific BON) to develop a framework for global biodiversity monitoring focused on a set of ecological variables, 2) Artic BON that has for goal to facilitate more rapid detection, communication, and response to the significant biodiversity–related trends and pressures affecting the Arctic and, 3) the national water quality monitoring council, what promoted the development and use of methods and protocols that support the collection of quality data about water across North America.

4. **Standards (7):** Among the standards, the three most remarkable for citizen observatories are: 1) The Sensor Web Enablement (SWE), which enable developers to make all types of sensors, transducers and sensor data repositories discoverable, accessible and useable via the Web, 2) the eXtensible Markup Language (XML), that is a markup language that defines a set of rules for encoding documents in a format which is both human–readable and machine–readable and, 3) the Web Ontology Language (OWL), which is a semantic markup language for publishing and sharing ontologies on the World Wide Web.

The full summaries of the standards, initiatives and networks from citizen observatories and the systematic literature review can be found in appendix XIV.

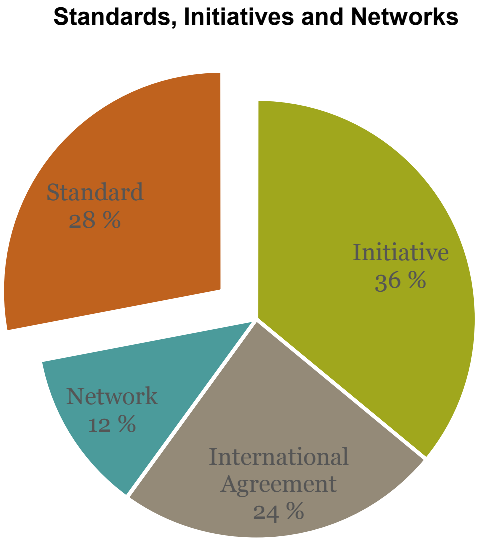

Figure 27: Standards, initiatives and networks from citizen observatories and systematic literature review

3.6 Recommendations for further studies

- There are open possibilities to find more relations and co–relations in the collected information about, types of gathered data, institutions, stakeholders and roles, technological trends, challenges, best practices, standards and recommendations. See appendixes V to XIV, for the detailed data.
- There is a need for further study to identify the specific role that companies play in the citizen observatories field, appendix VII can be used to find the list of websites of the 108 observatories this study identified, information about the role of companies can be derived from those sites.
- Regarding satellite data usage: this report didn't extract specific information about the use of satellite data. However, appendix VII can be used to find the list of websites of the 108 observatories this study identified and, information about the role of satellite data can be found in those sites.
- The data from citizen observatories can be aggregated and used for research about emissions.

4 Citizen Observatories: Current Initiatives in Finland

Citizen science has been a long tradition among citizens and government agencies in Finland, organizations such as LUOMUS (National History Museum of Helsinki) have received data from citizens that dates up to 1900s. This chapter focus are the active citizen observatories in Finland, a survey (which collected 12 responses) and seven interviews were carried with key stakeholders running well-established monitoring projects. The focuses, data collection techniques, practices, challenges and opinions of those observatories were identified. This chapter will be referring to 6 interviewed organizations since two interviews belonged to the same organization. (The methods to collect and analyze the data are explained in the section Research Methods).

Key findings in this chapter:

- Over half of the survey and interview respondents had a positive – already implemented, maybe or ongoing– opinion about opening their data for public use, combination, reuse and redistribution. Yet, there were citizen observatories that may not be willing to open their data due to data ownership and privacy issues.
- Clubs and non-governmental organizations is a new type of stakeholder classification found in this chapter.
- Less than half of the survey respondents uses social media to communicate with their users
- The participatory method of collecting data is the most common in among the surveyed citizen observatories.
- The interviewees specified they collect their data for business purposes (30%), research purposes (40%), legislation responsibility or objective of their organization (30%). In collaboration with volunteers that range from locals to experts which collect data individually or in groups.
- All the interviewed organizations reported to use internet based tools and mobile apps to collect observations. Also, they reported to use paper forms and accept physical specimens.
- Collecting feedback ideas and providing training from/to observers are engagement techniques are new clusters found in this chapter.
- The most common data type to store crowd–sourced data was XLS: Excel File Format and the last common were HTML: Hypertext Markup Language and XML: Extensible Markup Language.
- Less than half of the survey respondents use scientists to review and ensure the data quality. However, there is interest about techniques to generate automated classifications systems that are based on citizens' contributions.
- The biggest challenge for the survey and interview respondents regarding their observatories is technology management, specifically lack of knowledge about the field and automatic data validation.
- Finally, the perspectives for the future of the field from the survey and interview range from more active public involvement, a growth in funding opportunities, expanding the observatory, better technology, opening data to more active government institutions involvement.

The survey and interview responses were clustered under the classifications presented in section 1.1. New clusters were found during that process for those classifications. The combination of these groupings can be found in the summary of chapters section.

4.1 Survey study results:

The survey study had 12 responses (Figure 28) which were: executive directors or presidents (2), field experts (3), ICT specialists (3) and project managers (4) from organizations that have one or more citizen observatories running in Finland.

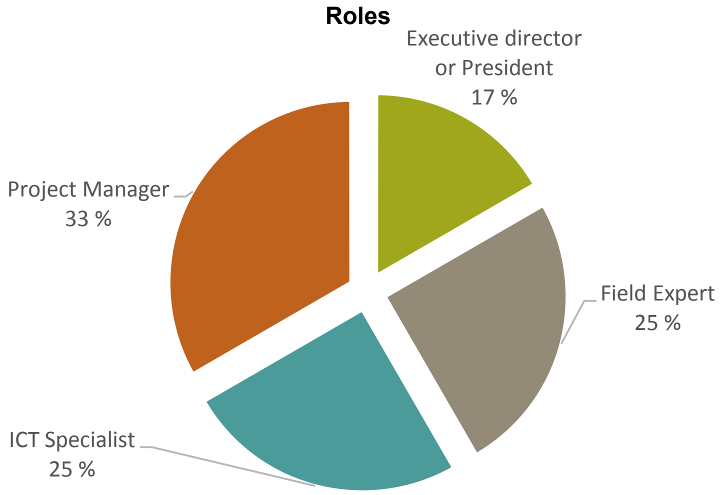

Figure 28: Survey responses – roles

4.1.1 Citizen observatories purpose and data collection practices

Most of the surveyed respondents reported that their citizen observatories are focused (Figure 29) on species monitoring (4), tools to support research and decision making (3), biodiversity monitoring (2), water quality monitoring (1) and tools for citizen engagement (1). Yet, 1 of the survey respondents didn't state the purpose of their citizen observatory, therefore that answer was excluded (definitions of each type of observatory can be found in section 1.1). These observatories, are collecting data about environment (Figure 30), ecology, hydrology, birds, wildlife, weather, noise, transport and others – such as exclusively plants biodiversity and a game to monitor traffic accidents.

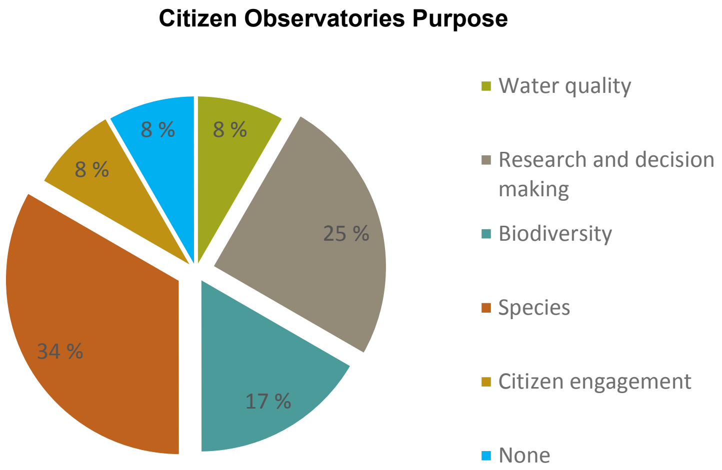

Figure 29: Survey responses – citizen observatories purpose

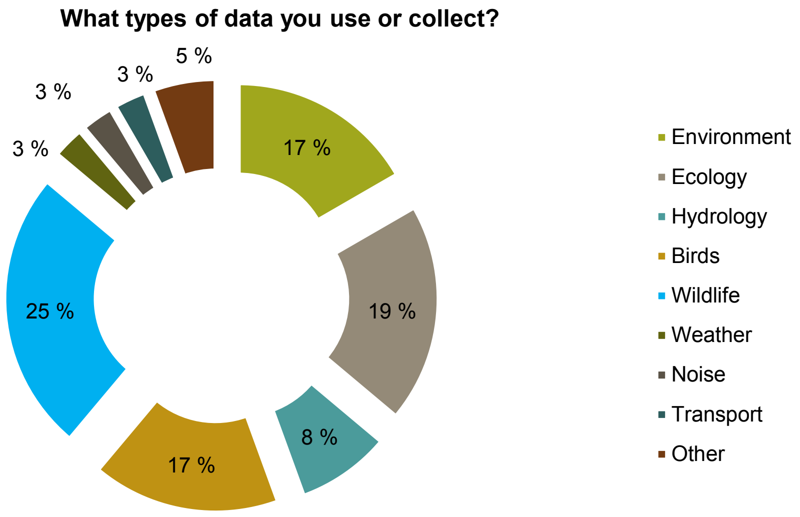

Figure 30: Survey responses – data collection

The 42% of the respondents, indicated that their citizen observatories has a metadata format in current usage (Figure 31) – such as Map data transferred to Excel, Hertta excel–files, EML (or custom made for biological collections), case dependent, collected data saved in database – The responses show that there is a need for a common understanding of what metadata (see Lexicon section) is in the context of citizen observatories, although this result might be explained by respondents fields of specialty. In addition, surprisingly only 42% of these citizen observatories have some type of social media presence to connect with their users (Figure 32).

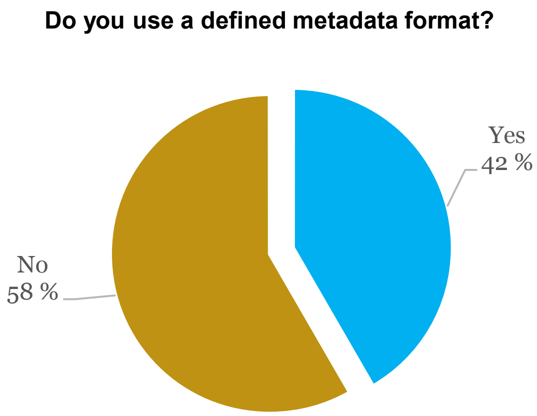

Figure 31: Survey responses – metadata usage

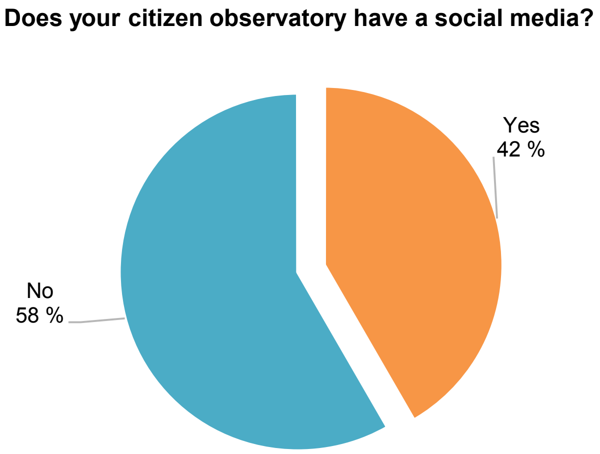

Figure 32: Survey responses – citizen observatories social media

4.1.2 Data storage and usage practices

The survey respondents were asked to rate their data storage processes according to a list of statements where (1= Close to this, 2 = Leaning towards this, 3 = Not performed yet, 4 = Leaning towards this, 5 = Close to this). According to the average rate of the results (Figure 33) which was 3, Finnish citizen observatories seem to not be using certain data storage strategies –such as: cloud storages, aggregate data sets, use open source databases, ontology definitions, and standardized data sets.

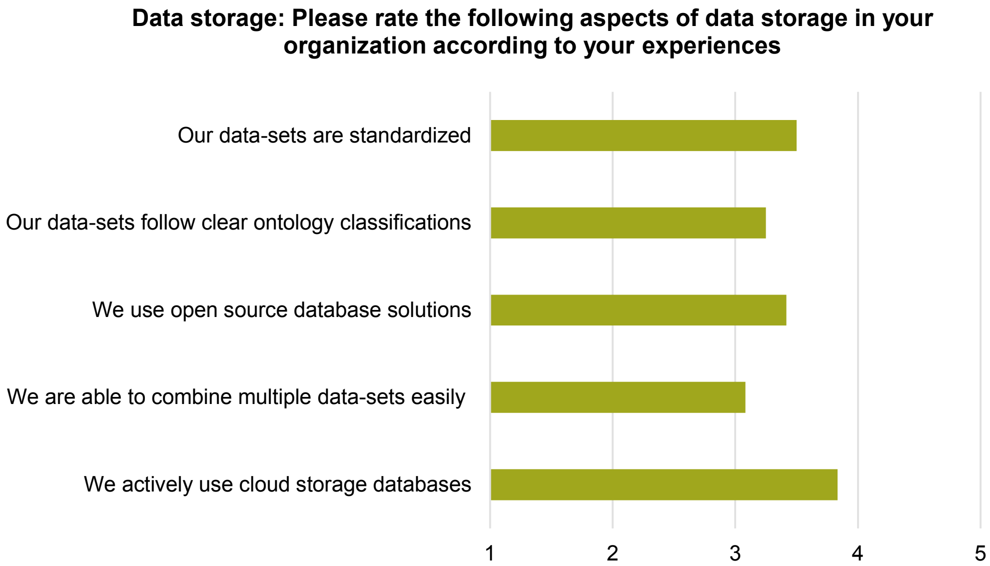

Figure 33: Survey responses – data storage practices: survey responses

Data from citizen observatories is rich and requires low calibration and, therefore, it can have multiple uses. The respondents were asked to select from a set of practices the ones that they are performing. The most common use for crowd–sourced data was the analysis to extract specific useful information, while the least common was to convert the data for a public API (application program interface). Among another uses feedback to the citizens was highlighted (Figure 34).

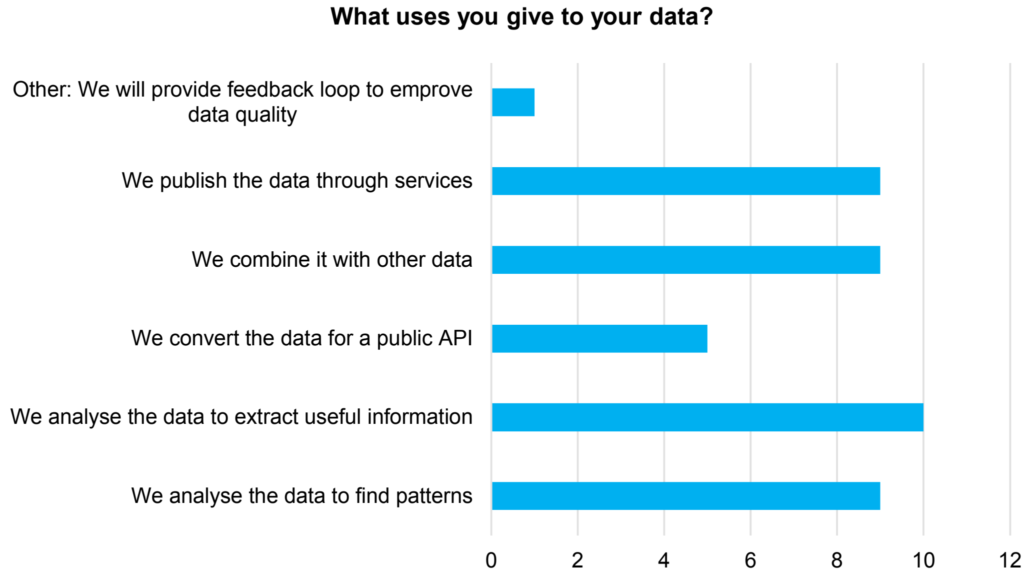

Figure 34: Survey responses – citizen observatories data usage

The most common data types (Figure 35) to store crowd–sourced data was XLS: Excel File Format and the last common were HTML: Hypertext Markup Language and XML: Extensible Markup Language. However, other data types and database solutions –and combinations of data those– were highlighted, such as: xml–rdf, PostegreSQL, SQL, Oracle.

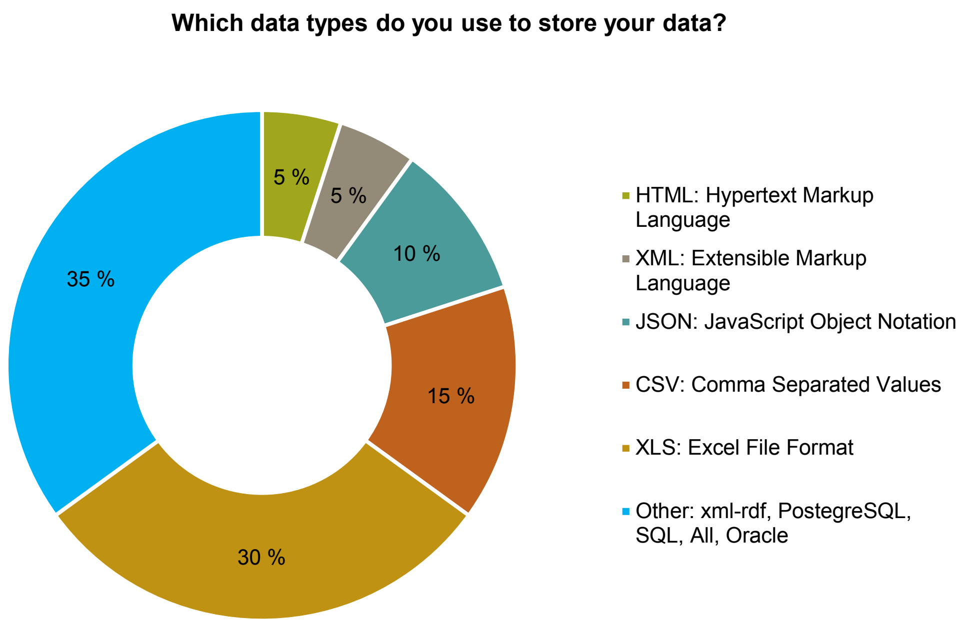

Figure 35: Survey responses – citizen observatories data storage

The survey respondents were asked to rate their data usage processes according to a list of statements where (1= Close to this, 2 = Leaning towards this, 3 = Not performed yet, 4 = Leaning towards this, 5 = Close to this). According to the average rate of the results (Table 16), the sampled citizen observatories do not publish their data – but rather use it for private usage– Logically, not everyone has access to this data to use, combine, reuse and redistribute; also, there seems to be a moderately strong need to collect more diversified data to meet their goals. Finally, the observatories are becoming more efficient using the data they collect to minimize the data that is not usable and useful for their purposes.

On the other hand, 67% of the sample had a positive opinion about opening their data for public use, reuse and redistribution. The main concern to publish their data is: data privacy and country regulations. Table 8 and figure 36 resume the answers about data usage.

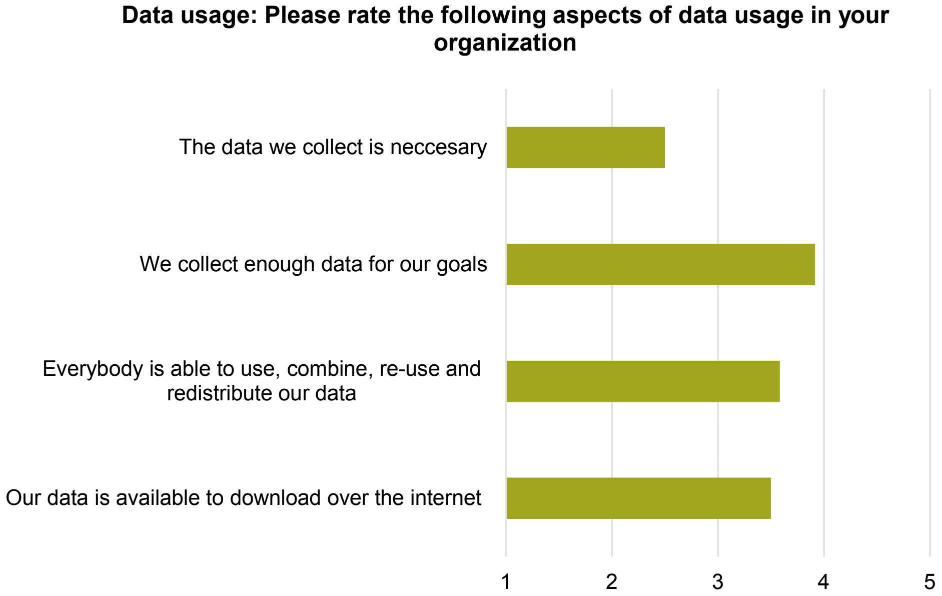

Figure 36: Citizen Observatories in Finland – data usage practices: survey responses

Table 8: Surveyed Citizen Observatories in Finland – Opening Data

Open already	8%
Maybe	33%
Ongoing	25%
None	8%

Open opinions about how do they feel about opening the data they collect were collected in this section as well, opinions ranged from: 1) highlight that their data is already open or that opening it is their ultimate goal, 2) there is need to solve some database and data aggregation issues, 3) need to get the know–how to do it, 4) need to appoint the privacy issues and limited data and 5) before opening the data, scientific contributions have to be made with it.Data quality plays an important role when collecting crowd–sourced observations, because the goal is that the collected data meets certain standards of integrity and coherence. From our respondents, the most common data quality validation method (Figure 37) appears to be direct review from scientists (3) or a combination between scientists and algorithms checks (4). Less common are citizens based classifications (2) and a combination of all the mentioned methods (1). Yet, 2 respondents did not specify any method for data validation.

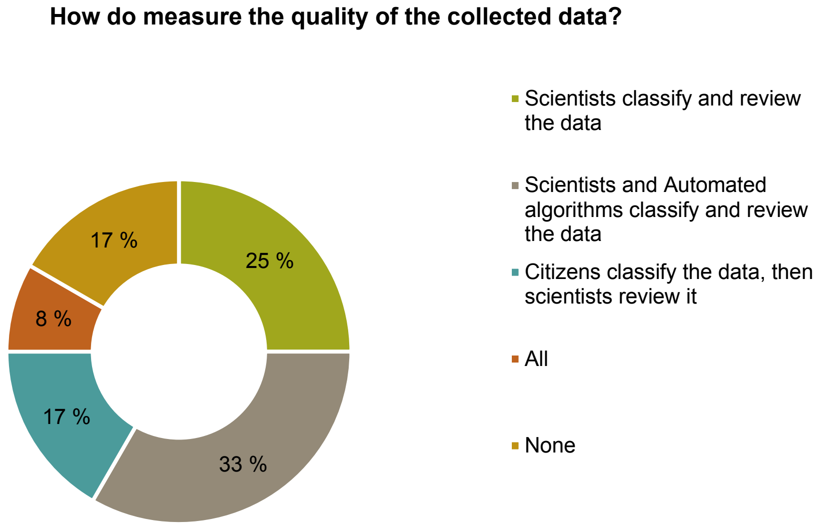

Figure 37: Survey responses – citizen observatories data quality

Among the biggest challenges in Finland for citizen observatories (Figure 38) found from the studies: technology – regarding map and geo location interfaces issues, analytics tools, different mobile and web platforms that are changing constantly, wrong infrastructure choices, databases complexity, failures with automation –, funding sources – involving big goals with short term funding and a strong lack of funding for constant development –, data standardization – regarding lack of quality on observations, need of more education about standards, lack of an IT head, lack of knowledge – social awareness, – concerning a need for, larger sets of users, more marketing and, a strong understanding about motivations and appropriate engagement methods – and partners –about a strong need for a better synchronization in cooperation and communication–.

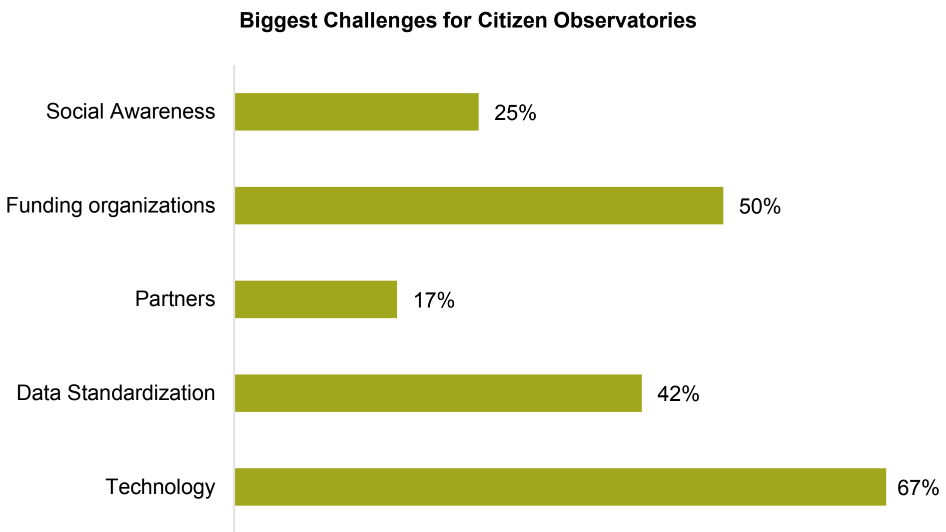

Figure 38: Survey responses – citizen observatories challenges

Finally, the expectations for the future of crowd–sourced observatories in Finland are (Figure 39): a raise in social awareness – such as open sources actively distributed on social networks, more observers and a raise in environmental education –, active public involvement – more campaigns and competitions to gather observations, provide services to involve people in decision making and development of motivational/rewarding approaches to enable large–scale observatories operations –, advanced useful technology – questionnaires on social media, capable and affordable mobile sensors and apps, smarter apps highly interconnected, satellite monitoring of species –, growth in funding opportunities – attracting more EU funding for citizen science projects, need of stable funding, develop business models based on attracting data end–user organizations as customers through being able to offer adequate data amount/coverage, data quality and reliability of operation from citizen observatories – and other –such as more education for decision makers, members, citizens and more interconnected systems, include gaming elements in applications to create better experiences–.

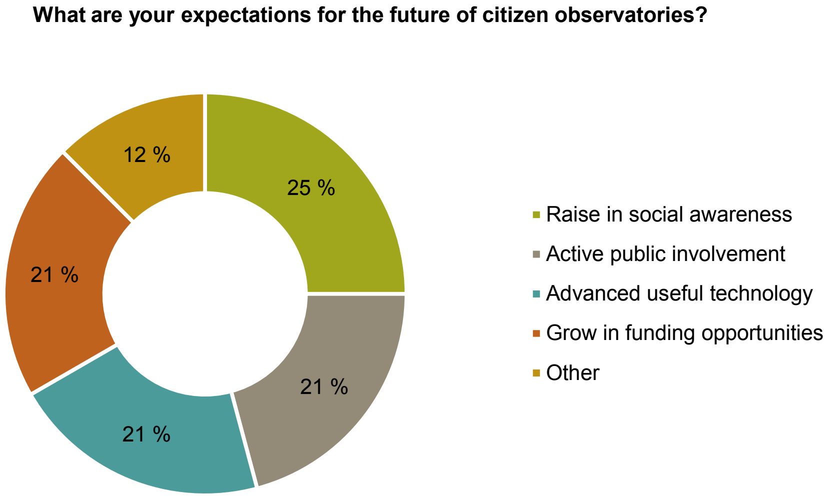

Figure 39: Survey responses – future expectations

4.2 Interview results

The interview study had 7 interviewees which were: project manager or observatory coordinator (5), maintainer (1) and, sales responsible (1) from organizations that have one or more citizen observatories running in Finland. Interviews 4 and 5 are reported as one, since the interviews were with two persons in the same organization/citizen observatory. Thus, this section will refer to 6 interviewed organizations.

Some of interview answers (stakeholders' type, observer's location techniques, motivation techniques and challenges) were clustered under the classifications presented in section 1.1 and section 2.1. New clusters were found for those classifications. The combination of these findings can be found in the summary of chapters at the end of this report. The full interview responses can be found in appendixes XV, XVI and XVII.

4.2.1 Data collection practices

The interviewed organizations were asked two main questions for this section of the interview: how do you collect your data? And why do you collect that data?

The interviewees reported that their citizen observatories are focused on species monitoring (4), biodiversity monitoring – forest – (1), Water, Streams, Snow, Sea observatories – lakes and sea – (1) and tools for citizen engagement (1) – geographic information – (definitions of each type of observatory can be found in section 1.1). All the organizations (6) reported to use internet based tools to collect observations. Also, they reported to use paper forms (2) and accept physical specimens (1).

Interviewees specified they collect their data for business purposes (2), research purposes (3), legislation responsibility or objective of their organization (2). In collaboration with volunteers that range from locals to experts which collect data individually or in groups.

4.2.2 Location and motivation of citizens

The interviewed organizations were asked four main questions for this section of the interview: What is your typical user profile? How do you locate your observers? How do you motivate your observers? And would you open your collected data?

Each interviewee reported that their observers were more than one type, table 9 summarizes these reports. Nature enthusiasts are the focus of most of the observatories (4), followed by any citizen (3) and the families and specific individuals (3) which are target of 6 observatories. Finally, academy and government (2) along with clubs and non-governmental organizations (2) which are the stakeholder type of 4 of the interviewed observatories.

Table 9: Interview results – stakeholder's type

Type of Stakeholder	Number of Observatories	Type of Observatory
Nature Enthusiasts	4	1 Biodiversity Monitoring 2 Species Monitoring 1 Water, Streams, Snow, Sea observatory
Any Citizen	3	2 Species Monitoring 1 Geographic information monitoring
Families plus specific individuals	3	2 Species Monitoring 1 Water, Streams, Snow, Sea observatory
Academy and government	2	1 Biodiversity Monitoring 1 Geographic information monitoring
Clubs and non-governmental organizations	2	2 Species Monitoring
Developers	1	1 Water, Streams, Snow, Sea observatory

Definitions of each type of stakeholder can be found in section 1.1. With the exception of the type: **clubs and non-governmental organizations**. Which are organizations that have citizen as members, becoming a partner and channel for direct communication with citizen observatories. The observatories that involve this type of stakeholder are mainly monitoring species.

Locating observers seems to be done among the interviewed citizen observatories by having, a well-known interest based observatory (3), where observers approach by their own will, partners that have members and recruit them as observers (2) and observers that are forced by law to report data through certain observatory (1). Table 10 summarizes these reports.

Table 10: Interview results – techniques to locate observers

Location Technique	**Number of Observatories**	**Type of observatory**
Interest based observatory	3	1 Species Monitoring 1 Biodiversity Monitoring 1 Water, Streams, Snow, Sea observatory
Partners manage the direct contact with volunteers	2	1 Species Monitoring 1 Geographic information monitoring
Observers are composed by law to report	1	1 Species Monitoring

To motivate their stakeholders, the interviewees use more than one technique. Table 11 summarizes the techniques used. Definitions of each type of engagement/motivation technique can be found in section 1.1. With the exception of the types: **collect feedback ideas** (observatories ask for feedback and actively use it when improving their data collection tools) and **provide training** (Observers can receive training from the observatory or a partner and hold a certificate or license for submitting their observations).

Table 11: Interview results – techniques to motivate stakeholders

Motivation Technique	Number of Observatories	Type of Observatory
Citizens Interest based monitoring	3	2 Species Monitoring 1 Water, Streams, Snow, Sea observatory
Collect feedback ideas	3	1 Biodiversity Monitoring 1 Species Monitoring 1 Water, Streams, Snow, Sea observatory
Partnership	3	1 Biodiversity Monitoring 1 Species Monitoring 1 Geographic information monitoring
Present Data Benefit	3	2 Species Monitoring 1 Water, Streams, Snow, Sea observatory
Provide Training	2	2 Species Monitoring
Unify observatories with recreational activities	2	1 Water, Streams, Snow, Sea observatory 1 Species Monitoring

Regarding the possibility of opening their collected data, 4 interviewees already have open their data or are working towards it. Yet, 2 citizen observatories may not be willing to open their data due to data ownership and privacy issues.

4.2.3 Success stories, challenges and future perspectives

The interviewed organizations were asked to talk about their success stories, challenges and future perspectives in the field as main questions for this part of the interview.

The interviewees specified as success stories, achievements related mainly with observers engagement (5), because of big numbers of observers and/or observations and the eagerness to learn to submit observations from observers. Also, the involvement of decision makers (1) was highlighted, because the collected data was used to govern.

The challenges reported were: technology limitations, social awareness – there is a need for observers –, funding sources –for continuity of the observatories –, standardization – regarding the need for a common language when developing citizen observatories with multiple specialists –, privacy issues – for building trust –, data aggregation – to ensure interoperability of data – and the user practices – since some stakeholders such as local governments are not always ready to start collaborating with a citizen observatory –.

Finally, the perspectives for the future of the field from the interviewees range from more active public involvement, a growth in funding opportunities, expanding the observatory, improving validity of data collected, opening data to more active government institutions involvement.

5 Highlights of Common Concerns in Citizen Observatories

This chapter aims to support the research question 5 of the report (how to engage citizen?). It is based on the systematic literature review study. Pieces of literature from the reviewed articles have been selected (by relevance) in order to show importance of certain challenges, elements and technologies while paving the road for research agenda and more investigations.

5.1 Tackling privacy issues and concerns

The first phase of citizen participation is to understand and answer questions such as who controls data collection, and who owns the data or benefits from them? Providers typically collect, store, and analyze the data out of view of the individual whose life they describe. The use of the data is not always restricted to the purpose for which they were collected. Citizen observatories need to create a trust–based relationship with their observers and partners. This requires that data ownership and usage is defined prior observatory development. When multiple stakeholders' concerns need to be addressed co–creation techniques are advisable.

Following a list of privacy and concern issues by [40], between paragraphs there are recommendations provided by the author of this report to address them:

Building trust: Users carry a degree of trust (which might be related to past experiences) and a perception of risk/benefit when using certain service.
Recommendation: Proper incentives could help to effect that perception and build trust. Also users often require a "translation" of the implication of the certain settings. This can be solved by using a simple language and examples.

Data quality: Data collected by citizens may not meet scientific standards.
Recommendation: Before data collection begins, scientists can provide citizens with appropriate training to citizens on how to submit records that are valid, complete and useful.

Data Sharing and intellectual property: Data sharing allows others to build on completed work and promotes dialog, debate, and critical feedback. The methods used and data collected by citizen scientists should be available to the public following the conclusion of the study.
Recommendation: Scientists who work with citizens should clearly discuss data ownership and other intellectual property issues with observers at the beginning of the project, and periodically and as needed, to ensure mutual understanding

Conflict of interest: Some citizen scientists may have relationships with private, non–profit, political organizations that sponsor research.
Recommendation: A common strategy for dealing with conflict of interest is disclosure. Disclosure embodies the virtues of openness and transparency.

Exploitation: Observers are usually providing assistance to researchers without the expectation of financial compensation, there is the potential for exploitation.
Recommendation: Though observers may not require authorship for career advancement, it is still important for professional scientists to give citizens appropriate credit to demonstrate gratitude for their work and as a matter of fairness.

On the other hand, Publishing of open transparent data increases the willingness of citizens to enroll as they can see that the system is trustworthy and that they are contributing to the common wealth. Users can be the main providers of objective data (observations) and subjective feedback (data out of observations). That can help to [21]:

- Raise awareness: about the relevance/need of the observations.
- Empower users: with the ability to check directly, in an easy–to–understand way.
- Promote active involvement: in the observation campaigns.

But provide users with transparent open data require [21]:

- The usage of a transparent and well–defined methodology for assessment.
- A provisioning of a freely downloadable client.
- The publication of open data, enabling anyone to analyze the experimental data collected.
- The ability to present to the observations' stakeholders information (extracted from the measurements data) which is most relevant for them.

The benefits of involving citizen scientists in scientific projects extend beyond the cost–effective science itself, and have been shown to be important in fostering 'earth stewardship' [41].

5.2 Participation and motivation concerns

In citizen science, participation can take four forms [32]: consultative (public contributes information to a central authority); functional (public contributes information and is also engaged in implementing decisions); collaborative (public works with government to decide what is needed and contributes knowledge) and transformative (local people make and implement decisions with support from "experts" where needed).

Participation approaches have progressed through a series of phases [19]: awareness raising in the 1960s, incorporation of local perspectives in the 1970s, and recognition of local knowledge in the 1980s, participation as a norm as part of the sustainable development agenda of the 1990s and, a recent e–participation trend in the 2000s among governments.

E–Participation appears as result of the citizens' demands for greater transparency and accountability from their governments, and want to participate in shaping the policies that affect their lives. Information and Communication Technologies (ICTs) and, particularly, Internet–based ICT, are considered a potential solution to these issues. In the last decade, governments have started to sponsor e–participation initiatives that seek to improve citizen engagement in the governance process. E–participation aims to support active citizenship and with the latest technology developments, increasing access to and availability of participation in order to promote fair and efficient societies and governments [42].

E–participation efforts can take many forms [42]:

- e–informing (informing citizens),
- e–consulting (limited input from citizens on a defined topic),
- e–involvement (development of open communication processes between government and citizens),
- e–collaboration (participation in the development of policy alternatives and solutions),
- E–empowerment (transfer of control over policy to citizens).

Motivating citizens

Encouraging pro–environmental behaviors in citizens has been a central question for a variety of disciplines. Information strategies and education are regarded as important components in the effort to induce change towards more sustainable practices [43]. They aim at affecting our attitudes via raising problem awareness, informing about the impact of our choices and increasing knowledge about the alternatives [44].

Humans are not only united by geographical and administrative territories, but also by emotional relationship, in which individual identity is built upon the bond of meaning and distinctive cultural values [45] – participation is built on public awareness –. For which, increased public access to environmental information can contribute to a greater awareness of environmental matters [46]. Pro–environmental behavior domains, these can be grouped under the following classifications by [47]:

- **Social environmentalism:** These behaviors typically include some type of interaction or communication designed to inform (or teach) others about the importance of conservation and the value of pro–environmental actions.
- **Land stewardship:** Directly related to improving the local landscape, including wildlife and habitat conservation actions. Such behaviors often centered on various forms of habitat enhancement.
- **Conservation lifestyle:** For many people, conservation lifestyle behaviors were among the first things that came to mind when asked how an individual could help to protect his/her environment
- **Environmental citizenship**: Environmental citizenship behaviors were less commonly mentioned. The simplest and most common form of civic engagement

Three primary reasons for citizens to volunteer collecting data for environmentally–focused citizen observatories: 1) concern for the environment and wildlife conservation, 2) opportunity to spend time in nature, and 3) opportunity to see wildlife [29]. Finally, internet use can increase: community attachment and engagement; social contacts for those with high social use of the Internet; a sense of belonging, and community activism [48]. As well as, mobile applications which are valuable devices for data collection [49].

This report summarized seven reasons that motivate stakeholders to collect data (see section 1.1) based on the systematic literature review and the found 108 observatories. Citizens seem to be encouraged to become observes because they, 1) want to be exceptional citizen, 2) have special interests that want to monitor, 3) enjoy achieving challenges or other game–base features in their applications, 4) feel/are as partners in the monitoring projects, 5) understand/get a direct benefit from the data collected, 6) save money because of the results as outcome from the data collection and 7) enjoy recreational activities with additional tasks such as observation of certain phenomenon.

Measuring Motivation

According to [29], motivation can be measured by asking volunteers three questions: 1) the primary reason(s) for participating as a observers, 2) personal time and money expended while observing and 3) self–reported levels of concern about the issue(s) under monitoring.

On the other hand, other studies reported the willingness of data collection from local residents' to participate as observers [50] are: 1) data regarding previous mappings and other relevant projects, 2) data on species/habitats if it is made simple enough to collect and, 3) data on main occupations and economic activities.

In order to measure the motivation, there must be a set of active observers. However, recruiting active participants seems to be remaining challenge for citizen observatories. [32] Presents two approaches (bottom–up and top–down) to create citizen observatories depending of the scale of participation needed (Figure 40). [51] Highlighted that citizen participation requires a bottom–up process for identifying problems and ways of finding solutions. That will include public meetings, workshops, events, etc. Top–down approaches are typically research–led (expert) and often start with the formulation of visions of future direction [28].

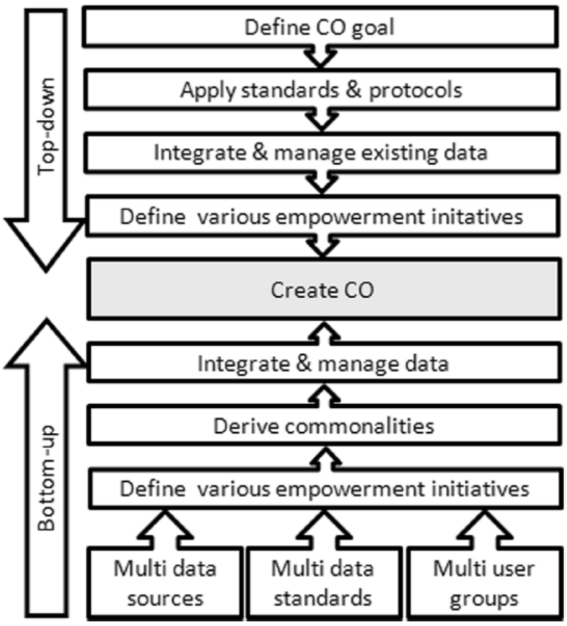

Figure 40: Bottom–up and top–down approaches for citizen observatories management. Source: [28]

5.3 Technologies to engage citizens

There is a need to engage citizens to find out how they can inform the community, and to empower citizens to improve their own health and wellbeing through actively making informed choices via the Citizens' Observatory (CO) process [28]. According to sociological research, the recent increase in pro–active participants of social IT media, with a particular focus on environmental issues, results from a shift from materialism to post–materialism [28]. Following some technologies that can help to engage citizens:

1. Gamification: User Engagement is seen as a typical outcome of Gamification, and the concept has been successfully applied to a wide range of businesses. For example, Frequent Flyer Programs use Gamification as a Loyalty Program.

   Gamified designs encourage technology adoption, motivate user behavior and enhance user satisfaction. This is because game–like activities and ludic interfaces tend to make technology more engaging, by encouraging users to adopt desired behaviors, by taking advantage of humans' psychological predisposition to engage in game and by leveraging people's natural desires for competition, achievement, self–expression and enjoyment [44].

   Also, in the area of mobile social reporting, gamification is becoming a popular means to encourage people to share information about where they are and what they are doing, usually through a points and trophies system whereby awards are made based on activity levels and context. Gamification is the use of game design elements in non–game contexts [52]. Moreover, games have been used in an attempt to engage people with green issues previously [37].

   Finally, Story–based games can be a powerful tool for attracting participants to citizen science tasks. Well–designed citizen science games with a purpose have the potential to attract large crowds of helpful volunteers, even in circumstances where the science task is difficult or uninteresting [53].

2. Participatory Sensing: Provides the enabling means to deploy community–based environmental citizen observatories, which can be used as a policy making and evaluation instrument for improving the quality of life of citizens [54]. This approach of data collection and interpretation relies on individuals, acting alone or in groups, along with their personal smartphones to systematically monitor personal information (e.g. health) and/or environmental information (e.g. noise levels, traffic conditions). A key concept in the operation of participatory sensing is the idea of a campaign, a series of systematic activities to gather a particular type of data. Campaigns usually specify a stakeholder's concern by defining the types of data that need to be collected and the goal [54,55].

3. The social web: The social web has enabled people to connect to others through shared objects of interest (for hobbies, work topics, socializing, etc.) or for shared motivations (for political campaigns, volunteerism, community activism, etc.), through applications such as social networks, blogs, wikis and video sharing [52,56]. The types of interaction in the social web by [57] are: queries, reactions and crisis requests. Where responsiveness, becomes in very practical terms as the ability of being "fast and right". Responsiveness in the social web refers to the speed of completing citizens' requests and to the capability to listen to the public and engage proactively.

   [57] Identified, three key themes that are relevant to address when using the social web for engagement:

   - Engaging on multiple channels and establishing information flows both to manage incoming messages and monitoring content. This involves selection of channels, using specialized software to manage multiple accounts and creating content to promote awareness campaigns or information about topics of interest.
   - Identifying networks of stakeholders and developing audience awareness across different channels.
   - Managing interactions with consideration to resources processes and structures, for example, how different interactions need to trigger different response processes.

6 Summary of Chapters and Key Findings

In chapter I: trends in the world and Europe: past, present and future, findings from the systematic literature review which located 108 observatories are presented. Each citizen observatory was studied in depth to identify common focuses, engagement techniques, technology uses, practices, stakeholders, standards use, challenges and future perspectives. Chapter II: citizen observatories: current initiatives in Finland, brings a detailed overview about active Finnish citizen observatories. The focuses, data collection techniques, practices, challenges and opinions of those observatories were identified. The results are based in a survey (which collected 12 responses) and seven interviews that were carried with key stakeholders running well-established monitoring projects in the country. Finally, chapter III, highlights of common concerns in citizen observatories, aims to support the research question 5 of the report (how to engage citizen?). It is based on the systematic literature review study. Pieces of literature from the reviewed articles have been selected in order to show importance of certain challenges, elements and technologies while paving the road for research agenda and more investigations.

Information about the world and Europe was gathered via a systematic literature review. Information about Finland was collected via surveys and interviews. Following a compilation of the key findings (which were complementary) from this report:

Data Collection and Technology Uses

- In the world, Europe and Finland the participatory data collection model is mainly used, in which users are actively involved in the collection process. Still, there is a raise since 2000s in observatories using opportunistic data collection methods, such as automatic data collection (e.g. geographical location).
- In the world and Europe, the technologies that are currently used to build citizen observatories follow a trend of digitalization regarding their data collection, which translates into the popular use of web, mobile, games, interactive displays, phone-based (e.g. interactive voice responder), sensors and a combination of those technologies. In Finland, all the studied organizations reported to use internet based tools or mobile apps but also some use paper forms and post-mail (e.g. for sending physical specimens) to collect observations.

Types of Stakeholders

- This study clustered the stakeholders of the identified observatories according to their occupation in a total of six categories (five from chapter I and one from chapter II): citizen, academy and government, nature enthusiasts, families plus specific individuals, developers and clubs, non-governmental organizations.

Engagement Techniques

This study clustered the ways stakeholders are currently being engaged by the studied citizen observatories in a total of nine clusters (seven from chapter I and two from chapter II): be an exceptional citizen (the activeness of a particular citizen as an observer is awarded with social recognition), citizens' interest based monitoring (citizens can set their own observatories to monitor their interests), gamification strategies (incorporating game elements into the citizen observatories), partnership (empowering organizations to collaborate and improve their decision making), presenting data benefit (create a benefit for the stakeholder from data reporting), saving money (data can be analyzed and used to create economic savings), unifying observatories with recreational activities(raising of emotional feelings for the observatory), collecting feedback (observatories ask for feedback and actively use it when improving their data collection tools) ideas and providing training(observers can receive training from the observatory).

Best Practices

This study clustered 17 best practices from the available information of the identified (108) citizen observatories, this clusters were reported in chapter I and used to classify the survey and interview data in chapter II. The clusters are the following: co–creation, data aggregation, environmental campaign in public spaces, feedback from observations, gamification, identify stakeholders and their motivations, interest based observatories, involve decision makers, measure motivation, observatory component based, open data for engagement, opportunistic data collection, participatory data collection, provide technology, provide training material, real time visualization, set common protocols for observers.

Common Challenges

In the chapter I, nine clusters for challenges that citizen observatories have been or are currently facing, were presented: user practices (when the target stakeholders, whom are not always ready for start contributing with a citizen observatory), data aggregation issues (due to multiple data formats and data structures which have to be used jointly to extract useful information), technology limitations (issues with devices size, consumption and reliability, lack of systematic methods to validate data), standardization (lack of reusable methods or frameworks for creating new observatories), limited knowledge (lack of expert knowledge in fields needed to build a citizen observatory), limited resources (there is a common need for extra resources for keeping the observatory maintained), privacy issues (understanding the concerns of stakeholder's regarding the ownership and use of their data is important and need adequate agreements and settings) , recognition of contribution (citizen observatories need to properly acknowledge the contributions and support of observers as social fairness) and data accessibility (making data available in a transparent and useful way to the relevant stakeholders is fundamental, stakeholders should be able to access, explore and analyze relevant information)

In the chapter II, the following challenges were reported via survey and interviews: technology limitations, limited resources, standardization, user practices and privacy issues.

Common Future Perspectives

From the systematic literature review results, six clusters from recommendations and future perspectives from the identified (108) citizen observatories were found: data collection (recommendations and future perspectives about ways to gather citizen observations, from whom, how and why), engagement (advices about how and why to engage certain stakeholders? What types of stakeholders can feel more comfortable doing what?), data Visualization (recommendations and future perspectives about interfaces, technologies, and techniques to create visually engaging applications), Standards (advices about avenues within standards for citizen observatories), data Analysis (advices about requirements for performing data analysis) and ICT management (perspectives about what issues to have into account when selecting or managing technologies for citizen observatories). The full summaries of the recommendations and future perspectives can be found in appendix XIII.

From the survey and interview results, respondents' perspectives for the future of the field ranged from a raise in social awareness, active public involvement, advanced useful technology, growth in funding opportunities, expanding the observatory, improving validity of data collected, opening data to more active government institutions involvement.

Finally, the author highlight that citizens appreciate being given space and time to arrive at their own responses and interpretations. Therefore, persuasion might not be an accurate technique when it comes to involving citizens as data providers. However, co-creation of solutions that involve data transparency, gamification elements, social media and common goals, have a greater the potential to become successful crowd-sensing applications.

7 Recommendations from the Study

How to run Citizen Observatories: Key Recommendations from the State of Art Review

About Data Collection:

- Organizations that are currently forced to opt for non–technological approaches to gather citizen observations would benefit greatly from an approach in which they can build their own observatory and it is not focused only in data collection but also in citizen coordination and feedback.
- Wearable technologies that can capture and propagate different information important for policy decision making, for example augmented reality support for citizens to match a real–life situation with a policy case and proceed according to the policy using the algorithmic instructions applied to the current use case and facilitated by the augmented reality annotations.
- Factors such as context knowledge of community members, accountability and adherence to social norms, are key for successful reception of social engagement applications.
- Mobile phones can help citizens engage directly with governments to provide feedback targeted at improving the performance of welfare schemes.
- Setting protocols for observations increases the quality in the data from observers.

About Engagement:

- From our studies, there are seven reasons why a citizen participates actively in a citizen observatory:
    1. The participant understand the data benefits from his/her contribution for society and in particular for himself/herself.
    2. The participant has special interest about monitoring certain phenomena due to personal concerns such as activism, allergies or generate savings.
    3. The participant practices particular recreational activities and, submit observations does not influence negatively its experience.
    4. The participant appreciates public recognition and, in some cases is very eager to pursue it (e.g. citizen of the year in certain town or certification as citizen observer of water).
    5. The participant enjoys getting immersed in games (which can be of different types) and achieve goals on it that can translate into real awards. Story–based games can be a powerful tool for attracting participants to citizen science tasks.
    6. The participant (citizen or organization) is eager to be a partner in a citizen science project, to receive responsibilities and gains from it.
    7. The participant is looking for new ways to save/earn benefits.
    8. The observer has ideas to improve the way data is being collecting and wants that those ideas are taken seriously.
    9. The observer appreciated to have a recognition for his knowledge providing observations due to trainings.

- The most common practices to build, manage and disseminate a citizen observatory are: co–creation, data aggregation, environmental campaign in public spaces, feedback from observations, gamification, identify stakeholders and their motivations, interest based observatories, involve decision makers, measure motivation, observatory component based, open data for engagement, opportunistic data collection, participatory data collection, provide technology, provide training material, real time visualization, set common protocols for observers. More details in chapter I.

- According to the systematic literature review and the interviews, most of the feedback when building a citizen observatory is often received outside the context of the website – during walks, travelling to deploy recording devices and, discussions.
- The motivation element has been little studied and should be taken seriously in the implementation of crowdsourcing systems, as with no participants the crowdsourcing platform is doomed to fail. This study presented motivation techniques from different aspects across each chapter.

About Data Analysis and Visualization:

- There is a need to develop tools for the analysis and further use of open government data as well as of big data and unstructured data conveying subjective opinions of individuals extracted e.g. from the social media.

About Standards:

- There is a need to develop data collection and metadata standards for the different EBVs (Essential Biodiversity Variables) in order to promote a more varied collection of environmental data.
- There is a need for a framework to build citizen observatories that can interoperate globally.
- Configurable citizen observatories represent a good example of the standardized used of an observatory globally. In this study such tools are classified under the cluster "Tools for citizen observatories" (more details in Chapter I and appendix V).

About ICT management:

- For citizen science projects with few resources, technologies with the least complexity and lowest cost are the only sustainable choices. In this study such tools are classified under the cluster "Tools for citizen observatories" (more details in Chapter I and appendix V).

LEXICON

CO	Citizen Observatory
Participatory data collection	Users are actively involved in the collection process by deciding on the spot when to report data.
Opportunistic data collection	Sensor sampling occurs whenever the state of the device (e.g. geographic location) matches the application's requirements described in a sensing task, without the knowledge of the individual phone user.
Spectrum monitoring (In this report)	1) The entire range of wavelengths of electromagnetic radiation. 2) Used to classify something in terms of its position on a scale between two extreme points.
Metadata:	Data that provides information about other data. The main purpose of metadata is to facilitate in the discovery of relevant information, more often classified as resource discovery.
BON	Biodiversity Observation Network
LUKE	Natural Resources Institute Finland
SYKE	Finnish Environment Institute
LAJI	Finnish Biodiversity Info Facility
FinBIF	Finnish Biodiversity Information Facility
LUOMUS	Finnish Museum of Natural History
Metadata	Data that provides information about other data. The main purpose of metadata is to facilitate in the discovery of relevant information, more often classified as resource discovery.
IoT	Internet of things
EnvO	Environment ontology

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APPENDIX I: SURVEY DESIGN

Survey on Citizen Observatories Processes

Please share with us your experiences on citizen science, crowdsourcing and citizen observatories!

We are gathering information on how citizen observations are currently being used in order to improve monitoring of the environment. For further details on our project, please check http://www.en

Results of this State-of-Art review of citizen observatory techniques and practices will be made publicly available in the web in January 2016. If you have any questions or comments feel free to co

Basic Information

1. Please indicate:

Name:

Email:

Your current role in your organization: *

The purpose of your citizen observatory *

Does your citizen observatory have a social media (facebook, twitter, instagam)? Which one?

Contact of the citizen observatory

Aspects of Data Collection and Analysis

2. What types of data you use or collect? *

- Environment
- Ecology
- Hydrology
- Oceans
- Birds
- Wildlife
- Weather
- Noise
- Transport
- Other

3. Please specify the following aspects according to your citizen observatory practices:

How do you collect your data? *

(optional) Please specify the IT responsible of your citizen observatory

4. Do you use a defined metadata format? *

- Yes, please specify:
- No

5. Please rate the following aspects of data storage in your organization according to your experiences:

	Close to this	Leaning towards this	Not performed yet	Leaning towards this	Close to this	
We actively use cloud storage databases	○	○	○	○	○	Each citizen observatory uses a local database
We are able to combine multiple data-sets easily	○	○	○	○	○	Our data-sets are in different formats and we can
We use open source database solutions	○	○	○	○	○	We use commercial database solutions
Our data-sets follow clear ontology classifications	○	○	○	○	○	We do not have ontology classifications
Our data-sets are standardized	○	○	○	○	○	Our data-sets are not standardized

6. What uses you give to your data? *

- We analyse the data to find patterns
- We analyse the data to extract useful information
- We convert the data for a public API
- We combine it with other data
- We publish the data through services
- Other

7. Which data types do you use to store your data? *

- HTML: Hypertext Markup Language
- XML: Extensible Markup Language
- JSON: JavaScript Object Notation
- CSV: Comma Separated Values
- XLS: Excel File Format
- Other:

8. Please rate the following aspects of data usage in your organization according to your experiences: *

	Close to this	Leaning towards this	Not performed yet	Leaning towards this	Close to this	
Our data is available to download over the internet	○	○	○	○	○	Our data is for private usage
Everybody is able to use, combine, re-use and redistribute our data	○	○	○	○	○	Specific groups are able to use, combine, r
We collect enough data for our goals	○	○	○	○	○	We need to collect more data
The data we collect is neccesary	○	○	○	○	○	We don't use all the data we collect

9. How do measure the quality of the collected data? *

- Scientists classify and review the data
- Citizens classify the data, then scientists review it
- Automated algorithms classify and review the data
- Other

10. How do you feel about the possibility of opening your data? *

Open data refers to data freely available to everyone to use, re-use, combine and redistribute.

Challenges and Future Perspectives

11. What have been the biggest challenges in your citizen observatory? *

- Technology, please specify:
- Data Standardization, please specify:
- Partners, please specify:
- Funding organizations, please specify:
- Social Awareness, please specify:

12. What achievements would you highlight from your citizen observatory? *

13. What are your expectations for the future of citizen observatories? *

- Raise in social awareness, please specify:
- Active public involvement, please specify:
- Advanced useful technology, please specify:
- Grow in funding opportunities, please specify:
- Other

14. Please, provide us examples of other citizen observatories which you consider to be interesting *

We would appreciate your collaboration to get to know more about observatories in your field.

15. (optional) Open feedback: If you think we missed something relevant, or want to emphasize some point, or just give us a feedback on this survey, please write it here.

Submit

APPENDIX II: INTERVIEW DESIGN

Informed Consent to Participate in State of the Art in Citizen Observatories Research

Maria Palacin-Silva, a researcher in the Department of Software Engineering and Information at Lappeenranta University of Technology under the supervision of Professors: Ahmed Seffah and Jari Porras, appreciate your participation in this research interview designed to collect information about citizen observatories in Finland and the world under the ENVIBASE Project of the Finnish Environmental Agency. You are asked to give an anonymous interview that should take up no more than 40 minutes of your time. It is hoped that we may gain valuable information about your experiences in environmental monitoring that can help to improve our understanding of how citizen observatories are currently working.

We anticipate no safety risk to you or impact on your privacy as a result of your participation in this study other than the inconvenience of the time to provide the interview. **The information that you give us on the interview will be recorded in anonymous form**. We will not release information that could identify you.

If you want to withdraw from the study at any time you may do so without penalty. The information on you up to that point will then be destroyed.

Once the study has been completed, we will be glad to give you the results. In the meantime, if you have any questions, please contact: Maria Victoria Palacin-Silva, Department of Software Engineering and Information Technology, Lappeenranta University of Technology, Tel. (358) 414986573, Email. maria.palacin.silva@lut.fi, Web. http://www.lut.fi/

On (**Date**), I (**Full name**) have read the understood the explanation and agree to participate in the study by giving my recorded agreement for it.

Section 1: Data Collection

- Goal: Understand what kind of crowdsourced citizen observation data do you gather and how do you gather it?
- Please, Tell us
  - What do you do?
  - How do you collect your data?
  - Why do you collect your data?

Section 2: Location and Motivation of citizens

- Goal: Understand how you recruit and motivate your citizen observers.
- Please, tell us:
  - Do you use ideas from citizens?
  - Describe your interaction with citizens and local goverments
  - What are the roles?
  - Do you have profiled your users?
  - Are you open for cooperation? (Giving data, collecting data for other organizations, etc).
  - Do you need help from the government? (problems)

Section 3: Challenges and Success Stories

- Goal: Understand your success and your biggest challenges
- Please, tell us
  - What has been the best so far you have achieved with your observatory?
  - What challenges have you faced estabilishing your citizen observatory?

Feedback Form

On behalf of The Finnish Environment Institute (SYKE) and Lappeenranta University of Technology we thank you for attending this presentation about the first draft on the: State of the Art Study on Citizen Observations around the world and Finland and, we would like to kindly ask you to fill this anonymous feedback form about the presentation.

1. **Please, indicate your field of experience:**

   ____
   _

2. **Please rate the presentation (1= Poor; 5=Excellent):**

   a. The presentation was clear and concise __

   b. The content was interesting and easy to understand __

3. **In your opinion, please detail:**

   a. What has been the most interesting findings of this study?

   b. What topics of this study should be investigated deeper?

4. **Please check, what is your primary motivation for attending this presentation?**

   - ☐ Learn about the topic
   - ☐ Interest in specific findings
   - ☐ Lean techniques for my own citizen observatory
   - ☐ Interest in know what is happening around the world in the topic
   - ☐ Networking with peers
   - ☐ Other (Specify):

Notes for Workshop

This section is designed to help you taking notes, during and after the presentation about the first draft on the: State of the Art Study on Citizen Observations around the world and Finland. Please, have into account that this notes will be useful for the workshop discussion, feel free to write your answers in Finnish or English.

a) **What topics SYKE should focus on to develop their observatories?**

b) **What type of motivation techniques do you consider relevant for SYKE observatories?**

c) **What benefits can be created from SYKE's observatories? And How to bring them to the Finnish context?**

APPENDIX IV: WORKSHOP RESULTS

A workshop after the presentation of results of the state of the art study on citizen observatories, was organized on December 7th, 2015 at SYKE Offices in Helsinki with the participation of field experts within Finland. The outcomes of this workgroup is presented below:

1.1. Ideas about potential focus areas for SYKE

a) *What topics SYKE should focus on to develop citizen observatories?*

Most popular ideas:

a. SYKE should focus on the parameters that are most important (e.g. parameters that meet the requirements of the Water Framework Directive) or parameters that are impossible to detect otherwise (e.g. non–native/ invasive species). (10 votes)
b. CO should use social media. (6 votes)
c. Steering the citizen observatories. SYKE may guide and instruct the citizens about where and when they should make the measurements. (6 votes)
d. Co–operation between various institutes and organizations. (6 votes)

Other ideas

e. It is important to build a practical/workable system, where uploading and downloading data is easy, the data quality is OK, the data has proper metadata files etc. (5 votes)
f. An open API for uploading CO data. Citizens may build their own application to make measurements. E.g. Open311 API. (5 votes)
g. CO data collecting system should be dynamic and easy to edit. One place where can leave all kind of observations. (5 votes)
h. Subjective place–related information. Where citizens feel safe/unsafe, bad/good, happy/unhappy etc. (4 votes)
i. Catalogue of species. Citizens may take a photo of a plant, send it and receive the name of the species, area of distribution and other information (3 votes)
j. Users as designers, not necessarily dedicated observers (3 votes)
k. Observations of toxic or hazardous waste (2 votes)
l. Participation is important (1 vote)
m. Observations of phonological events

b) *What type of motivation techniques do you consider relevant for SYKE observatories? How to get more observations on the long run, how to encourage new observers and include new observer groups?*

Most popular ideas:

a. Can see the influence (8 votes)
b. Personal benefits (6 votes)
c. Feedback (6 votes)
d. If the observation is part of everyday life it would be remembered better (6 votes)
e. People want good (3 votes)
f. To have better knowledge of environment (3 votes)
g. People feel useful (2 votes)
h. If the system to report observations works well (2 votes)

Other ideas:

i. People are interested of the environment (1 vote)
j. Protection area planning (1 vote)
k. Land value (1 vote)

l. Shore property owners
m. Protection pressure (1 vote)
n. The desire to influence the environment (1 vote)
o. Information on what was done by observations, what was the effects and benefits
p. Public awareness
q. Social responsibility public private (pp) cooperation
r. Conversation with other observers
s. Owner flow, get the appreciation in the community
t. Money, when it is in accordance with the purpose
u. Try different technologies
v. Sustainable consumption, why do people evaluate products, green consumption
w. Game or some kind of counter, according from the users

c) *What benefits can be created from SYKE's citizen observatories? How to make them work in the Finnish context?*

Most popular ideas:
a. Open decision making (4 votes)
b. Direct and transparent link to planning and decision making (4 votes)
c. Corporate social responsibility (4 votes)

Other ideas:

d. AKK
e. Military servicemen may observer
f. Village associations as partners or resource integrators (2 votes)
g. Online results from the mutual data available for all users (1 vote)
h. Cottage owners (4 votes)
i. Forest owners
j. Decentralized
k. CO affects consumer behavior (1 vote)
l. Carbon neutrality data
m. Building heat budgets vs local weather data (1 vote)
n. To make a concrete functioning system for multiple observations, feedback etc.
o. Noise
p. Combining CO and conventional science (cost–effectiveness) (1 vote)
q. My back yard (1 vote)
r. People who grow veggies etc. on their yard or farm – to get to know the pests
s. Biodiversity information
t. Better measurement devices
u. Pilots (1 vote)
v. Data aggregation for different stakeholders –> third–party applications (3 votes)
w. Better apps
x. Phosphorus
y. Help individuals and communities to act systematically for public interest (society and environment)
z. Calibration and validation data for researchers. Environmental administrations need the data for environmental monitoring and reporting. Public and private co–operation: The public sector publishes research results as open data. Private companies may utilize the results.
aa. Long–term behavior (attitudes?). Change on participation.
bb. Trek skaters
cc. Summer house owners could observe water quality and phonological events

dd. Pupils in school may observe under the guidance of a teacher of geography/biology
ee. Teachers for getting their pupils explore the environment (3 votes)
ff. Learn from: how excellent our home area is –> increase in value
gg. Situational awareness (1 vote)
hh. Learn new things to share or teach to others
ii. The [hobby] enthusiasts collect data nationwide, e.g. hunters collect data from stock of game
jj. Municipality (1 vote)
kk. Maintenance of roads and constructions, and cleaning litter
ll. City, monitoring the built environment (2 votes)
mm. Communication with society. Company/ factory explaining smells etc. from factory
nn. Divers are interested in water quality and underwater nature. (3 votes)
oo. Non–professional fishermen are interested in things that affect fish (and possibility to catch them.) Associations are good contacts. (2 votes)
pp. Sailing/boarding community, interested in the state of the sea
qq. SME (small and medium–sized enterprises) companies participating in the ecosystem. (3 votes)

APPENDIX V: SUMMARY OF CITIZEN OBSERVATORIES

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Observatories (tab)

APPENDIX VI: CITIZEN OBSERVATORIES' TYPE OF DATA GATHERING

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Observatories (tab)

APPENDIX VII: CITIZEN OBSERVATORIES CONTACT INFORMATION

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Observatories (tab)

APPENDIX VIII: INSTITUTIONS RUNNING CITIZEN OBSERVATORIES

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Observatories (tab)

APPENDIX IX: CITIZEN OBSERVATORIES' STAKEHOLDERS

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Stakeholders (tab)

APPENDIX X: CITIZEN OBSERVATORIES' TECHNOLOGY

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Technology (tab)

APPENDIX XI: CITIZEN OBSERVATORIES' CHALLENGES

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx
> Problems–Limitations (tab)

APPENDIX XII: CITIZEN OBSERVATORIES' BEST PRACTICES

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Practices (tab)

APPENDIX XIII: CITIZEN OBSERVATORIES' RECOMMENDATIONS AND FUTURE PERSPECTIVES

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx
> Recom–Fut Perspectives (tab)

APPENDIX XIV: CITIZEN OBSERVATORIES' USED STANDARDS AND NETWORKS

Location: https://helda.helsinki.fi/handle/10138/164810 >SYKEre_28_2016_Appendixes.xlsx > Standards in CO CS (tab)

APPENDIX XV: INTERVIEW ANSWERS (ANONYMIZED) – DATA COLLECTION

	What data you collect?	How do you collect your data?	Why do you collect that data?
Interview 1	Forrest Data	Through a free mobile application available on google play App is used by experts in Finland and other countries. App has been offered to citizens, still they don't use it much.	Because there is a lack of forest data around the globe We want to perform classification of satellite images

		We provide the application for each new country, since there are hardcoded elements that need to be changed with the location.	To support our research
Interview 2	Species Data	Participants input their data via internet 6-7 volunteering groups collect data constantly The collected data is open	Because it is the main objective of our organization Legislation/Directives require our reporting
Interview 3	Species Data	We use paper forms, a web based site and a mobile app Volunteers are hunters, some of them required by law to collect data about the animals they hunt	There is a need of species data for decision makers to not endanger species It is our commercial product
Interview 4,5	Species Data	We use paper forms and web forms Physical specimen are also received by post Our partners are responsible of collecting the data (usually they are organizations with large numbers of citizens hobbyists as members)	This data is useful for our research and complement the data we have from the past Legislation requires us to monitor species Support the creation of new businesses
Interview 6	Lakes and Sea Data	Wiki webpage Observers are in charge of the data they collect We have themed campaigns to collect data The collected data is open	Because it is one of the objectives of our organization
Interview 7	Geographic Data	Online platform where citizens can create surveys with mapping capabilities	It is our commercial product To help local government to encourage public participation communicating issues related to a spatial location.

APPENDIX XVI: INTERVIEW ANSWERS (ANONYMIZED) – LOCATION AND MOTIVATION OF CITIZENS

	How do you locate your observers?	How do you motivate your observers?	What is your typical user profile?	Would you open your data?
Interview 1	Users have been experts who knew about the tool Hikers and citizens are a potential group that we need to grow	Researchers in the partner organizations were very eager to use the application. They had inner interest. The ideas and recommendations from users are taken into account in the app Users can recommend the application to their contacts	Our typical user is a researcher with forest science background	Opening our data is an interest Open source is a goal we are looking to achieve
Interview 2	Joint partners have large numbers of citizens hobbyists as members (they do the data collection), they contact them directly We have 15000 active users	Observers are not paid and they use their free time and own transportation for getting observations Users understand the importance of the data for their own hunting quota The application was planned with the finals users (co-created) There is an extra page for getting new ideas and comments in their app (useful comments have been inputted through it)	There are two groups: any citizen and trained volunteers (data is treated different depending where it comes from)	We are willing to fully open their data and aggregate it
Interview 3	Our volunteers are hunters, some of them are obliged by law to report	Users understand that without collecting data the estimation of species population might be wrong Users own the data, this is useful for tracking their own past records Data is anonymized before being used by agencies We believe that if an agency can create an		Opening data might be challenging due to our data ownership settings (observers own the data)

		application that citizen finds useful for himself then the agency will get the data needed They have used ideas from citizens to create the app, those ideas have validated some features too		
Interview 4,5	Our organization has long history collecting data from hobbyists. They come to us to report data.	Training is offered by the agency running the observatory (certificate and licenses are provided) Users need the data for their activities Users see results and understand benefit Recognition to the citizens in the website empowers them	Hobbyists who are interested in specific species	We have some data open and are working towards to fully open the data and aggregate it, without compromising users' trust
Interview 6	Users come to us to record their data of interest	They are in charge of the data and get benefit (graphs) Users get the credit for the data collected in the wiki Promotion campaigns Flagship lakes for region Competitions helped reaching more people Citizens understand why it is important to monitor the lakes (problems) Users have helped correcting the data in the wiki through a forum	Cottage owners and locals	Data is already open
Interview 7	This is a commercial solution sold to local government whom have the direct contact with citizens	The platform is mainly used for the purpose of collecting ideas from citizens	Local governments and citizens	Opening data seems complicated due to the restrictions of data ownership and the business model

APPENDIX XVII: INTERVIEW ANSWERS (ANONYMIZED) – SUCCESS STORIES, CHALLENGES AND FUTURE PERSPECTIVES

	Success Stories	Challenges	Future Perspectives
Interview 1	Sending the application to be used abroad was a 100% success because: Users were eager to learn and do extra tasks and they understood and used the application rapidly. Due to the users abroad better results than the ones recorded before were found	Measurements are limited due to technical limitation of measurements, which limits the usage in Finland There is a need for more citizens Research funding is needed	Wish participatory sensing becomes more spread Citizen science data can complement the rest types of data about environment More data in locations where there is no data to train satellite models is good Deforestation and forest degradation is a potential area observatories can help
Interview 2	Collected data is seriously used by legislators Different stakeholders from field experts (biologist), technical engineers to volunteer organizations was key	Vocabulary was a challenge during the citizen observatory development because of the different fields of stakeholders (from technicians, field experts to citizens)	Citizen science is growing in Finland How can all the observatories merge? How to merge the data about environment that different organizations are monitoring? There is a need of a central database about observations
Interview 3	Big number of users	Building trust with users is challenging. To show that the data is not used for anyone else benefits	We expect to expand our service
Interview 4,5	Millions of observations already in the platform	Interoperability of the data Data ownership is an issue, that limits the openness of the data Building trust with users is challenging Distribution of the data is not even among all the species Research funding is needed	Continuity in funding on the projects in the field Citizen science is not about handing monitoring responsibilities but the development of proper tools and motivations Observations are key to get accurate data There is still a challenge of validity of the collected data Experts validating data is an interesting approach
Interview	Constant amount of users	Need of constant maintenance	Game elements in observa-

6			tions Attachable sensing devices for mobile phones
Interview 7	Wide reach nation wise	Local governments resist to understand why public participation geographic information systems are important in their governance	The communities and public organizations will be more actively using public participation geographic information systems and crowdsourcing methods to gain more participation and activity from the citizens. The open data that is produced this way and with these tools will also create more business as well as spur discussion regarding public projects and participation. Private organizations will also begin utilizing crowdsourcing and subjective citizen observations more as source of information to gather important information supporting their business goals.

APPENDIX XVIII: SUMMARY OF REVIEWED PUBLICATIONS (LIST OF MOST RELEVANT)

Study ID	Author	Title	What	Where
1	Del Rio, J.; Aguzzi, J.; Hidalgo, A.; Bghiel, I.; Manuel, A.; Sbragaglia, V.; Sarda, F	Citizen science and marine community monitoring by video cabled observatories: The OBSEA Citizen Science project	OBSEA costal–cabled video–observatory	Spain
2	Krontiris, I.; Langheinrich, M.; Shilton, K	Trust and privacy in mobile experience sharing: future challenges and avenues for research	Security and examples of crowsensing applications	USA
3	Miso, S.; Homos, M.J.; Rodriguez, M.L	Adaptive geolocated cultural information system for mobile devices	App for cultural information in mobiles	Spain
4	Cagliero, L.; Cerquitelli, T.; Chiusano, S.;	Monitoring the citizens' perception on urban security in Smart City environ-	Sensing the perception of citizens on urban security for Smart City manage-	Italy

Study ID	Author	Title	What	Where
	Garino, P.; Nardone, M.; Pralio, B.; Venturini, L	ments	ment	
5	Miorandi, D.; Carreras, I.; Gregori, E.; Graham, I.; Stewart, J	Measuring net neutrality in mobile Internet: Towards a crowdsensing based citizen observatory	A crowdsensing approach, coupled with Open Data philosophy, as the way to build a "citizen observatory" on net neutrality in mobile Internet.	Italy, UK
6	Zaman, J.; De Meuter, W.	DisCoPar: Distributed components for participatory campaigning	DisCoPar is a component–based system aimed to enable a flexible composition of citizen observatory features. It allows citizens to set up their own citizen observatory by enabling them to specify the types of data that have to be gathered, how this data should be aggregated, and what type of feedback should be sent back to the participants.	Belgium
7	Oliveira, A.; Campolargo, M.; Martins, M.	Human Smart Cities: A Human centric model aiming at the wellbeing and quality of life of citizens	They have developed new models to engage citizens and public authorities in the co–design and co–creation of services to solve their needs under the concept of Human Smart City. They implemented an example called MyNeighbourhood.	Portugal
8	Bardaji, R.; Piera, J.	Low cost moored instrumentation for citizens' education and participation inenvironmental stewardship	Citclops European project aims to develop systems to retrieve and use data on seawater optical properties using low–cost sensors combined with contextual information	Spain
9	Charitos, D.; Theona, I.; Rizopoulos, C.; Diamantaki, K.; Tsetsos, V.	Enhancingcitizens'environmental awareness through the use of a mobile and pervasive urban computing systemsupporting smart transportation	The design and evaluation of an application (MITOS–Multi–Input TranspOrt planning System) that sought to promote a more environmentally conscious urban	Greece

Study ID	Author	Title	What	Where
			mobility paradigm, via the provision of advanced transportation services in a Smart City context.	
10	Stapleton, C.; Smith, E.; Hughes, C.E	The art of nurturing citizen scientists through mixed reality	Details the implementation of a Mixed Reality experiential learning application that expands our ability to provide dynamic content structures for venues to engage the user's physical environment and interactive imagination by incorporating the conventions of story, play and game employed in competing leisure time activities.	USA
11	Pokric, B.; Krco, S.; Pokric, M.; Knezevic, P.; Jovanovic, D.	Engaging citizen communities in smartcities using IoT, serious gaming and fast markerless Augmented Reality	Focus on engaging citizen communities around the air pollution and environmental monitoring issues utilizing loT ekoNET service, an approach in engaging citizen communities based on serious gaming incorporating integration of the physical and digital worlds through aggregation of Internet of Things (loT) service with Augmented Reality (AR) data visualization.	Serbia
12	Psyllidis, A.; Biloria, N	OntoPolis©: A Semantic Participatory Platform for Performance Assessment and Augmentation of Urban Environments	A semantic participatory platform for performance assessment and augmentation of urban environments	The Netherlands
13	Royo, S.; Yetano, A.; Acerete, B.	E Participation and Climate Change: Are Local GovernmentsActively Promoting Responsible Behaviors and Offering Opportunities for Citizen Involvement	Analyze of the level of development of e–participation in European local governments in relation to environmental topics and climate change specifically and the factors that explain the level of development of these	Spain

Study ID	Author	Title	What	Where
			practices.	
14	Crowley, D.N.; Breslin, J.G.; Corcoran, P.; Young, K	Gamification of citizen sensing through mobile social reporting	Present many examples of observatories and introduce the concept of social mobile reporting where a community of people report on issues within their environment.	Ireland
15	Aasbakken, M.; Jaccheri, L.; Chorianopoulos, K.	Evaluation of user engagement and messagecomprehension in a pervasive software installation	This work explores the relationship between pervasive software and user engagement towards environmental issues, it gives an example of an interactive project implemented to raise awareness in kids about water importance for plants.	Norway, Greece
16	Zell, E.; Huff, A.K.; Carpenter, A.T.; Friedl, L.A	A UserDriven Approach to Determining Critical Earth Observation Priorities for Societal Benefit	This work presents a list of the 10 highest ranked observations needs due to its priority for our world. Also, it presents some observatories.	USA
17	Dallora Moraes, A.L.; Fonseca, F.; Esteves, M.G.P.; Schneider, D.; de Souza, J.M	A metamodel for crowdsourcing platforms in Data Collection and Participatory Sensing	this paper proposes a meta–model which aims to fit generic solutions related to a specific subset of crowdsourcing designed to accomplish a specific task: Data Collection and Participatory Sensing to leverage the engagement of volunteers with Science and Environmental issues	Brasil
18	Laut, J.; Henry, E.; Nov, O.; Porfiri, M	Development of a MechatronicsBased Citizen SciencePlatform for Aquatic Environmental Monitoring	They present Brooklyn Atlantis, an integrated citizen science project consisting of a mechatronics–based system and an online peer–production platform. Volunteers participate in Brooklyn At-	USA, UK, Italy

Study ID	Author	Title	What	Where
			lantis by analyzing water quality data and wildlife images on the project website, which are uploaded remotely by an aquatic surface vehicle.	
19	Mark Cottman–Fields, Margot Brereton, Jason Wimmer, Paul Roe	Collaborative extension of biodiversity monitoring protocols in the bird watching community	This paper report observations and lessons on the design of extensions to established biodiversity monitoring protocols.	Australia
20	Alan Chamberlain, Mark Paxton, Kevin Glover, Martin Flintham, Dominic Price, Chris Greenhalgh, Steve Benford,Peter Tolmie, Eiman Kanjo, Amanda Gower, Andy Gower, Dawn Woodgate, Danaë Stanton Fraser	Understanding mass participatory pervasive computing systems for environmental campaigns	This papers presents the results of a Participate a 3–year collaboration between industry and academia to explore how mobile, Web and broadcast technologies could combine to deliver environmental campaigns.	UK, Saudi Arabia
21	Daisy Yoo, John Zimmerman, Tad Hirsch	Probing bus stop for insights on transit co–design	This study investigates how social computing might support citizen's co–design their transit service.	USA
22	Rachel Jacobs, Steve Benford, Mark Selby, Michael Golembewski, Dominic Price, Gabriella Giannachi	A conversation between trees: what data feels like in the forest	This study shows how artists engaged the public with scientific climate change data. The artwork visualised live environmental data collected from remote trees, alongside both historical and forecast global CO2 data. Visitors also took part in a mobile sensing.	UK
23	Andrea Wiggins	Free as in puppies: compensating for ict constraints in citizen science	Presents citizen science projects detailing their techniques and ICT and highlighting the techno-	USA

Study ID	Author	Title	What	Where
			logical gaps each one faces	
24	Carl DiSalvo, Marti Louw, Julina Coupland, MaryAnn Steiner	Local issues, local uses: tools for robotics and sensing in community contexts	six creativity support tools (Neighborhood Sensor Walks, Canary Test Kits, Collage in Context, Robot Storyboarding, Concept Mock–Ups, and System Mapping) were developed to foster community engagement and expression with robotics and sensing, assessing the benefits and shortcomings of each tool.	USA
25	Dragana Majstorovic, Maria A. Wimmer	Future scenarios of ICT solutions for governance and policy modelling	This study presents: eGovPoliNet through 6 scenarios, scholars have developed visionary scenarios to envisage how ICT–supported open and public governance and policy making might emerge in the years to come.	Germany
26	H. Tangmunarunkit, C. K. Hsieh, B. Longstaff, S. Nolen, J. Jenkins, C. Ketcham, J. Selsky, F. Alquaddoomi, D. George, J. Kang, Z. Khalapyan, J. Ooms, N. Ramanathan, D. Estrin	Ohmage: A General and Extensible End–to–End Participatory Sensing Platform	This paper presents Ohmage which is a modular and extensible open–source, mobile to Web PS platform that records, stores, analyzes, and visualizes data from both prompted self–report and continuous data streams.	USA
27	Christopher A. Le Dantec, Mariam Asad, Aditi Misra, Kari E. Watkins	Planning with Crowdsourced Data: Rhetoric and Representation in Transportation Planning	In this paper, they look at how data from a purpose–built smartphone app (Cycle Atlanta)they deployed were incorporated into a three day urban planning event from the local goverment.	USA

Study ID	Author	Title	What	Where
28	Henrik Korsgaard, Martin Brynskov	City bug report: urban prototyping as participatory process and practice	This paper explores the wider contexts of digital policy, transparency, digitisation and how this changes city administration and the role of the (digital) publics, using City Bug Report as a design case.	Denmark
29	Tawanna R. Dillahunt, Jennifer Mankoff	Understanding factors of successful engagement around energy consumption between and among households	Paper about the cultures of participation, the opportunities and drawbacks this can have in our mordern societies.	USA
30	Mari Ervasti, Shideh Dashti, Jack Reilly, Jonathan D. Bray, Alexandre Bayen, Steven Glaser	iShake: mobile phones as seismic sensors — user study findings	This paper presents the “iShake” system which uses smartphones as seismic sensors to measure and deliver ground motion intensity parameters produced by earthquakes more rapidly and accurately than currently possible.	Finland, USA
31	Gerhard Fischer	Understanding, fostering, and supporting cultures of participation	They deployed a social–energy monitoring application across 15 households, in two distinct locations and monitored how competition can engage users to reduce their energy consumption	USA
32	Dipanjan Chakraborty, Aaditeshwar Seth	Building citizen engagement into the implementation of welfare schemes in rural India	They leveraged the deep penetration of mobile phones in India to design a suite of IVR (Interactive Voice Response) tools that can help capture community perceptions, improve awareness of the people, and verify o cial records directly by the beneciaries themselves.	India
33	Andrea Botero, Joanna Saad–Sulonen	Enhancing citizenship: the role of in–between infrastructures	In this paper, they draw on material from a participatory design project (The Urban Mediator)	Finland

Study ID	Author	Title	What	Where
			that focused on the practices, infrastructures, and technologies used for creating and sharing information about the urban environment.	
34	Gang–Hoon Kim, Silvana Trimi, Ji–Hyong Chung	Big–data applications in the government sector	They evaluate the bigdata innitiatives from governments and compare their implementations with the business ones to find possible gaps for improvement	Korea, USA
35	Consuelo Valdes, Michelle Ferreirae, Taili Feng, Heidi Wang, Kelsey Tempel, Sirui Liu, Orit Shaer	A collaborative environment for engaging novices in scientific inquiry	This paper presents Green–Touch, which consists of a mobile user interface for capturing data in the field, a web application for data curation in the "cloud," and a tabletop interface for exploratory analysis of heterogeneous data.	USA
36	Uta Wehn, Jaap Evers	The social innovation potential of ICT–enabled citizen observatories to increase eParticipation in local flood risk management	This paper analyses the social innovation potential of such ICT–enabled citizen observatories to increase eParticipation in local flood risk management.	The Netherlands
37	Uta Wehn, Maria Rusca, Jaap Evers, Vitavesca Lanfranchi	Participation in flood risk management and the potential of citizen observatories: A governance analysis	This paper introduces a framework for analysing the potential for participacion via ICT–enabled citizen observatories	The Netherlands
38	C. Richard Ziegler, J. Angus Webb, Susan B. Norton, Andrew S. Pullin, Andreas H. Melcher	Digital repository of associations between environmental variables: A new resource to facilitate knowledge synthesis	This paper proposes open–access and online sharing of environmental variables associations.	United States

Study ID	Author	Title	What	Where
39	Dirk S. Schmeller, Romain Julliard, Peter J. Bellingham, Monika Böhm, Neil Brummitt, Alessandro Chiarucci, Denis Couvet, Sarah Elmendorf, David M. Forsyth, Jaime García Moreno, Richard D. Gregory, William E. Magnusson, Laura J. Martin, Melodie A. McGeoch, Jean–Baptiste Mihoub, Henrique M. Pereira, Vânia Proença, Chris A.M. van Swaay, Tetsukazu Yahara, Jayne Belnap	Towards a global terrestrial species monitoring program	The paper proposes a global terrestrial species monitoring program	Germany
40	António Correia, Jorge Santos, Diogo Azevedo, Hugo Paredes, Benjamim Fonseca	Putting “Human Crowds” in the Loop of Bibliography Evaluation: A Collaborative Working Environment for CSCW Publications	This paper reports on a bibliographic information system for semantic analytics focused on what scientific research data means and how it can be interpreted through a division of intellectual labot among social, computer and citizen scientist	Portugal
41	Nuria Castell, Mike Kobernus, Hai–Ying Liu, Philipp Schneider, William Lahoz, Arne J. Berre, Josef Noll	Mobile technologies and services for environmental monitoring: The Citi–Sense–MOB approach	This work presents The Citi–Sense–MOB Citizens’ Observatory will be part of an environmental health monitoring system and environmental health knowledge base, created from information provided by GNSS (Global Navigation Satellite Systems) signals such as GPS (Global Positioning	Norway

Study ID	Author	Title	What	Where
			System) and Citizens' Observatory data.	
42	R.I. Rojas–Caldelas, E.A. Corona Zambrano	Urban observatories opportunities for environmental monitoring: Solid wastes	This paper presents a local urban observatory for waste management and compares it with the global habitat agenda and the local agenda of the region where it is implemented	Mexico
43	Joana Ferreira Hipólito	Multimedia mobile services with applications in environment	Explores the use of mobile multimedia services for boosting citizens participation	Portugal
44	Kylie Paul, Michael S. Quinn, Marcel P. Huijser, Jonathan Graham, Len Broberg	An evaluation of a citizen science data collection program for recording wildlife observations along a highway	They investigated whether the opportunistic observations of live animals by volunteers along a 46–km section of Highway 3 in the Crowsnest Pass area ("RoadWatch in the Pass" data collection program) in Alberta, Canada, had a similar spatial pattern as systematically collected data by the researchers along the same road section.	Canada
45	Flora Salim, Usman Haque	Urban computing in the wild: A survey on large scale participation and citizen engagement with ubiquitous computing, cyber physical systems, and Internet of Things	This paper proposes a taxonomy for categorising and characterising urban computing technologies and approaches with regards to the level of participation	Australia, UK
46	Understanding the multi–dimensional structure of pro–environmental behavior	Understanding the multi–dimensional structure of pro–environmental behavior	They examined the multi–dimensional structure of pro–environmental behavior (PEB) in a mixed–methods study of rural residents of New York, USA	United States

Study ID	Author	Title	What	Where
47	McKenzie F. Johnson, Corrie Hannah, Leslie Acton, Ruxandra Popovici, Krithi K. Karanth, Erika Weinthal	Network environmentalism: Citizen scientists as agents for environmental advocacy	This study identify a three–step process whereby highly motivated individuals, or environmental opinion leaders, seek out citizen science opportunities due to an interest in one or more environmental issues; gain expertise through citizen science participation; and diffuse acquired skills and knowledge to peers through social networks, education of other non–scientist Indian citizens, and/or changes in career or education trajectories.	United States
48	Dyah Retno Wijayanti, Sri Suryani	Waste Bank as Community–based Environmental Governance: A Lesson Learned from Surabaya	This paper discusses an implementation of waste bank as community–based environmental governance.	Indonesia
49	Stuart E. Newson, Hazel E. Evans, Simon Gillings	A novel citizen science approach for large–scale standardised monitoring of bat activity and distribution, evaluated in eastern England	This work describes a semi–automated step–wise method for processing this large volume of recordings to assign identity to species or genus level with low error rates using citizens as data collectors.	UK
50	Panos Panagiotopoulos, Liran Christine Shan, Julie Barnett, Áine Regan, Áine McConnon	A framework of social media engagement: Case studies with food and consumer organisations in the UK and Ireland	This study proposes an application of the framework identifies three key capabilities that can frame the contribution of social media engagement in this context: (1) consistency in managing social interactions, (2) creating content to engage with specific audiences and (3) using social media as information sources to develop network alertness. Moving	UK

Study ID	Author	Title	What	Where
51	Nathan R. Prestopnik, Jian Tang	Points, stories, worlds, and diegesis: Comparing player experiences in two citizen science games	They conducted an experiment to examine how people perceive differences between points–based and story–based gamification approaches	USA, China
52	C.B. Embling, A.E.M. Walters, S.J. Dolman	How much effort is enough? The power of citizen science to monitor trends in coastal cetacean species	In this study they investigated how much effort is required by citizen scientists to dectect trends in the cocurrence of a protected population of bottlenose dolphins.	UK
53	David B. Resnik, Kevin C. Elliott, Aubrey K. Miller	A framework for addressing ethical issues in citizen science	citizen science also raises ethical issues that should be addressed when projects begin and throughout the course of scientific investigation. To promote ethical research, scientists should develop guidelines for involvement of citizens in research, communicate effectively with participants and local communities at the outset of their involvement in research projects	United States
54	Scott R. Loss, Sara S. Loss, Tom Will, Peter P. Marra	Linking place–based citizen science with large–scale conservation research: A case study of bird–building collisions and the role of professional scientists	We use the example of bird collisions with buildings in North America—an issue for which the majority of data have been collected by citizen science programs that each operate in a different city—to outline simple study design and data collection steps that will ensure that data can contribute to large–scale research syntheses	United States
55	Jason Papathanasiou, Robert Kenward	Design of a data–driven environmental decision support system and testing of stakeholer data collection	present the requirements and top level design of a decision support system that facilitates the exchange of environmental	Greece, UK

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			information between local level and higher levels of government	
56	Hai–Ying Liu, Mike Kobernus, David Broday, Alena Bartonova	A conceptual approach to a citizens' observatory – supporting community–based environmental governance	This study propose a conceptual framework for a Citizens' Observatory programme as a system that supports and promotes community–based environmental governance. Next, we discuss some of the challenges involved in developing this approach.	Norway
57	Yuan–Fang Li, Gavin Kennedy, Faith Davies	PODD: An Ontology–Driven Data Repository for Collaborative Phenomics Research	This paper describes our effort in designing and developing an ontology–driven, open, extensible data repository to support collaborative phenomics research in Australia.	Australia
58	Leela Damodaran and Wendy Olphert	Strategies for Citizen Engagement (ii) – Tools and Techniques	Compilationo of citizen engagement tools and techniques for particular contexts. Special focus is put in building capacity of stakeholders to contribute effectively.	UK
59	Carijn Beumer, Pim Martens	Biodiversity in my (back)yard: towards a framework for citizen engagement in exploring biodiversity and ecosystem services in residential gardens	In this paper, an indicator framework is proposed that aims to engage citizens in experiencing and exploring biodiversity and ecosystem services in their own domestic outdoor spaces	United States, The Netherlands
60	Eréndira Aceves–Bueno, Adeyemi S. Adeleye, Darcy Bradley, W. Tyler Brandt	Citizen Science as an Approach for Overcoming Insufficient Monitoring and Inadequate Stakeholder Buy–in in Adaptive Management: Criteria and Evidence	Based on adaptive management literature, they developed a set of criteria for successfully addressing monitoring and stakeholder related failures in adaptive management and then used these criteria to evaluate 83 citizen science case studies from peerreviewed literature	United States

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			and created a model to boost engagement.	
61	Junjun Chen, Bronwen Cowie	Developing ‘Butterfly Warriors’: a Case Study of Science for Citizenship	This paper focuses on studying how students in a year–4 primary class-room learnt about New Zealand butterflies through thinking, talking, and acting as citizen sci-entists.	New Zea-land
62	Simo Hosio, Jorge Gon-calves…	Exploring Civic Engage-ment on Public Displays	This paper seek to aug-ment urban space with public displays to pro-mote civic engagement by ad-dressing local and tempo-rally and spatially rele-vant issues.	Finland
63	Alison Donnelly, Olivia Crowe, Eugenie Regan	The role of citizen science in monitoring biodiversity in Ireland	Paper focused in bringing examples of citizen sci-ence projects in Ireland	UK
64	Kazjon Grace, Mary Lou Maher, Jennifer Preece	A Process Model for Crowdsourcing Design: A Case Study in Citizen Sci-ence	This paper presents a process model for crowdsourcing experience design.	United States
65	Zaheer Khan, Saad Liaquat Kiani, Kamran Soomro	A framework for cloud–based context–aware in-formation services for citi-zens in smart cities	In this paper, they high-light the issues that give rise to these multi–faceted challenges for citizens and public administra-tions of smart cities, iden-tify the artefacts and stakeholders involved at both ends of the spectrum (data/service producers and consumers) and pro-pose a conceptual frame-work to address these challenges.	UK
67	Cathy C. Conrad, Krista G. Hilchey	A review of citizen science and community–based environmental monitoring: issues and opportunities	They reviewed the last 10 years of relevant citizen science literature for areas of consensus, Literature was examined for evi-	Canada

Study ID	Author	Title	What	Where
			dence of common benefits, challenges, and recommendations for successful citizen science	
68	Wehn, U (Wehn, Uta); Evers, J (Evers, Jaap)	Citizen observatories of water: Social innovation via eParticipation?	This paper analyses the social innovation potential of such ICT–enabled citizen observatories to increase eParticipation in local governance processes related to flood risk management.	The Netherlands
69	Holmer, HB	Constructing and constraining participation in participatory arts and HCI	They describe how a set of artists, concerned with environmental issues and community engagement, frame and enact participation, and describe how the nature of this participation deviated from both artists' and our ideas of what participation would be.	United States
70	Bonter, David	The current state of citizen science as a tool for ecological research and public engagement	Presents how citizen science has been used as a tool for public participation and environmental resources monitoring that combines research and field activities.	United States

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