

**ADDIS ABABA UNIVERSITY  
SCHOOL OF GRADUATE STUDIES**

**The Impacts of Social-Economic and Demographic  
Factors on the Level of Accuracy of Hydrological Data  
Collection in Ethiopia**

**BY: Melat Yemane**

**Advisor: Melese W. Araya, (PhD)**

**November, 2020  
ADDIS ABABA, ETHIOPIA**

## **ABSTRACT**

*Water resources cannot be managed unless we know where they are, in what quality and quantity, how they are likely to be in the foreseeable future. Data from hydrological monitoring networks are used by public and private sectors for variety of different applications. This paper assesses the value propositions of the collection of data, how it is collected, how accurately it is collected and how observers can be incentivized. This study, therefore, examines the existing institutional arrangements for hydrological monitoring and the practices of other institutions. The main aim of the study was to assess what determinates the observer's level of accuracy, in Ethiopia. In order to achieve the objective of the study, data were collected from 105 observers via telephone from the 9 sub basins and from citizen science stations. The 4 accuracy cut-off points were determined seeing the 15 years data and using different criteria. The collected data were analyzed descriptively and Econometric model (Ordered Probit Model). The result from the study is interpreted by how different variables affect the level of accuracy. Based on the findings, the study concludes and recommends that MOWIE could fill their recurrent gaps and take a lot from IWMI's approach of citizen science. Hence these two institutes could in Conesus to work together on a hybrid approach, in order to enhance the level of accuracy of data collected by river gauging observers.*

**Key words:** Accuracy, Observers, Sub Basin, Citizen Science, Rivers, Ethiopia

## **ACKNOWLEDGMENT**

First of all I would like to praise the Lord for everything concerning this paper. Next, I would like to thank my parents, my mother Tigist W/mariam and my father Yemane Abay. . I would like to thank my advisor, Dr. Mesele W. Araya, for his constructive suggestions and patience while preparing this paper. I would like to extend my gratitude to my family and friends for every support they have given me so that I can finish this study. I would like to thank Lemi Taye, Delina G, NOLA and Tsehay.

I would like to thank government officials and key informants from the Ministry of Water, Irrigation and Energy (MOWIE), for their cooperation.

I would like to thank people who reviewed the draft version of this paper and provided valuable comments which helped me to improve the quality of the final version: Dr.Alemseged Tamiru Haile Researcher - Hydrology/Hydrological Modelling at IWMI, Addis Ababa, Ethiopia and Likimyelesh Nigussie a Research Officer at the International Water Management Institute (IWMI), Addis Ababa, Ethiopia. Last but not least I want to extend my gratitude to IWMI's PhD students.

## Table of Contents

List of Acronyms and Abbreviations .....	vi
CHAPTER ONE .....	1
INTRODUCTION .....	1
1.1 Background of the Study .....	1
1.2 Statement of the problem .....	3
1.3 Research Questions.....	4
1.4 Objectives .....	4
1.4.1 General objective .....	4
1.4.2 Specific objective.....	4
1.5 Methodology .....	5
1.6 Significance of the Study .....	5
1.7 Scope and Limitation of the Study.....	5
1.8 Organization of the Paper .....	6
CHAPTER TWO .....	7
LITERATURE REVIEW .....	7
2.1 Theoretical Literature Review .....	7
2.1.1 The concept of citizen science .....	7
2.2 What has been done in citizen science? .....	9
2.2.1 Citizen science in hydrology .....	9
2.3 Institutional aspect of citizen science.....	10
2.4 Level of engagement of citizen scientists .....	11
2.5 Incentives .....	12
2.5.1 Types of incentives .....	13
CHAPTER THREE .....	14
DATA AND METHODOLOGY .....	14
3.1 Description of the study area .....	14
3.2 Sampling Technique .....	15
3.3 Sample Size.....	16
3.4 Data Source.....	16
3.5 Data collection procedure and Quality Assurance .....	17
3.6 Data Analysis.....	18
3.7 Model Specification .....	18
3.8 Variable Specification.....	21
3.9 Accuracy cutt-off criteria.....	23
CHAPTER FOUR.....	25

DATA ANALYSIS AND DISCUSSION.....	25
4.1 Descriptive Analysis .....	25
4.1.1 Socio-Economic and Demographic Characteristics of Households.....	25
4.1.2 The ordered outcome of Accuracy .....	28
4.1.3 Training of observers .....	29
4.1.4 Distance of observers house to Station .....	30
4.2 Econometric Analysis .....	31
CHAPTER FIVE .....	40
CONCLUSION AND POLICY RECOMMENDATION .....	40
5.1 Conclusion .....	40
5.2 Recommendation .....	42
REFERNCES.....	44
APPENDIX.....	49
INTERVIEW QUESTIONS IN ENGLISH .....	50
INTERVIEW QUESTIONS IN AMHARIC .....	53

**List of Tables.....Page**

Table 1: Number of Hydrological Stations in Ethiopian River Basin..... 15  
Table 2: Description and Specification of the Explanatory Variables in the Model..... 21  
Table 3: Socio-Demographic Characteristics of Observers ..... 27  
Table 4: Ordinal level of accuracy ..... 28  
Table 5: Accuracy of the different stations ..... 29  
Table 6: Trainings and Accuracy ..... 29  
Table 7: River gauging stations distance from house to stations ..... 30  
Table 8: Results of the Ordered Probit Regression and the Marginal effects ..... 32  
Table 9: Marginal effects of different outcomes..... 37  
Table 10: of predicted probability of the oprobit ..... 39

**List of Figures.....Page**

Figure 1: Types of incentives ..... 13  
Figure 2: the 12 Sub basins in Ethiopia ..... 14

## List of Acronyms and Abbreviations

BDA	Basin Development Authority
CBM	Community-based Monitoring
ETB	Ethiopian Birr
FGD	Focus Group Discussion
GDP	Gross Domestic Product
GTP	Growth and Transformation Plan
IP	Innovation Platform
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
MoA	Ministry of Agriculture
MoWIE	Ministry of Water, Irrigation and Energy
MoWR	Ministry of Water Resources
NMA	National Meteorology Agency
SGW	Shallow Groundwater
SLMP	Sustainable Land Management Programme
ABDA	Awash Basin Development Authority
ARBDA	Abbay Basin Development Authority
RVBDA	Rift Valley lakes Basin Development Authority

# CHAPTER ONE

## INTRODUCTION

### 1.1 Background of the Study

The concept of citizen science is well established, and several different definitions are given by several researchers, both formal and informal, Citizen Science is most commonly defined as science by non-scientists (Buytaert et al., 2014). A form of science enacted and developed by citizens/public themselves the participation of the general public in the research design, data collection, data analysis and interpretation process together with scientists (WIRE's Water, 2018). The public gains increased awareness about the environment while scientists obtain valuable data at low-cost and with accuracy. Citizen science refers to the participation of the general public in the generation of the new scientific knowledge (Buytaert et al., 2014). The nature of this participation varies from data collection, analysis and use of data for policy decision making based on their level of engagement of the participants. The main concerns in citizen science are data quality or the accuracy of the data collected, lack of practical guidance on how to set up citizen science monitoring programs, and initiating and sustaining and up scaling citizens involvement (Rutten et al., 2017).

Water science is not an obvious discipline for the use of citizen science because many measurements are technologically demanding (WIREs Water, 2018). But the technological development, over the past two decades, made it possible to participate citizen scientists in more endeavours such as measurement of precipitation, quality and quantity of water bodies, hydrological risk reduction and resilience building etc. Hydrology remains a highly data-scarce science; in many regions, if data exist, the lengths of the time series are insufficient.

Thus, involving citizen scientists or volunteers is very essential in order to improve the problems we are facing today. Traditional methods struggle to create locally relevant, actionable knowledge. For instance, traditional water level and discharge monitoring is usually based on a sparse network of gauges that require extensive and technologically complex maintenance, while accuracy issues over data can frustrate researchers.

In Ethiopia, the Ministry of Water, Irrigation and Energy (MOWIE) and the Basin Development Authority (BDA) have the mandate to collect hydrological data. Every data collected by observers in every stations, is then gathered by the supervisors from all the

stations in the country and it was submitted to MOWIE, where all collected ledger books are encoded to MOWIE's data base till the year 2015 (Mohammed, MOWIE, July 2020). Since then for three consecutive years, the three sub basins out of the twelve sub basins were delegated by MOWIE to collect, process, analyze, disseminate high-quality accurate hydrological data's and submit all data from this three BDA'S to MOWIE, to document all national hydrological data all together. The three sub basins were; Awash sub-basin, Abay sub-basin and Rift Valley lakes sub-basins which were changed to Awash Basin Development Authority (ABDA), Abay Basin Development Authority (ARBDA) and Rift Valley lakes Basin Development Authority (RVBDA) respectively. But in 2018, MOWIE realized all this three sub-basins are better-off under one delegate called the Basin Development Authority (BDA). With consent of reporting and submitting the data collected by the observers of the past three years while they were under their own authorities and after they come under one BDA but they still haven't sent the collected data ledgers till today. The hydrology data is not well documented and well gathered.

Hydrological monitoring requires a continuous and lasting effort since hydrological flow rate and states are highly variable both in space and time. Therefore, there is a concern that, even though citizen scientists are engaged voluntarily, citizens maybe become reluctant to volunteer for repeated, frequent and long term measurement. Different types of level of engagement have been stated by different researchers, which are clearly stated in the literature part of this study. However, the participatory approach has shown to work best when there is active buy-in from the local community that is, the incentives to local stakeholders should be highlighted (Haklay, 2012).

Incentives are very essential in order to keep them motivated and the good work they have been doing so far should be rewarded. Motivation is defined as an individual's degree of willingness to exert and maintain an effort towards organizational goals. Whereas, motivation is in turn influenced by incentives (Kragh., 2016). The quality of data which is collected by citizens is often a major concern due to low technical capacity. However, the data can be reliable (Fore et al., 2001), therefore the quality of data should be critically evaluated using both qualitative and quantitative method.

## 1.2 Statement of the problem

One of the most commonly asked questions about river flow (or level) data are ‘How good/accurate are the data? This generic question is asked by almost all data users, whether consultants working on flood or water resources studies, scientists undertaking research, ‘strategic’ data users, such as government departments, the public or media, and environmental managers. It is also a question asked by hydrometrists themselves.

Zemadim et al. (2013) highlighted that hydrological monitoring for the provision of high-quality accurate hydrological data is crucial to support decisions on sustainable land management and water allocation strategies, and for weather forecasts and early warnings.

Citizen science has great potential as a tool for environmental monitoring. Volunteers already make a valuable contribution by monitoring various environmental attributes, thus increasing the use of citizen science. There are many major concerns regarding the effectiveness, reliability and accuracy of government led hydrological monitoring. This is due to a lot of, regular payments to observers is often interrupted , there is barely a regular visit of the gauging sites by the supervisors , slackness of the observers and supervisors, lack of awareness of how important is hydrological monitoring etc..Therefore, the long term data collected is not reliable, adequate, accurate or complete.

Evidence shows that there are gaps in hydrological data in Ethiopia due to limited coverage, and poor data quality and continuity (Haile et al. 2017). Some of the underlying causes of these data gaps are outdated and out-of-service gauging stations, inadequate equipment calibration, limited telemetry systems and lack of adequate or modern data acquisition and management systems (NBI 2016).

As such, some of the existing collected time series data is either incomplete or not accurate. Citizen science can help in filling the existing gaps (Walker et al., 2016). Therefore, empowering citizens by citizen science, as scientists, can help improve the whole management scheme and limit the drawbacks of national river monitoring process. However, citizen scientists are still lacking a push factor that motivates citizens to invest their time, energy etc... to engage in a citizen science projects (Tipaldo and Allamano, 2017). It is very crucial to understand what motivates citizens to participate on citizen science and give them the perception about the importance of accurate collection of hydrological data and information for the country as a whole.

### **1.3 Research Questions**

How to incentivize citizen scientists in order to motivate them in collecting accurate data?

What are the existing incentive mechanisms used by different institutions (MOWIE, NMA, IWMI and others, if any) to motivate observers monitoring rivers in an accurate and cost effective way?

Is financial incentive really recommendable? Financial Vs non-financial/ intrinsic incentives?

What incentive mechanism works best to enhance the level of engagement of volunteer citizens participating in monitoring of rivers?

What are the opportunities and challenges of adopting citizen science in a cost effective, efficient and accurate manner?

What should be the probability of getting different level of accurate data when different variables vary?

### **1.4 Objectives**

#### **1.4.1 General objective**

To conduct an Ordered Probit Model analysis of different levels of Accuracy various mechanisms adopted by different institutions (MOWIE and IWMI) for observers monitoring river gauging and recommend accurate mechanisms for collecting quality data.

#### **1.4.2 Specific objective**

Evaluate the various variables affecting accuracy of data and identify the constraints affecting the whole data collection process?

To achieve cut-off point of accuracy for each stations.

Identify opportunities and constraints at MOWIE for adopting a particular incentive mechanism for observers.

Evaluate the implication of scaling up and main streaming citizen science across Ethiopia?

Cost minimization technique through citizen science approach in relative to the traditional method at MOWIE?

## **1.5 Methodology**

This study is based on data collected from two institutions. Used both primary and secondary data are gathered and analyzed. Primary data set are obtained through phone interviews. The secondary data set are taken from MOWIE and IWMI. The study use Ordered Probit Model to estimate regressions. It uses a continuous data set, more about methodology is briefly discussed in chapter 3.

## **1.6 Significance of the Study**

This research contributes to the understanding of factors that are determinants of accuracy of the data collected by observers across Ethiopia. This may be important for several reasons. In addition, the study incorporates citizen science stations tested by IWMI as one of the factors that can determine accuracy of data collected by observers. Thus, the study findings further provide relevant and valuable information that can be used to come up with policies that enhance accuracy of data across Ethiopia. Moreover, this paper can be used as a reference material to future researchers who aspire to conduct related studies and also will help to supplement existing empirical studies on accuracy and hydrology. It can also help concerned parties to focus their efforts towards helping observers and address the problem and working together to fill their gaps.

## **1.7 Scope and Limitation and Challenges of the Study**

The scope of the study focuses on the determinants of observer's accuracy in Ethiopia. Its spatial scope, as the title implies, is confined to Ethiopia. This study targets nine out of the total of twelve sub basins existing in Ethiopia. The total numbers of station in Ethiopia that are under MOWIE are 520 and the ones under the IWMI 30 stations. The main limitation of the study is the lack of data collected by organizations related to the study objective and the fact that we didn't reach to the required number of sample size due to Covid 19 and time constraint. The other limitations, that the researcher faced was office bureaucracy from MOWIE. Lastly, it was very hard for the researcher to communicate on the phone interview due to lack of trust between the two parties which made it very challenging in uncovering how much they earn monthly or annually if they are farmers and some of them speak and hear Amharic just to the basics, which made it very challenging to communicate.

## **1.8 Organization of the Paper**

The remaining part of the study is organized as follows; in Chapter two theoretical and empirical literatures are reviewed. Following that chapter 3 gives a clear over view of data and methodology. Chapter four presents and discusses the results of both the descriptive and econometrics analysis. The last, chapter five presents conclusions and recommendations of the research.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

This chapter focuses on reviewing both the theoretical and empirical literature on the concept of the determinants of accuracy towards adopting citizen science or hybrid or the current method. The theoretical literature review focus on the construction of theories based on the study. The empirical literature focuses on empirical evidence from developing countries in general and Ethiopian, even though little has been done on this specific topic.

#### **2.1 Theoretical Literature Review**

##### **2.1.1 The concept of citizen science**

Citizen science is not a new phenomenon, but revived in the 20<sup>th</sup> century and gained popularity worldwide over the past two decades. The historical starting point for citizen science was largely based on environmental data collection by volunteers. Citizen science has a long tradition in the natural sciences and its primary impact has been found in studies of ecological changes in natural habitats (Dickinson et al., 2012). In recent years, citizen science has been transformed and has gained momentum in a wide range of disciplines; especially in the fields of ornithology, astronomy, meteorology and microbiology (Kullenberg et al., 2016).

Citizen science refers to the participation of the general public (i.e., non-scientists, citizens or community members that volunteer) in the generation of new scientific knowledge, together with professional scientists (Buytaert et al. 2014). Within the emerging trend of democratizing science, the participation of nonprofessional scientists in research projects that involve data collection, interpretation, and analysis is often termed citizen science. (WIREs Water, 2018). Citizen science is a way to generate new scientific or environmental knowledge through the involvement of members of the public in scientific research (Dickinson et al, 2012).

Community-based monitoring provides many benefits to society, including environmental democracy, scientific literacy, social capital, citizen inclusion in local issues, strengthened governance, and healthier ecosystems (Conrad et al., 2011). Citizen Science is a manifestation of the collaboration of the public with researchers for common good. Some of the importance of applying citizen science in conducting research is that data is collected, with a relatively short period of time, reduce cost, community engagement by making it

easier to monitor projects and patterns for researchers. The increase in the use of citizen science for research progression raises data quality concerns (Rise of the citizen scientist, 2015).

For citizen science projects to achieve sustained volunteer participation, communication pathways between scientists, citizen scientists and non-participating community members need to be carefully considered (Buytaert et al. 2014). Citizen Science is characterised by three fundamental elements: (1) inclusion of citizens in the scientific process; (2) contributions to both science and the public, and (3) reciprocity, i.e. a two-way communication between scientists and the public (Golombic et al. 2017: 2).

The concept of citizen science is well established, and several different definitions are given by several researchers, both formal and informal, Citizen Science is most commonly defined as science by non-scientists. A form of science enacted and developed by citizens themselves the participation of the general public in the research design, data collection and interpretation process together with scientists (WIREs Water, 2018). Citizen Science is also about creating public engagement and it has the potential to stimulate public education as well as facilitating democratic participation and increased public understanding of science (Bonney et al., 2016).

Citizens can cost-effectively support hydrological monitoring (Weeser et al., 2018). Water science is not a known discipline for the use of citizen science because many measurements are technologically demanding. But the technological development, over the past two decades, made it possible to participate citizen scientists in more endeavours such as measurement of precipitation, quality and quantity of water bodies, hydrological risk reduction and resilience building etc...(WIREs Water, 2018).

Hydrology remains a highly data-scarce science; in many regions, if data exist, the lengths of the time series are insufficient. Thus, involving citizen scientists or volunteers is very essential in order to improve the problems we are facing today. Traditional methods struggle to create locally relevant, actionable knowledge. For instance, traditional water level and discharge monitoring is usually based on a sparse network of gauges that require extensive and technologically complex maintenance, while accuracy issues over data can frustrate researchers.

## **2.2 What has been done in citizen science?**

A lot has been done on citizen science in world and in our country as well. (Tamiru et al, 2019) examined in the Wutame and Branti watersheds of Ethiopia, that there was the capacity for community based monitoring. In Wutame, there is a water shortage during dry season. There are few well owners, since most people live on landscapes with poor shallow ground water potential. When wells have been dug, owners often encountered rocks by 5 meters depth and eventually abandoned efforts when the water table was not met (10-15 metre depth).

In Branti, however, there is a better understanding of the link between groundwater occurrence and rainfall. Wells were dug during the dry season to extract water from the ground that entered during the wet season. Also, the community recognizes the threat of Eucalyptus trees which monopolise groundwater. Many households have hand dug wells which they don't think they are using to their full potential because of lack of better water lifting technology and irrigation application technology. However, in Wutame because wells were not dug during the dries period the water level drops below the well bottom several weeks before the next rainy season. Therefore, wells are perceived as unreliable. It was hypothesised that citizen science could empower the communities to monitor hydrology so that areas of potential recharge could be identified to exploit shallow ground water aquifers during dry season. There were many barriers or a limitation during the study among them was the river water level during floods, lack of awareness of the importance of citizen science and poor literacy of the community.

### **2.2.1 Citizen science in hydrology**

The application of citizen science in hydrology and water resource science arrived rather late in the former's history, mainly because of the advanced technology required for monitoring many aspects of the water cycle, which excluded the active involvement of non-professional scientists.

Hydrological data are often difficult to interpret intuitively, while measurements tend to be expensive. For these reasons, intensive scientific training and specialization is normally a prerequisite for data analysis and manipulation (WIREs Water, 2018). Hence, development of technology is paving the way for the more rapid uptake of citizen science. As technology has progressed; citizens are now able to take part in sophisticated and extensive hydrological data

monitoring. Though citizen science is a relatively new term, people have been contributing to scientific projects for many years.

Mobilisation of many volunteer monitors in Ethiopia for several years has demonstrated that the citizen science method has great potential to legitimise and build capacity for groundwater government. It was found that citizen scientist collects reliable hydro-meteorological data which can be further refined by quality controls and varying incentives in tandem with changing motivations (Osborne, 2019).

In their extensive study, Weeser et al.,(2018), evaluated the quality and quantity of data generated by citizens in a remote kenyan basin and assesses whether crowd sourcing is a suitable method to overcome data scarcity. The methodology used is by installing thirteen water level gauges equipped with signboards explaining the monitoring process to passers-by. Results were sent via a text-message based data collection framework that included an immediate feedback to citizens. A public web interface was used to visualize the data. Within the first year, 124 citizens reported 1175 valid measurements. They have identified thirteen citizens as active observes providing more than ten measurements, whereas, 57% only sent one record.

A comparison between the crowd-sourced water level data and an automatic gauging station revealed high data quality. The results of this study indicate that citizens can provide water level data of sufficient quality and with high temporal resolution. Using the best incentivizing scheme in order to motivate citizen scientists is very essential. It is important to understand the driving factors that keep participants motivated. Giving feedback to participants is necessary, since it keeps the participants updated and prevents raising unrealistic expectations associated with monitoring, management planning and rewards.

### **2.3 Institutional aspect of citizen science**

Managing volunteers, however, is a difficult undertaking. Due to their non-contractual relationship with nonprofits, volunteers “vote with their feet” and leave organizations when they are dissatisfied (Walk et al, 2018). Hence, when looking in to citizen science it is also necessary to see the interaction of the participatory approach from an administrative/ institutional point. It is essential to see how volunteering citizen scientists are handled institutionally.

The ministry of Water, Irrigation and Energy (MOWIE) is responsible for obtaining the data, but at present there is no structure to do so at a community level (Osborne, 2019)

However, the Ministry of Agriculture has structures in place spanning from a federal to community level. However, the Ministry of Agriculture does not have the mandate to collect hydro-meteorological data and needs permission from MOWIE to do so (Osborne, 2019).

Institutions are sceptical of the accuracy and reliability of citizen science to populate these data sparse areas and inform governmental decisions regarding water resources. Certainly, there must be proof of the accuracy, such as statistical validation (Osborne, 2019).

The government of Ethiopia encourages the engagement of the community in natural resource management (Nigussie et al.,2019). For the data to gain legitimacy, it needs to be institutionalised, incorporated into policy, and officiated as a data stream (Irwin, 2018).

Community-led hydrological monitoring is a robust and low-cost alternative to filling the gaps in data sparse areas of Ethiopia, which inhabited by tributaries and groundwater sources which go ungauged and unexploited. This issue was even highlighted by MOWIE and river basin authorities as a challenge facing the country which constraints water resource management and translating scientific knowledge into practice in the recent GCRF Water Security and Sustainable Development Hub Project. There is a hesitation from these authorities to adopt the citizen science approach (Osborne, 2019).

#### **2.4 Level of engagement of citizen scientists**

An emerging shift has been noted from a broad-scale, top- down assessments towards more community based, participatory, bottom-up approaches. Citizen science approach has recently emerged as a promising direction in the provision of researches. The organization and degree of involvement of the citizen scientists varies widely.

Community engagement can have a positive effect on the decision-making process, if the science community and individuals benefit from the process (Vann-Sander et al. 2016). Also, it helps to gain a better understanding of the key issues of different stakeholders (Cunha et al. 2017).

Levels of participation vary according to the design of the Citizen Science project, ranging from ‘the simple contribution of information in contributory projects, through collaborative

projects having the additive value of data analysis and interpretation, through co-created projects that involve the public in all stages of the research process' (Golombic et al. 2017: 2).

Different researchers categorized, mode of engagement of citizen scientist, in different ways. In his extensive review, Haklay, (2012) suggested the level of participation of citizen scientists, be labelled in to four categories; where level 1 Crowd sourcing citizen scientists as sensors which involves a very limited direct community engagement. Level 2 Distributed intelligence citizen scientists as basic interpreters. Level 3 Participatory science citizen scientists participate in problem definition and data collection. Level 4 Extreme citizen scientists in problem definition, data collection, data analysis which is a collaborative science. Citizens are involved from problem definition to the dissemination of results. In this interpretation, the emphasis is not on the citizen as a scientist, but on the scientist as a citizen (WIREs Water, 2018).

The extreme level of practicing science is currently not widely accepted in the academic community taking into account local needs, practices, and culture; it requires scientists to engage at an intensive level with the social and ethical aspects of their work. The crowd sourcing level of engagement involves very limited direct community engagement. However, the participatory approach has shown to work best when there is active buy-in from the local community that is, the incentives to local stakeholders should be highlighted (Haklay, 2012).

Other ways of categorizing the modes of participation of citizen scientists lays on whether they are casually or regularly engaged. Those who are regularly engaged are usually monitoring intensively more than one measurement. Those who are casually engaged monitor one or two things aside from their main job form time to time. Philips et al.,(2019) examined the dimensions of level of engagement in to four behavioural activities, affective/feelings, learning/cognition and social/project connections.

## **2.5 Incentives**

A participant is only a citizen scientist when they actively volunteer (i.e., they are motivated by one or more factors) and maintain their activity (and contact with the professional scientists) throughout the duration of the project. In some citizen science projects participants have lost interest and/or fallen out of contact with scientists, or, as 'citizen sensors,' collect data passively without any obvious motivation. However, the recent tendency is to involve

volunteers in all intellectual aspects of the science, rather than capitalizing on them as a low-cost workforce WIREs Water, (2018). Motivation is defined as an individual's degree of willingness to exert and maintain an effort towards organizational goals. Whereas, motivation is in turn influenced by incentives kragh,(2016).

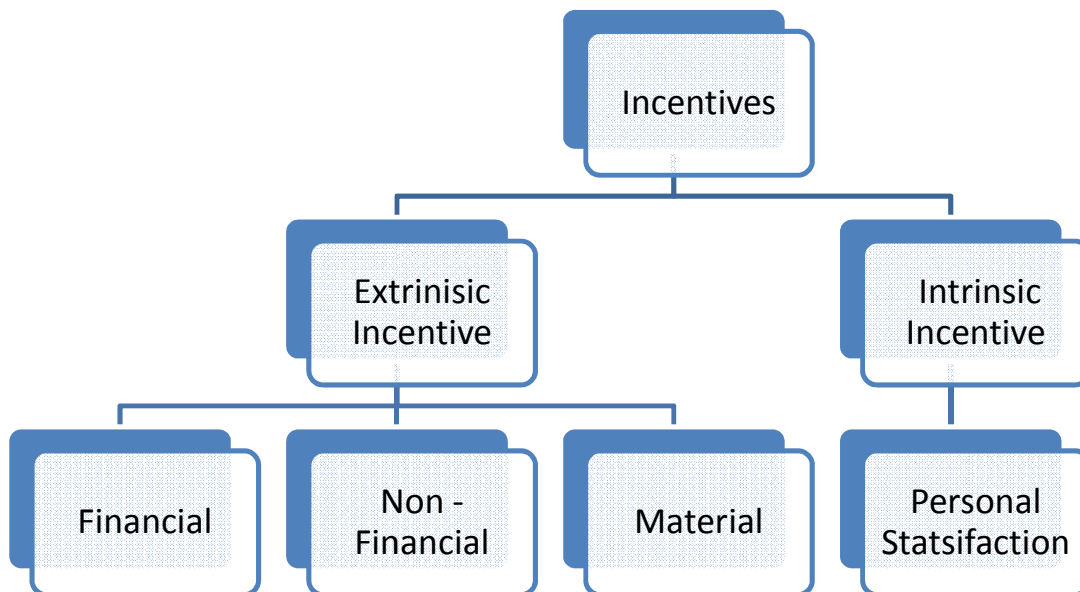
### 2.5.1 Types of incentives

We broadly classify factors that influence motivation as intrinsic and extrinsic incentives. Extrinsic factors leads to behaviour because it is instrument.

They can take the form of financial, material or non-material incentives. Financial incentives range from fixed salaries for those formally employed and allowances for volunteers, to performance-based incentives. Material incentives may include health insurance, clothing or tools of the trade such as boots and backpacks. Non-material incentives include community recognition, preferential treatment and developing new skills. WIREs Water, (2017).

Intrinsic factors stimulate behaviour that is performed out of enjoyment or interest. For example, to witnessing positive change and personal growth. Intrinsic motivation is said to be the strongest that will make citizens put a greater effort in activity considered. Besides enjoyment a personal interest in the topic could motivate people to participate as well WIREs Water, (2017).

**Figure 1: Types of incentives**



# CHAPTER THREE

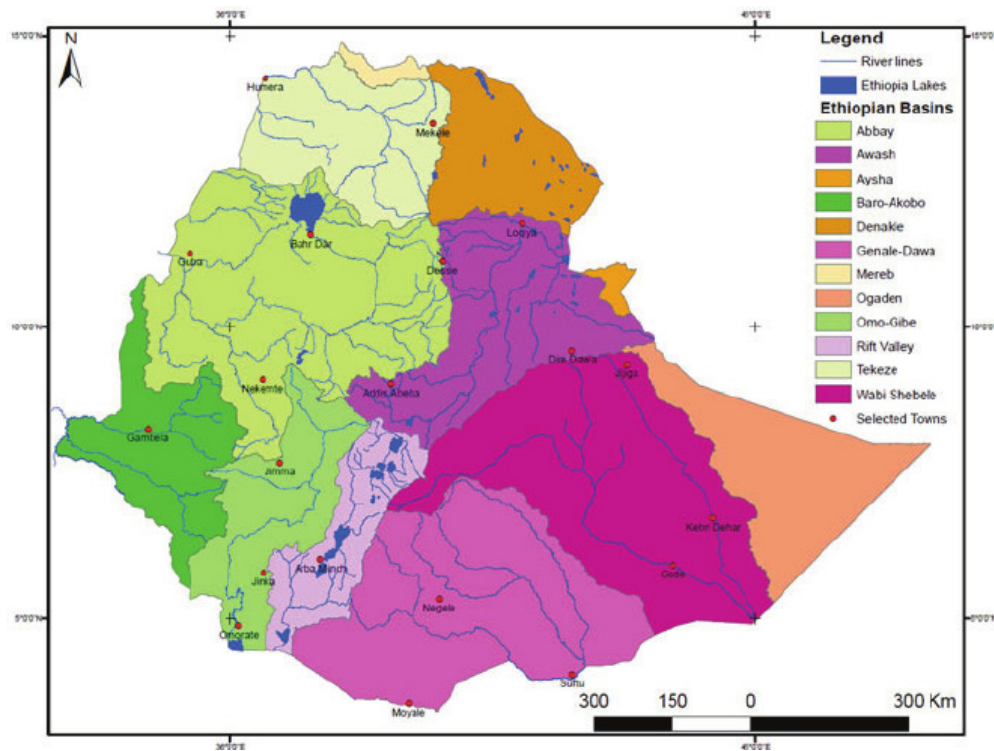
## DATA AND METHODOLOGY

This chapter presents the research methodology employed in the study. It describes the study area, sample technique, and sample size. In addition, it indicates the data collection, sources, and analytical strategies and the econometric model employed in the research.

### 3.1 Description of the study area

Ethiopia is endowed with a substantial amount of water resources but very high hydrological variability. The surface water resource potential is impressive, but little developed. The country possesses twelve major river basins as depicted below. In this study, we will focus only on the nine sub basins, as the three are not operational.

**Figure 2: the 12 Sub basins in Ethiopia**



Source: MOWIE

The study focuses on the accuracy of data collected by the observers. Stations are selected from the nine sub basins out of the total of twelve sub basins, as the table 1 below shows which sub basins have operational stations.

**Table 1: Number of Hydrological Stations in Ethiopian River Basin**

<b>No.</b>	<b>Basin</b>	<b>Established</b>	<b>Operational</b>
<b>1</b>	<b>Awash</b>	97	72
<b>2</b>	<b>Abbay</b>	160	131
<b>3</b>	<b>Wabi-Shebelle</b>	50	30
<b>4</b>	<b>Genale Dawa</b>	38	36
<b>5</b>	<b>Rift Valley</b>	70	54
<b>6</b>	<b>Omo-Gibe</b>	57	46
<b>7</b>	<b>Baro Akobo</b>	31	32
<b>8</b>	<b>Tekeze</b>	40	39
<b>9</b>	<b>Dankile</b>	12	11
<b>10</b>	<b>Ogaden</b>	-	-
<b>11</b>	<b>Aysha</b>	-	-
<b>12</b>	<b>Mereb</b>	5	3
	<b>Total</b>	<b>560</b>	<b>454</b>

Source: MOWIE (2008)

### **3.2 Sampling Technique**

Stratified sampling is where the population is divided into strata (or subgroups) and a Random sample is taken from each subgroup. A sub group is a natural set of items. Subgroups might be based on company size, gender or occupation (to name but a few). Its purpose is to ensure that every stratum is adequately represented (Ackoff, 1953). We used stratified random sampling, from all the nine sub basins.

First what we did was separate the operational from the established. We managed to get to 454 operational stations out of the total 560 stations. Then to increase the addressability we consider one sub basin as a one stratum; and we selected randomly from all nine strata or sub basins.

### **3.3 Sample Size**

The sample size for collecting quantitative data via telephone was determined by percentage. The sample size was made by assuming that 50% of the individuals included in the study have accurately gathered their data sets. Due to time constraints and the Covid 19 pandemic outbreaks and another major factor is that the ministry wasn't willing to give out phone numbers of the observers. Due to all the above problems, we couldn't surpass 105 individuals or 24% of the observation out of 454 total populations. A good maximum sample size is usually around 10% of the population, as long as this doesn't exceed 1000 observation. Therefore, the researcher believes the sample can explain the total observation.

### **3.4 Data Source**

This study will be based on data collected from different institutions:- National metrology agencies (NMA), ministry of water, irrigation and energy (MOWIE), International Water Management Institute (IWMI), that have their own incentive mechanisms for motivating observers monitoring rivers. Primary and secondary data will be gathered and analyzed in order to identify how indicators of Accuracy vary and the cost effective incentive mechanisms for collecting quality data. Specifically, primary data will be collected to understand:

- ✓ The different types of costs involved in river monitoring activities by the institutions
- ✓ The incentive mechanism used by the two institutions (IWMI and MOWIE) for observers and other actors involved in the process to encourage their participation and to get quality data.
- ✓ Check and recommend whether the probability of getting accuracy under the citizen science method or under the current monitoring method or a hybrid method.

Such data and information will be collected for comparison purpose and identifying the most accurate approach for monitoring accuracy of data collected from rivers. For this purpose:

observers, volunteers, supervisors, para-hydrologist and relevant experts from the institutions mentioned above. Key informants will be selected for interview based on their knowledge and expertise. Interview guiding questions will be used to guide the interview process. However, due to the pandemic, primary data are collected through phone interviews.

Costs related to MOWIE practices for river monitoring should be estimated in order to compare and analyze the costs under citizen science approach. Cost related to citizen science under financial incentives, through various incentive techniques are tested by IWMI. By comparing and analyzing the various approaches, the study will recommend an accurate data technique through cost effective incentive mechanisms for generating reliable data that could be applied across the country. The study will also consider experiences from other countries in order to compare effectiveness of citizen science approach. It is the probability of getting accurate data when varying different variables that internally define accuracy. Which will help us analyze, in choosing the probability of getting accurate data under citizen science or under the current MOWIE practice or a hybrid.

### **3.5 Data collection procedure and Quality Assurance**

The data collection questionnaires were developed in a way that goes in line with the objective the study wants to achieve. The questionnaires were primarily prepared in English and translated to Amharic and then back to English to check its consistency. The plan was to hire people (enumerators) that have experience and that will help throughout the data collection process from the beginning to end, by gathering required information and going to the selected stations in person. Perhaps, giving enumerators, those who are collecting data, two days training on the purpose, procedures and data collection to achieve the goal of collecting valuable and accurate data. But rather, due to the pandemic of Covid19, the researcher has shifted to phone interviews, which were conducted with the aid of a semi-structured questionnaire, which was developed based on the objectives of this study.

Phone numbers of observers of the selected stations, were taken from MOWIE and IWMI. As the ministry doesn't just hand out for the phone numbers of their station observers, it took a long chain of discussion and office bureaucracy up from the minister to the department of hydrology.

Out of the total 12 sub basins of rivers in Ethiopia, phone numbers of selected stations from nine sub basins were taken as the other three sub basins have either political unrest or have

long dry seasons that fluctuates and makes it hard to capture the data from those stations. Other nine stations, where taken from IWMI, one from each sub basins, which where citizen science stations i.e, the observers are citizen scientists that collect data voluntarily and receive incentives which are less than, what the MOWIE is providing for their observers. The questionnaire has been pre-tested in stations which are found in Addis Ababa, and which are both from the MOWIE and IWMI sample stations to check and improve and ensure its clarity. Therefore, all the data collection phone interviews were carried out by researcher.

### **3.6 Data Analysis**

In this study, both descriptive statistics and econometric model is used for the analysis of data collected. Descriptive statistics were used to describe relevant aspects of variables and to provide detailed information about the accuracy of gathered data from stations. The study employs an ordered probit model to analyze the determinants of accuracy in across Ethiopia.

The socio-economic data obtained from the questionnaires which were under taken by phone interviews was cleaned and organized using STATA. The latest STATA version statistical software will be used to run the regression and the resulting output will be interpreted. The collected data is presented in tables and diagrams using different statistical techniques in chapter 4.

### **3.7 Model Specification**

An Ordered Probit Model is a nonlinear regression model specifically designed for polychotomous and ordinal placement of the unobservable dependent variables (Girolami and Rogers, 2005). This study applied the Ordered Probit Model to observe the effect of socio-demographic variables on the probability of the getting accuracy of data collection.

Where,  $Y$  is an ordinal dependent variable (not accurate, less than accurate, neutral, rather accurate and fully accurate) and the  $x$ 's are a vector variables which are assumed to influence the outcome of  $Y$  and which will be enumerated later, and  $\beta$ 's are coefficients. For this study, latest STATA version statistical software will be used to run the regression and the resulting output will be interpreted.

Accuracy is internally defined as a function of the variables;

Accuracy = F {Education level, frequency of visit, Age, expenditure, income, incentive, continuity, and distance from house, training, community recognize.....}

We will be using the Ordered Probit function, where the dependent variables ordinal values that is fully accurate, less than accurate, rather accurate or not at all accurate. The purpose of the model is to estimate the probability that an observations with a particular characteristics will fall in to one of the categories.

In the **Ordered Probit Model**, F is the standard normal cdf, we can generalize the model as expressed as below:

$$P(X \leq Z) = F(Z) = e^z / (1 + e^z)$$

$$P(X \leq Z) = F(\beta_0 + \beta_1 \text{ age} + \beta_2 \text{ sex} + \beta_3 \text{ risk} + \beta_4 \text{ inv't} + \beta_5 \text{ edu} + \beta_6 \text{ freqs} + \beta_7 \text{ dist} + \beta_8 \text{ comrec} + \beta_9 \text{ training} + \beta_{10} \text{ freqo} + \beta_{11} \text{ married} + \beta_{12} \text{ incent} + \beta_{13} \text{ exp})$$

$$P(X \leq Z) = F(\beta_0 + \beta_1 \text{ age} + \beta_2 \text{ sex} + \beta_3 \text{ risk} + \beta_4 \text{ inv't} + \beta_5 \text{ edu} + \beta_6 \text{ freqs} + \beta_7 \text{ dist} + \beta_8 \text{ comrec} + \beta_9 \text{ training} + \beta_{10} \text{ freqo} + \beta_{11} \text{ married} + \beta_{12} \text{ incent} + \beta_{13} \text{ exp})$$

With the full set of normalization in place, the likelihood function for estimation of the model parameters is based on the implied probabilities the implied probabilities,

$$\text{Prob} [y_i = j/x_i] = [F(\mu_j - \beta' x_i) - F(\mu_{j-1} - \beta' x_i)] > 0, j=0,1,\dots,j$$

Let  $y_i^*$  represent an unobservable variable that captures the accuracy of the  $i$ th individual. It can be expressed as a function of a vector of explanatory variables ( $x_i$ ) using the following linear relationship;

$$y_i^* = \alpha_0 + \alpha_1 x_1 + \alpha_2 x_2 + \dots + \alpha_k x_k + \epsilon$$

$$y_i^* = \alpha_i + X\beta + \epsilon_i, y_i = 1 [y_i^* > 0] \text{ where, } \epsilon \sim N(0, 1)$$

$y_i$  may indicate whether person  $i$  is working accurately in period  $t$  or not. Error term  $\epsilon$  it has a symmetric distribution with distribution function  $F(\cdot)$  across individuals and time and independent of all  $x_i$ s. Even in this case the presence of  $\alpha_i$  complicates estimation, both when we treat them as fixed unknown parameters and when we treat them as random error terms. It assumed that  $y_i^*$  is related to the observable variable  $y_i$  as follows:

$y_i = 1$  [not at all accurate] if  $-\infty < y_i^* \leq 1$

$y_i = 2$  [less than accurate] if  $1 \leq y_i^* \leq 2$

$y_i = 3$  [neutral] if  $2 \leq y_i^* \leq 3$

$y_i = 4$  [rather accurate] if  $3 \leq y_i^* \leq 4$

$y_i = 5$  [fully accurate] if  $y_i^* > 4$

Recognising the fact that marginal effects for categorical independent variables are easy to understand and can be made more intuitively meaningful (Williams 2012).

### 3.8 Variable Specification

The determinate of the accuracy of data quality to the demographic and socioeconomic condition of a household. In this study, gender of observer, age, income, expenditure, incentive, distance of station, frequency of observers, frequency of supervisors, distances, marital status and education are the explanatory variables that affect the accuracy of the data collected in nationwide.

**Table 2: Description and Specification of the Explanatory Variables in the Model**

Variable		Definition	Specification
Dependent Variable			
<b>Accuracy</b>		Accuracy of data set collected	An ordinal variable outcome 1=not accurate outcome, 2= less accurate outcome 3=neutral outcome 4 rather Accurate, outcome 5= fully Accurate
<b>Explanatory variables</b>			
<b>1</b>	<b>Sex</b>	Gender of observers	A dummy variable: 1= male; 0 = female
<b>2</b>	<b>Age</b>	Age of observers	Continuous variable: Age in years from birth
<b>3</b>	<b>Mar</b>	Marital status of the observers	A dummy variable: 1=married; 0= not married
<b>4</b>	<b>Edu</b>	Education level of household head	A dummy variable: 0 = able to read and write , 1 =primary education, 2= secondary education, 3= tertiary education
<b>5</b>	<b>FreqO</b>	Frequency of observers	Continuous variable
<b>6</b>	<b>Income</b>	observers annual income	In birr

<b>7</b>	<b>Incentive</b>	Observers annual incentive from MOWIE or IWMI	In birr
<b>8</b>	<b>FreqS</b>	Frequency of supervisors	Continuous variable
<b>9</b>	<b>Training</b>	Number of training received in the past 10 years	Continuous variable
<b>10</b>	<b>Distance</b>	Station distance from observers house	In kilometres
<b>11</b>	<b>Exp</b>	Expenditure of observers related to station, annually	In birr
<b>12</b>	<b>ComRec</b>	Community recognition	A dummy variable: 1= yes recognized ; 0= not recognized
<b>13</b>	<b>Risk</b>	Riskiness of the station from their house.	A dummy variable: 1= yes risky ; 0= not risky
<b>14</b>	<b>CS</b>	Citizen scientists	A dummy variable: 1= yes cs stations; 0= not cs stations

Some of the Variables need some elaboration;

Risk is a variable that considers what obstacles do the observers face while going to the stations. It could be discrimination, harassment, peacefulness, dirty....are among the few problems they be encountering. The researcher wanted to see whether riskiness, affects the accuracy of the data being collected. CS is a dummy variable where; if it CS=1 shows the citizen science stations by IWMI and CS=0 shows the station of the MOWIE.

ComRec is a very important variable which is an intrinsic incentive. It is a dummy variable. It shows whether what they are doing is recognized by the community or not. It is an important push factor to give the observers an acknowledgment of what they are doing by the Community and MOWIE. Exp is expenditure of what the observers spend annually for

stations related expenditures. Training is another important variable that is taken under consideration. How much training did the observers receive in the past ten years?

Distance is the amount of km's it takes them to go back and forth from the stations to their house within a day; during morning and evening trips. Frequency of the observers is a variable to show how many times they go to the station within a day. Frequency of supervisors is a variable that shows how many times the supervisors visit the station and the observers within a year. Incentive is another variable showing how much the observers get paid for stations related observing works yearly while income shows how much they make yearly generally from their normal day to day work.

### **3.9 Accuracy cut-off criteria**

Unobservable variables are quite common in Economics (Krelle, 1997). Many of the phenomenon that we wish to explain are either measured with error or not directly measurable. This includes intelligence, education, management expertise accuracy etc. The modelling strategy we used is upon the specification of a system of equations which specify the relationship between a set of unobservable latent variables and observable endogenous indicators. Unobservable variables that can be represented only through closely related substitutes called "proxies" that can be used as surrogates. There is no direct way to measure accuracy of data collection of a given station. The only way around it is by using proxy. The criteria's we incorporated are using the data book of 15 years data and giving it a scale of 1 to 10. We used six criteria's; the first one was to check whether there exist missing value and give it a rating of one to ten. The second was checking whether it had repeated values and rate it again in a similar way. The third was checking if it had exaggerated peaks. The fourth is to check whether it had suspicious jumps in the base flow data. The fifth is to check whether it exists a suspicious rise in the river flow data set and the sixth is to check whether it exists a suspicious recession and scale all one to ten and after taking the average to label it. We have already obtained four cut of points as follows;

$$y_i = 1 \text{ [not at all accurate] if } 0 < y_i^* \leq 2$$

$$y_i = 2 \text{ [less than accurate] if } 2 \leq y_i^* \leq 4$$

$y_i = 3$  [neutral] if  $4 \leq y_i^* \leq 6$

$y_i = 4$  [rather accurate] if  $6 \leq y_i^* \leq 8$

$y_i = 5$  [fully accurate] if  $y_i^* > 8$

## **CHAPTER FOUR**

### **DATA ANALYSIS AND DISCUSSION**

This Chapter presents the analysis and discussion of data obtained from observers of stations found in the nine sub basin, sample survey. In the descriptive analysis, the study analyzes and discusses the general characteristics of sample of observers taken from stations including incentive, trainings, frequency of visit of both the observes and supervisors characteristics that are expected to affect accuracy of the observers, nation widely. In econometric analysis, Ordered Probit Model results are presented and discussed, the factors/characteristics that affect the accuracy of data's collected by observers.

#### **4.1 Descriptive Analysis**

##### **4.1.1 Socio-Economic and Demographic Characteristics of Households**

This is the demographic characteristics of river gauge observers; such as sex, age, marital status and education level. The River gauge, observers were asked to indicate their, Sex in order to establish how the Demographic characteristics of observers affect level of accuracy. The result indicates in Table 3 below shows, 87.62% of observers are male while, the rest 12.38% of them are female observers. This implies that most of observers engaged in river gauging are dominated by male observers. This might be because, most of rural households in Ethiopian are known to be a male dominated. Being female, is expected to have a negative effect on the accuracy of data collection; as being female has a retrospect of more burden on the female head than the male counterparts.

The age composition of observers, as illustrated in table 3 below, is that 41.9% of the observers are in the age between 29-40 years, while 20%, 29.5% and 8.56% of the observers in the survey are between the age of 17-28 years, 41-52 years and above 53 years, respectively. The age ranges of observers, in the survey taken are between 17 to 60 years of age. This implies that the largest population of the survey are middle-aged, which is a good working age. Age is expected to have a negative relation, to accuracy of data collected by observers. As age increases, the ability of observers to walk to the stations twice a day (morning and evening) and to go in to the rivers to read the gauge will be harder, therefore we expect a negative relation.

The observers were asked about their marital status. The responses of river gauge observers indicate that the majority, about 76.19% of the observers are married, while 23.81% are not married. The results are presented in Table 3 below. Out of the 105 sample survey, 80 observers are married while 25 observers are not married. Observers who are married are seen to be more accurate than observers who are not married. As seen in the, table A.1, observers who are married have larger number of fully accurate and rather accurate observers.

The river gauging observers educational level, is illustrated in table 3 below, has shown that 56% of the observers have a primary level of education while, 22% are secondary level and 14 % are preparatory level educated and 13% are tertiary level educated . Therefore, as the level of education increases it is expected to affect accuracy positively.

**Table 3: Socio-Demographic Characteristics of Observers**

<b>Variables</b>	<b>Percentage</b>	<b>Standard Deviation</b>	<b>Mean</b>
<b>Sex of Observers</b>		0.3309438	0.1238095
Male	87.62%		
Female	12.38%		
<b>Age Category</b>		10.4071	38
17-28	20%		
29-40	41.9%		
41-52	29.5%		
53 years and above	8.56%		
<b>Marital status</b>		0.4279605	0.7619048
Married	76.19%		
Not Married	23.81%		
<b>Educational Category</b>		1.07221	1.847619
Primary	56%		
Secondary	22%		
Preparatory	14%		

Tertiary	13%		
----------	-----	--	--

#### 4.1.2 The Ordered outcome of Accuracy

The survey sample of observers Accuracy were given by considering the six criteria's as explained briefly, in the methodology, to give rate of accuracy of a given observers per each station nation widely, from all the nine sub basins. Their average scores are levelled 1 up to 10 with four cut of points, demarked at two levels of scales. It is highlighted in the table 4 below, 24.76 % of the observers are fully accurate, while 36.19% of the observers are rather accurate and 28.57 % are neutral accuracy and 9.52 % have less than accurate and 0.95% have not accurate .

**Table 4: Ordinal level of accuracy**

Accuracy	Freq.	Percent	Cum.
Not accurate	1	0.95	0.95
Less accurate	10	9.52	10.48
Neutral	30	28.57	39.05
Rather accurate	38	36.19	75.24
Fully accurate	26	24.76	100.00
Total	105	100.00	

As the hydrological data obtained from rivers by observers, is very essential for a country and it should be close to accurate. As we can see in the table 5 below, out of the 16 tested citizen science stations, 10 of them are fully accurate and 5 are rather accurate and 1 is neutrally accurate. We can see from table below that we don't have less accurate and not accurate stations when it is under citizen science. The only differences to the MOWIE stations are the fact the people have intrinsic incentives and the people that are engaged under citizen science have more knowhow of how important it is to accurately fill the books that are handed out for them.

**Table 5: Relationship between Accuracy of MOWIE and IWMI**

Accuracy	cs		Total
	0	1	
Not accurate	1	0	1
Less accurate	10	0	10
Neutral	29	1	30
Rather accurate	33	5	38
Fully accurate	16	10	26
Total	89	16	105

As we can see in table 5, we have chosen 89 MOWIE stations and 16 Citizen Science stations. We have given a dummy of 1 to citizen science stations and 0 to the MOWIE stations in order to see the differences between these two different stations at different levels of accuracy. We can see from table 5 that the citizen science stations have relatively better performance than the MOWIE.

#### 4.1.3 Training of observers

We took training as the number of trainings they received in the past ten years. The more training observers receive, the more fully accurate will be the accuracy of data collection. As training increases, it is important and allows you to strengthen those skills that each observer needs to improve and feel ownership. Therefore, we expect training to have a positive effect on accuracy.

**Table 6: Relationship between Trainings and Accuracy**

Accuracy	Training (1 0 yr.)	
	10	Total
Not accurate	0	1
Less accurate	0	10
Neutral	0	30
Rather accurate	3	38
Fully accurate	10	26
Total	13	105

#### 4.1.4 Distance of observers house to Station

On the station distance, the observers were asked how far the station is from their homes. As clearly showed in table 7, 67.62% of the observers head indicates that the river station is 1-4 km far from their house, 27.62% of observers were 5-8 km far from their houses, the rest 3.8 % and 0.96% of the observers are 9-12 km and 13-16 km respectively, away from distance from the River stations to their houses. This implies that most of the observers are 1-4 km distance from the River stations. This also means, the majority of the River observers in Ethiopia, live close to the river gauging stations. This shows a low chance of missing out to fill the station data books by observers in turn affecting, the accuracy of data collection positively. Therefore, distance is expected to have a negative sign; as distance increases it decreases accuracy because it will be highly unlikely for the observers to fill out the forms always either twice a day (morning and evening) or every day.

**Table 7: River gauging stations distance from house to stations**

	Percentage	Mean	Standard Deviation
Distance in Kilometres (km)		3.928571	2.632479
1-4 km	67.62%		
5-8 km	27.62%		
9-12 km	3.8%		
13-16 km	0.96%		

## **4.2 Econometric Analysis**

In this section, the study presents the results of econometric analysis. In the econometric analysis, socio-economic and demographic variables are included to explain the unobservable dependent variable. As described in the methodology part, to examine factors that determine and affect the accuracy of the River data collected by observers. Ordered Probit mode is used in this study. The results of the Ordered Probit Regression and the marginal effects of the outcome 5(fully accurate) are both presented, in different tables below. We will be looking at the marginal effects of the all Ordered Probit outcomes, in table 9. As mentioned in the methodology section, 105 observers were used in the regression. As the result shows sex, age, education level, risky, incentive, income, distances, frequency of supervisors and community recognition have significant influence towards adopting the accurate method of data collection in all the nine sub basins, in Ethiopia.

**Table 8: Results of the Ordered Probit Regression and the Marginal effects**

<b>Variables</b>	<b>Coefficient of Probit</b>	<b>Marginal effects for Fully accurate</b>
<b>Age</b>	-0.0158** (0.014)	-0.004** (0.003)
<b>Frequency of Observation</b>	0 (omitted)	0 (omitted)
<b>Frequency of Supervisors</b>	0.291** (0.025)	0.083** (0.035)
<b>Sex</b>	-0.537** (0.040)	-0.122** (0.063)
<b>Married</b>	0.296** (0.257)	0.076** (0.785)
<b>Incentive</b>	0.007** (0.034)	0.002** (0.011)
<b>Training10yr</b>	0.169** (0.019)	0.046** (0.033)
<b>IncomeM</b>	-0.001** (1.040)	-0.286** (1.070)
<b>Secondary</b>	0.071** (0.069)	0.016** (0.071)
<b>Preparatory</b>	0.560** (0.365)	0.162** (0.118)
<b>Tertiary</b>	0.969** (0.152)	0.317** (0.169)
<b>Expen</b>	-0.247 (0.021)	-0.681** (0.061)

<b>DistanceKm</b>	-0.007** (0.045)	-0.002** (0.012)
<b>Has_recognition</b>	0.077** (0.063)	0.020** (0.020)
<b>Risk</b>	-0.41** (0.048)	-0.102** (0.063)

**N.B: \*\* are coefficients and (.) standard deviation**

As Indicated in Table 8, age of observers has a negative effect on the probability of getting fully accurate of data collection. It is statistically significant. When the age of observers increases by one year; the probability of getting fully accurate data collection will decrease by 0.4%. It can be concluded that the younger the observers age is the better than older age observers in collecting accurate data in all the nine sub basins.

The sex of observers has a negative effect on the probability of getting fully accurate of data collected from all the nine sub basins. It shows female observers are 12.2% less likely to work fully accurately compared to male observers. It is also statistically significant. This indicates female observers, in the nine sub basins have a lot of burden at hand, which makes them to miss out filling the books always compared to the male observers. This clearly shows the gender inequity and burden on women compared to men in rural Ethiopian. We have seen in the interview that only 12.38 % are women which is a relatively a small compared to men. This is due to women have a lot of burden in rural areas and they are not encouraged to get involved in any kind of sector.

Marital Status of the observers is also one of the determinants of observer's accuracy of data collection nationwide. According to the result, being a married observer has a positive effect on the accuracy of data collection. This shows that being married increases fully accuracy by 7.6% compared to the not married individuals. However, the result is not statistically significant.

The education levels of the observers from all the nine basins have a positive effect on the accurate data collection. Our bench mark is primary education. The observers with secondary education has a 1.6% more chance of collecting data fully accurately than with the

primary educated observers. It is statistically significant. The observers with preparatory education have 16.2% more chance of collecting fully accurate data than that of the primary educated observers and it is statically not significant. In addition, the observers with tertiary level of education have 31.7% more chances of collecting fully accurate data than that of the primary educated observers. It is not statistically significant. This suggests that the more Rivers gauging observers get more education they might be more likely to be exposed to more information such as how important it is to collect data accurately however, it doesn't show that it has any effect on increasing accuracy being in preparatory or tertiary level of education in relative to the primary level of education. Only secondary level of education shows that it has the probability of increasing accuracy of data collection by gauge station observers with a statically significant variable.

The distance of the observer's home to the River stations has a negative sign. When the Observers house distance from the stations increase by one km it affects the probability of getting fully accurate data decreases by 0.2%. It is statistically significant. This is due to the longer the distance of the station from their houses it decreases commitment, hence affects accuracy of data collection.

The observer's annual income has a negative impact of the accuracy of data collection in all the nine sub basins. It has a negative sign which means with more annual income is more likely to decrease accuracy. The variable is statistically significant. It shows annual income of observers increase by one; the probability of getting fully accurate data decreases. This is due to as their incomes increase they will reluctant to work this job, since the payment from this work is relatively smaller. Hence, as income increases by one unit the probability of getting fully accurate data decrease by 28.6%.

The observer's incentive which they are receiving from both institutes is found to be one of the influential factors which are affecting the accuracy of collecting quality data. Incentive has a positive sign thus, the increases in incentive also increases accuracy of the data collection. As incentive, increases by one unit the probability of getting fully accurate data increases by 0.2%. It is statistically significant. Therefore, now we know incentive has a positive impact on accuracy of data collection, but it has a very small impact. This implies that financial incentive have positive but little effect on the accuracy of data collection. The difference between the financial incentives in both institutions (IWMI and MOWIE) is that under MOWIE, they get paid a constant of 7,200 ETB annually without knowing of how

important it is for them to fill out the books accurately for both the ministry and Country. While, under citizen science (IWMI) observers get paid less than what the ministry pays observers but the accuracy of data collected under citizen is relatively more accurate compared to MOWIE stations. This is because, under citizen science it works on the close follow-up of what they are doing by their supervisors (Para-Hydrologists) and on hand-trainings and capacity building of what they are doing and how important it is for the country, so they feel ownership and work responsible with full accuracy as volunteers but not for the money sake. Thus, this shows that incentive has a little impact on the accuracy of data collection.

Community recognition is another important variable that affects the probability of getting fully accuracy of data collection positively. As most of the observers are farmers living in rural areas community recognition is an important factor it plays a huge role. Thus, when there is community recognition the probability of getting fully accurate data increases by 2%. Hence, community recognition enhances accuracy of data collection by observers. This is an intrinsic incentive and it is statistically significant.

Another important variable is training given to the observers in the past ten years, in the methodology part (Chapter three) was taken under consideration. It was expected that as the number of trainings they got in the past ten years increase the probability of getting accurate data collection will increase. As the number of trainings increase in the past ten years the probability of getting fully accurate data increase by 4.6%. The number of trainings received from MOWIE does not exceed four times and some station not even once, from all the observations that are taken as a sample in the phone interview but under citizen science every observer got 10 times training in the past ten years, meaning they have received trainings every year. The variable is statistically significant.

Frequency of observers was omitted from the regression because all observers went twice a day in morning 6:00 AM and evening 6:00 PM. Since the variable is constant from the overall observation in the sample it automatically omits the variable. But the right question to still ask is, do they really go twice a day and fill the books trustworthily? Or do they just fill out the journal books from their houses without going to the stations.

Frequency of supervisors is another important variable, as explained in the methodology part frequency of supervisors was taken on a yearly basis. As frequency of supervisors increases the probability of getting fully accurate data increases by 8.3%. Under MOWIE the

supervisors only visit either 4 or 3 or 2 times on a yearly basis, just to give the journal books and payments of the observers but under citizen science the supervisors (para-hydrologists) visit twelve times a year, or every month. The para-hydrologists are people who follow up the observers monthly and change journal books for them. Therefore, this close follow in turn increases accuracy of data collected. This variable is statistically significant.

Expenditure is another variable affecting the probability of getting fully accurate data collection negatively. Expenditure is the amount of money that the observers spend annually based for the purpose gauging related purposes from themselves, as this are not given to them from the ministry. They spend money on such as; raincoats, umbrella, safety boots etc..... As expenditure, increases a unit the probability of getting fully accurate data collection decreases by 68.1%. The variable is statistically significant.

Riskiness on the road from the house of the observer to the station is expected to have a negative impact on the probability of getting fully accurate data collection. Riskiness is a question of what obstacles they encounter while going to the gauging stations. It is a question of how risky is the road? What they encounter on the road; whether it is clean, peaceful, harassment. When there is Riskiness of one of a kind the probability of getting fully accurate data decreases by 10.2%. The variable is statistically significant. Thus, the accuracy depends on the condition of the road from home to the gauging station.

**Table 9: Marginal effects of different outcomes**

<b>Variables affecting Accuracy</b>	<b>Marginal effects of “Fully Accurate”</b>	<b>Marginal effects of “Rather Accurate”</b>	<b>Marginal effects of “Neutral”</b>	<b>Marginal effects of “Less Accurate”</b>	<b>Marginal effects of “Not Accurate”</b>
<b>Age</b>	-0.004** (0.003)	-0.001** (0.001)	0.004** (0.003)	0.001** (0.001)	0.0001** (0.001)
<b>Frequency of Observers</b>	0 (omitted)	(omitted)	0 (omitted)	0 (omitted)	0 (omitted)
<b>Frequency of Supervisors</b>	0.083** (0.035)	0.025** (0.017)	-0.077** (0.035)	-0.027** (0.014)	-0.001** (0.001)
<b>Female</b>	-0.122** (0.063)	-0.084** (0.076)	0.132** (0.076)	0.069** (0.058)	0.004** (0.007)
<b>Married</b>	0.076** (0.785)	0.034** (0.053)	-0.077** (0.092)	-0.031** (0.043)	-0.001** (0.003)
<b>Incentive</b>	0.002** (0.011)	0.007** (0.004)	-0.002** (0.009)	-0.007** (0.003)	-0.330** (4.77)
<b>Training10yr</b>	0.046** (0.033)	0.014** (0.012)	-0.044** (0.032)	-0.016** (0.011)	-0.007** (0.001)
<b>IncomeM</b>	-0.286** (1.070)	-0.918** (1.70)	0.275** (1.13)	0.984** (1.92)	0.431** (1.64)
<b>Secondary</b>	0.016** (0.071)	0.010** (0.044)	-0.018** (0.077)	-0.008** (0.036)	-0.004** (0.002)
<b>Preparatory</b>	0.162** (0.118)	0.032** (0.032)	-0.144** (0.092)	-0.048** (-0.028)	-0.002** (0.003)
<b>Tertiary</b>	0.317**	0.021**	-0.231**	-0.062**	-0.002**

	(0.169)	(0.084)	(-0.091)	(-0.028)	(0.003)
<b>Expen</b>	-0.681** (0.061)	-0.219** (0.001)	0.655** (0.001)	0.235** (0.001)	0.103** (1.77)
<b>DistanceKm</b>	-0.002** (0.012)	-0.006** (0.004)	0.002** (0.012)	0.007** (0.004)	0.003** (0.001)
<b>Has recognition</b>	0.020** (0.020)	0.007** (0.052)	-0.020** (0.120)	-0.007** (0.049)	-0.003** (0.002)
<b>Risk</b>	-0.102** (0.063)	-0.053** (0.054)	0.106** (0.074)	0.047** (0.042)	0.002** (0.004)

As indicated in above table 9, we will now see interpretation of all five outcomes. The marginal probabilities of the Ordered Probit Model are interpreted as the relationship of each predictor, X, to the probability that an observer will be in each category of accuracy level or above compared to all the lower. We have only interpreted the first two from the table as we have interpreted the fully accurate ones in table 8.

When the age of observers increases by one year; it is 0.4% less likely to fully accurate data collection. When the age of observers increases by one year; it is 0.1% less likely to be in rather accurate data collection. When the age of observers increases by one year; it is 0.4% more likely to be getting neutral accuracy data collection. When the age of observers increases by one year; it is 0.1% more likely to be in less than accurate data collection. When the age of observers increases by one year; it is 0.01% more likely to be in not accurate data level of data collection. Therefore, we can conclude that higher age leads to lower accuracy of data collection.

When the frequency of supervisors increases it is 8.3% more likely to be fully accurate data collection. When the frequency of supervisors increases it is 2.5% to be more likely to rather accurate data collection. When the frequency of supervisors increases it is 7.7% less likely to neutral level of data collection. When the frequency of supervisors increases it is 2.7% less likely to less accurate level of data collection. When the frequency of supervisors increases it is 0.01% less likely to not accurate level of data collection. This shows, as more increases frequency of supervisors leads to more fully accurate level of data collection.

**Table 10: of predicted probability of the oprobit**

```
. sum p1oprobit p2oprobit p3oprobit p4oprobit p5oprobit
```

Variable	Obs	Mean	Std. Dev.	Min	Max
p1oprobit	105	.0086848	.0197829	3.89e-10	.1595467
p2oprobit	105	.0933398	.0990915	8.04e-07	.4794264
p3oprobit	105	.2916193	.1413589	.0001875	.4651242
p4oprobit	105	.3639832	.130526	.0114739	.4803846
p5oprobit	105	.2423728	.2485844	.0019582	.9883378

We can see with the from table A2, that it's not that different from the tabulated level of accuracy.

## CHAPTER FIVE

### CONCLUSION AND POLICY RECOMMENDATION

#### 5.1 Conclusion

Ethiopia is known for its huge water resources. The main forms of resources are rivers and lakes. There are 12 major river basins in the country. The total annual surface run off from these basins is about 110 billion m<sup>3</sup>. The Hydrological Department under the Ministry of Water Resources is responsible for hydrological data collection, processing analysis and dissemination to users. MOWIE is the institution with the mandate to collect hydrological data. This institute is challenged by different constraints to deliver reliable and accurate hydrological data. The hydrological data gaps are linked to different factors. But mainly it is due to limited capacities of this institute to control and manage the hydrological data accuracy collected by observers.

As we have seen in the econometric analysis in chapter 4, financial incentives have positive impact but the impact it has is little about 0.2% to bring it in to the category of fully accurate level of data collection. And when we come to community recognition which is an intrinsic incentive, it has the probability of 2% effect that the observers will get to the category of fully accurate level of data collection. We can see that intrinsic incentives have more impact to get the observers in to fully accurate level of data collection than that of the financial incentives.

The MOWIE existing stations are not rehabilitated the, many of the observers that I have interviewed have told me that the stations are either taken by flooding or the stations need to be fixed. As the observers have explained they have already told the ministry on lots of occasions but still do not get immediate response on time. Therefore, till they get further notice they use normal meters to estimated and fill the ledger books. Which usually under or over estimates, the values and which in turn is usually far from being accurate.

Another important problem seen was that, the supervisors visiting the observers from MOWIE they barely go 4 or less times on a yearly basis. The observers have told me that they even barely go out of the car to check the condition of the station or to compliment on what the observers have been doing. According to MOWIE, they have stated that the supervisor go 4 times a year or once in three month and give them a new ledger book and

take the existing ones; which they have been gathering data and filling in the past three months. One ledger book only has a line to record only for three month i.e morning and evening based. But the supervisors don't go every three month except for few stations which leads the observers to buy normal exercise books and fill out the recording, which usually is inflated or not readable for the people in the ministry who are in charge of encoding the data digitally to computers. And other observers, in some stations they just wait for the supervisors till they come these hence leads a huge data gaps. This is very catastrophic problem with in the ministry.

Another major problem is that the fact that they don't receive frequent trainings and the fact that they don't have community recognition has affected their level of accurate data collection performance. Expenditure has also brought a negative impact; since they are getting paid small amount of salary or incentive by both institutes even less by the citizen science, they are not willing to spend money on station related expenditures.

Another major problem is that there is an intense problem of communication between the BDA and MOWIE. The national data faces a huge deal of risk; it is not stored under MOWIE's data base.

## 5.2 Recommendation

The study findings are important to implicate policies recommendation for the accurate level of data collection in Ethiopia, nation widely. Hence this study draws the following policy implication to enhance accurate data collection in the country.

Citizen science has great potential as a tool for environmental monitoring. Volunteers already make a valuable contribution by monitoring various environmental attributes, thus increasing the use of citizen science. We can learn a lot as a country and an institute from IWMI, as they have implemented citizen science method. Using the community who are living around there as scientists and empowering them into feeling they have ownership and they are doing something for their country is a huge deal. This is a positive pushing factor for them to work more accurately. We have also seen what the observers are receiving as incentives from the citizen science is relatively smaller; therefore this method is also cost effective.

Whenever, the ministry gets a notice that the station is broken or there is a problem, they need to fix it as soon as possible. Therefore, the values won't be inflated by the observers whenever they fill out the ledgers with measuring by meters and estimating it.

The problems of frequency of supervisors should be modified to the citizen science approach because this approach has shown to be very satisfying and helpful. The citizen science method by IWMI has shown to have relatively fully accurate data collection methods; i.e no data gaps, no missing values in the books; that fulfil all the six criteria. They have their own para-hydrologists, people working around there at woreda level, who work as supervisors. The para-hydrologists are supervisors who are in charge of looking after the observer's performances and data collection process, they handout ledger recording books every three month and give them backup recording books as well in case something happens to the para-hydrologists. They are also in charge of looking after the station; in case there is some problems within the station as the observers inform them the para-hydrologists are in charge of fixing it. In case, it is more than what they can do they will automatic report to their heads that will fix for them as soon as possible. They normally check upon what the observer's works on every month. The fact that they are living and working around the station makes it less costly for them to visit more frequently unlike the MOWIE who is sending supervisors to check on the observers from far away which, in turn decrease commitment level of the supervisors.

Another recommendation that I would like to give is that for a country, like Ethiopia that is called the water tower of East Africa the number of existing operational stations are relatively small. New stations should be built to broaden the scope.

The observers who are engaged in this work need to be given certain kinds of safety clothing's from the institutes that will in turn reduce the amount of expenditure they are spending for station related expenditure. As we have seen in chapter 4, expenditure has a negative effect on fully accuracy level of data collection. Therefore, institutes should be able to provide them with uniform (that can differentiate them from the rest of the people in the community), raincoats, umbrella, safety boots, extra ledger books, pens, shovel and meters in case. These whole costs shouldn't be out of the observer's pocket. As a country seeing how these data accuracy is important spending on these aspects should be encouraged from both institutes.

Trainings should be given more often; as we have seen in the analysis part of chapter 4, that training has relatively positive effect on accuracy. We have also seen in table 5, the interaction of being accurate to trainings. We have seen the more training was given to them the more they got to outcome 5 or fully accurate. IWMI or citizen science approach gives training to them every year and on top on that the monthly visit from the para-hydrologists are always on hand every month they come to visit them. Trainings are relatively less than once in two years when it comes to majority of MOWIE station.

Empowering the community is another essential factor that affects the collection of data quality. The observers are seeking for recognition by MOWIE, than just contractual workers because many of them worked for more than 10 or more years. Who ask for acknowledgment by the ministry as a full time river gauging workers? We have also seen that community recognition has a positive effect on accuracy as it encourages them to work better and better by the day to make their community proud.

Every data collected should be under one data base nation widely. The BDA should create that platform and submit recording to MOWIE.

## **REFERENCES**

Araya M and Woldehanna T, (2017). Early Investment in Preschool and Completion of Secondary Education in Ethiopia.

Berhanu, B. Seleshi, and Y. Melesse, A.M. 2014. Surface water and groundwater resources of Ethiopia: Potentials and challenges of water resources development. In: Nile River Basin, (eds.) Melesse, A. Abteu, W. Setegn, S. Springer, Cham. pp. 97-117.

Beza, E. Steinke, J. van Etten, J. Reidsma, P. Fadda, C. Mittra, S. Mathur, and P. Kooistra 2017. What are the prospects for citizen science in agriculture? Evidence from three continents on motivation and mobile telephone use of resource-poor farmers.

Buytaert, W.; Zulkafli, Z.; Grainger, S.; Acosta, L.; Alemie, T.C.; Bastiaensen, J.; De Bièvre, B.; Bhusal, J.; Clark, J.; Dewulf, A.; Foggin, M.; Hannah, D.M.; Hergarten, C.; Isaeva, A.; Karpouzoglou, T.; Pandeya, B.; Paudel, D.; Sharma, K.; Steenhuis, T.; Tilahun, S.; Van Hecken, J.; Zhumanova, M. 2014. Citizen science in hydrology and water resources: Opportunities for knowledge generation, ecosystem service management, and sustainable development.

Buytaert,. Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development.

Cadilhon, J-J. 2013. A conceptual framework to evaluate the impact of innovation platforms on agrifood value chains development. Paper prepared for the 138th EAAE Seminar on Pro-poor Innovations in Food Supply Chains, Ghent, Belgium, September 11-13, 2013.

Carlson, T.; Cohen, A. 2018. Linking community-based monitoring to water policy: Perceptions of citizen scientists. *Journal of Environmental Management* 219: 168-177

Chambers, R. 1994a. Participatory rural appraisal (PRA): Challenges, potentials and paradigm. *World Development* 22(10): 1437-1454. [https://doi.org/10.1016/0305-750X\(94\)90030-2](https://doi.org/10.1016/0305-750X(94)90030-2)

Chambers, R. 1994b. The origins and practice of participatory rural appraisal. *World Development* 22(7): 953-969. [https://doi.org/10.1016/0305-750X\(94\)90141-4](https://doi.org/10.1016/0305-750X(94)90141-4)

Chambers, R. 2008. *Revolutions in development inquiry*. London, UK: Earthscan. 245p.

Chemin, Y.; Desalegn, M.; Curnow, J.; Johnston, R. 2015. Water dynamics in Fogera and the Upper Blue Nile - Farmers perspectives and remote sensing. *Geophysical Research Abstracts* 17, EGU2015-4786.

Conrad, C. and Hilchey, K. (2010). A review of citizen science and community-based environmental monitoring: issues and opportunities. *Environmental Monitoring and Assessment*.

Cunha, D.G.F.; Marques, J.F.; de Resende, J.C.; de Falco, P.B.; de Souza, C.M.; Loiselle, S.A. 2017. Citizen science participation in research in the environmental sciences: Key factors related to projects' success and longevity. *Anais da Academia Brasileira de Ciências* 89(3): 2229-2245. <https://doi.org/10.1590/0001-3765201720160548>

Danielsen, F.; Burgess, N.D.; Balmford, A. 2005. Monitoring matters: Examining the potential of locally-based approaches. *Biodiversity and Conservation* 14(11): 2507-2542. <https://doi.org/10.1007/s10531-005-8375-0>

Danielsen, F.; Burgess, N.D.; Jensen, P.M.; Pirhofer-Walzl, K. 2010. Environmental monitoring: The scale and speed of implementation varies according to the degree of people's involvement. *Journal of Applied Ecology* 47(6): 1166-1168. <https://doi.org/10.1111/j.1365-2664.2010.01874.x>

Dessalegn, M. 2013. Wild coffee conservation by participatory forest management: Bio-cultural investigation of the coffee forest and associated communities in South West Ethiopia. Amsterdam, the Netherlands: Sustainable Livelihood Action.

Federal Democratic Republic of Ethiopia (2015) The Second Growth and Transformation Plan(GTPII)(2015/16-2019/20).Addis Ababa: Government Press.

Fishbein, M. & Ajzen, I. (1975). *Belief, attitude, intention, and behavior: An introduction to theory and research*. Reading, MA: Addison-Wesley

Geoghegan, H.; Dyke, A.; Pateman, R.; West, S.; Everett, G. 2016. Understanding motivations for citizen science. Final report on behalf of the UK Environmental Observation Framework (UKEOF). Reading, UK: University of Reading; York, UK: Stockholm Environment Institute (University of York); Bristol, UK: University of the West of England.

GIZ Ethiopia. 2015. Lessons and experiences in sustainable land management. Bonn and Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).

Green, W.H, (1997). *Econometric Analysis*. New York, Macmillan Publishing Company.

Haile, A.T.; Akawka, A.L.; Berhanu, B.; Rientjes, T. 2017. Changes in water availability in the Upper Blue Nile basin under the representative concentration pathways scenario. *Hydrological Sciences Journal* 62(13): 2139-2149.

Haile, A.T.; Gowing, J.; Parkin, G. 2019. Scope of citizen science for hydrologic monitoring in small watersheds in Ethiopia. Chapter 34 in *Extreme hydrology and climate variability: Monitoring, modelling, adaptation, and mitigation*, (eds.) Melesse, A.M.; Abtew, W.; Senay, G. Elsevier. pp. 435-444.

Haklay M. Citizen science and volunteered geographic information – overview and typology of participation. In: Sui DZ, Elwood S, Goodchild MF, eds. *Volunteered Geographic Information, Public Participation, and Crowdsourced Production of Geographic Knowledge*. Berlin, Germany: Springer; 2012.

Kemper, K.E. 2007. Instruments and institutions for groundwater management. In: *The agricultural groundwater revolution: Opportunities and threats to development*, (eds.) Giodarno, M.; Villholth, K.G. Wallingford, UK: CABI. pp.153-172. (Comprehensive Assessment of Water Management in Agriculture Series 3).

Lakshminarayanan, S. 2007. Using citizens to do science versus citizens as scientists. *Ecology and Society* 12(2)

Lemma, M.; Getachew, A. 2018. Consultative workshop on national framework on climate services in Ethiopia, Capital Hotel, Addis Ababa, Ethiopia, April 26-27, 2018. Addis Ababa, Ethiopia: National Meteorology Agency.

Lowry, C.S.; Fienen, M.N. 2013. CrowdHydrology: Crowdsourcing hydrologic data and engaging citizen scientists. *Groundwater* 51(1): 151-156. MoWR (Ministry of Water Resources). 1999. *Ethiopian water resources management policy*. Addis Ababa, Ethiopia: Ministry of Water Resources.

National Planning Commission. 2016. *Growth and Transformation Plan II (GTP II) (2015/16-2019/20)*. Addis Ababa, Ethiopia: National Planning Commission.

Negash, F. 2012. Managing water for inclusive and sustainable growth in Ethiopia: Key challenges and priorities. European Report on Development. Addis Ababa, Ethiopia: Ministry of Water and Energy.

Nigussie, L.; Barron, J.; Haile, A.T.; Lefore, N.; Gowing, J. 2018. Gender dimensions of community-based groundwater governance in Ethiopia: Using citizen science as an entry point. Colombo, Sri Lanka: International Water Management Institute (IWMI). 24p. (IWMI Working Paper 184). Available at <https://www.iwmi.cgiar.org/publications/iwmi-working-papers/iwmi-working-paper-184/> (accessed on April 24, 2020).

Nigussie, L; Haile, A. T; Gowing, J. (2019) Citizen science in community-based watershed management:an institutional analysis in Ethiopia.unpublished

Ormel et al. Human Resources for Health, (2019) Salaried and voluntary community health workers: exploring how incentives and expectation gaps influence motivation.

Osborne, D (2019) viability of sustainable community-led hydrological monitoring for hydro geological understanding and water management in less economically developed countries.

Roy, H.E.; Peacock, M.J.O.; Preston, C.D.; Roy, D.B.; Savage, J.; Tweddle, J.C.; Robinson, L.D. 2012. Understanding citizen science and environmental monitoring. Final report on behalf of UK Environmental Observation Framework. Lancaster, UK: National Environment Research Council (NERC) Centre for Ecology and Hydrology; London, UK: Natural History Museum.

Turrini, T.; Dörler, D.; Richter, A.; Heigl, F.; Bonn, A. 2018. The threefold potential of environmental citizen science - Generating knowledge, creating learning opportunities and enabling civic participation. *Biological Conservation* 225: 176-186.

Vann-Sander, S.; Clifton, J.; Harvey, E. 2016. Can citizen science work? Perceptions of the role and utility of citizen science in a marine policy and management context. *Marine Policy* 72: 82-93.

Walker, D.; Forsythe, N.; Parkin, G.; Gowing, J. 2016. Filling the observational void: Scientific value and quantitative validation of hydrometeorological data from a community-based monitoring programme. *Journal of Hydrology* 538: 713-725.

Walker, D.; Haile, A.T.; Gowing, J.; Forsythe, N.; Parkin, G. 2019. Guideline: Selection, training and managing para-hydrologists. Oxford, UK: University of Oxford. REACH Program. 31p. (REACH Working Paper 6).

Woolley, J.P.; McGowan, M.L.; Teare, H.J.A.; Coathup, V.; Fishman, J.R.; Settersten Jr., R.A.; Sterckx, S.; Kaye, J.; Juengst, E.T. 2016. Citizen science or scientific citizenship? Disentangling the uses of public engagement rhetoric in national research initiatives. *BMC Medical Ethics* 17(33).

Zemadim, B.; McCartney, M.; Langan, S.; Sharma, B. 2013. A participatory approach for hydrometeorological monitoring in the Blue Nile River Basin of Ethiopia. Colombo, Sri Lanka: International Water Management Institute (IWMI). 32p. (IWMI Research Report 155). Available at <https://www.iwmi.cgiar.org/publications/iwmi-research-reports/iwmi-research-report-155/> (accessed on April 24, 2020).

Zemadim,B.(2013) A participatory approach for hydro-meteorological monitoring in the blue Nile river basin of Ethiopia.

## APPENDIX

**Table A.1: Accuracy of married and not married observers**

Accuracy	Marital		Total
	Not Marri	Married	
Not accurate	0	1	1
Less accurate	4	6	10
Neutral	3	27	30
Rather accurate	7	31	38
Fully accurate	11	15	26
Total	25	80	105

---

**Table A.2: tabulated level of accuracy**

. tab acc

Accuracy	Freq.	Percent	Cum.
Not accurate	1	0.95	0.95
Less accurate	10	9.52	10.48
Neutral	30	28.57	39.05
Rather accurate	38	36.19	75.24
Fully accurate	26	24.76	100.00
Total	105	100.00	

## INTERVIEW QUESTIONS IN ENGLISH

A survey evaluating the existing river gauging stations by MoWIE and IWMI to determine and recommend what technique will enhance the accuracy of the data collected by observers. Information to be collected from each station during field visit is as follows;

### 1) Talk to the observer to evaluate/ background information

- Name of observer?
- Age and sex of observer?
- Education level of the observer?
- When did the observer start data collection (Month and Year)?
- What trainings did the observer received? At what frequency? When was the last training? Who provided the training?
- How far the observer lives from the gauging station?
- How is the monitoring system around Akaki station so far?
- What is the monitoring process?
- Frequency of supervisor's visit
  - ❖ What is done by the supervisor when visiting the site?
  - ❖ How many times per year does the supervisor visit?
  - ❖ Do you receive any feedback on the data quality
  - ❖ What does the observer suggest improving the supervision quality?
- Does he inform MOWIE if something went wrong at the gauging site?  
Using what communication line? Do they respond urgently?
- How many times per day do you visit the site? Does it interfere with your work?
- How well are peak flows captured by the specified observation time (twice per day at 6:00 Am and 6:00 PM)? At what time of the data does peak flows usually occur?
- Are you fully employed as a river gauge monitor?
  - ❖ Timeliness
  - ❖ Amount
- When is the recent data on which the observer received salary?
- When was the recent salary payment you received?
- Do you receive the payment on time? If delayed, how long? And is it often delayed?

2) Explore the various incentive mechanisms used for observers monitoring rivers mechanisms based

- Any additional incentives in the past in addition to salary? If so, when is the last time you received such incentive? In what kind did you receive it?
- Do you believe if incentives were provided, would it improve the river gauge monitoring process?
- What does MOWIE think about giving incentives to observers in order to encourage them in doing their job appropriately?

3) Identify opportunities and constraints at MOWIE for adopting a particular incentive mechanism for observers. For eg. Explore the various opportunities and constraints at MOWIE to adopt accurate and reliable incentive mechanism for observers monitoring river?

- Are there any factors that interfered with data collection in the past? Ask the observer to elaborate this?
- What does MOWIE think about giving them opportunities or a platform in which they get more trainings or job creation for observers?
- When is the longest period in which recording was interrupted? Why was it interrupted?
- Do you believe there is a problem in the river monitoring system? If so where do you think is the root cause? What should be improved by MOWIE?
- What are the constraints for adopting particular incentive mechanisms?
- Is MOWIE aware of lack of continuity of data or data gap? If so, anything done to improve it?
- What is the view of MOWIE on the whole river gauge monitoring? Where do they think is the problem? What do they intend to improve?
- What are the major costs you incur in the river gauge monitoring process? Can we get the list of costs per station or nationwide?

4) Evaluate the implication of scaling up and main streaming citizen science across Ethiopia?

- What would be the response of MOWIE in scaling up citizen science method at least to some stations or all if it has shown to be effective in bringing accurate data and improve the river gauge monitoring process in general?

- What steps would it take within the institution to change the current process?

5) Cost-benefit analysis technique through citizen science approach in relative to the traditional method at MOWIE?

- What does MOWIE think about training and empowering citizen scientists? As observers, supervisors, encoders etc...Based on their level of engagement, which seems to be cheaper than employing experts?
- What would be the view of MOWIE on data accuracy even if it turns out to be costly?

## INTERVIEW QUESTIONS IN AMHARIC

1 ስም \_\_\_\_\_

2 ምሥራቅ \_\_\_\_\_

3 እድሜ \_\_\_\_\_

4 የትምህርት ደረጃ \_\_\_\_\_

የግብ/ች \_\_\_\_\_

የላግብ/ች \_\_\_\_\_

5 ተቆጣጣሪው ለመጨረሻ ጊዜ የመጣው መቼ ነው? \_\_\_\_\_

6 ተቆጣጣሪው ለመጨረሻ ጊዜ ከመምጣቱ በፊት የመጣው መቼ ነበር? \_\_\_\_\_

7 የማህበረሰብ እውቅና አላችሁ? \_\_\_\_\_ ማህበረሰብ የሚሰሩትን ያውቃል ወይ? \_\_\_\_\_

አዎ \_\_\_\_\_

አይ \_\_\_\_\_

8 በዚህ አስር ዓመት ውስጥ ስንት ጊዜ እርስዎ እና ቤተሰብዎ ስልጠና አግኝተዋል?

\_\_\_\_\_

9 ጠዋት ከቤቶ እስከ እስቴሽን/ መቆጣጠሪያ ደርሶ መልስ ስንት ሰዓት ይፈጃል?

\_\_\_\_\_

10 የትምህርት ደረጃ \_\_\_\_\_

11 ምን ዓይነት መሰናክሎች ያጋጥሟል

ጥቃት \_\_\_\_\_

ቆሻሻ \_\_\_\_\_

ስላማዊ \_\_\_\_\_

12 በዚህ ስራ ላይ ለስንት ዓመታት ሠርተዋል? \_\_\_\_\_

13 በዚህ ስራ ላይ የተቀጠሩት መቼ ነበር? \_\_\_\_\_

14 በዚህ ስራ ላይ እንደ ሙሉ ጊዜ ሰራተኛ ነው የተቀጠሩት ወይስ እንደ ትርፍ ጊዜ ስራ

\_\_\_\_\_

15 አይ ከሆነ መልስዎ፣ ከዋና ስራዎ ጋር ይጋጫል ወይ? \_\_\_\_\_

16 ከእርስዎ በተጨማሪ ከቤተሰብ ውስጥ ይህንን ስራ የሚሠሩ የቤተሰብ አባል አለ ወይ? \_\_\_\_\_

17 ለምን ያህል ጊዜ ነው ይህ የምዝገባ ስራ ተቋርጦ የሚያወቀው ምክያቱስ ምን ነበር?

18 ክፍያዎን በትክክለኛ ስዓት ይረከባሉ ? \_\_\_\_\_

- አይ ከሆነ መልሱ ለምን ያህል ጊዜ ቆይቶ ይስጠታል? \_\_\_\_\_
- እና ሁል ጊዜ ቆይቶ ነው የሚደርሱት \_\_\_\_\_

19 የመጨረሻ ደምዘትን መች ነው የተረከቡት? \_\_\_\_\_

20 እስከዛሬ ድረስ ተጨማሪ ጥቅም ጥቅም ትረክብው ያውቃሉ ? \_\_\_\_\_

- አዎ ከሆነ መልሱ መች ነበር የተበረከብት ? \_\_\_\_\_
- በምን አይነት ነው የተበረከቶለት? \_\_\_\_\_

21 እዚህ የወንዝ ውሃ ቁጥጥር ላይ ችግር አለ ብለው ያምናሉ? \_\_\_\_\_

- አዎ ፣ ዋናው ችግር የቱ ጋር ነው ብለው ያስባሉ? \_\_\_\_\_

22 ከሚኒስትሪው ምን መስትካከል አለበት ብለው ያስባሉ? \_\_\_\_\_

23 ተጨማሪ ጥቅም ጥቅም ቢበረከትሎት አሰራሩን ያሻሽለዋል ብለው ያስባሉ? \_\_\_\_\_

24 ተቆጣጣሪው ሲመጣ ምን ምን አይነት ተግባራትን ይፈሥማል? \_\_\_\_\_

25 ከሚኒስትሪ ወይም ከተቆጣጣሪው አስተያየት ይስጠታል ስልምትሰሩት ስራ? \_\_\_\_\_

25 ተቆጣጣሪው ምን አይነት ነገሮችን ማስተካከል አለበት ብለው ያስባሉ? \_\_\_\_\_

26 ችግር ካለ ሳይቱ ላይ ለምን ያሳውቃሉ? እንዴት ያሳውቃሉ? የማሳወቅ ሂደቱ ምን ይመስላል? በፈጥነት መልስ ያስጠታል? \_\_\_\_\_

27 ከሚኒስቴሩ ምን አይነት አዳዲስ ነገሮችን ተስተካክሏል እርሶ ስራ ከጀመሩ በኋላ? ምን አይነት ለውጥ አይተዋል? \_\_\_\_\_

\_\_\_\_\_

28 ሚኒስትር መስሪያ ቤቱ የዳታ አስባስብ መቋረጥ እንዳለ ያውቃል? ከሆነ ለማስተካከል ምን አይነት እርምጃዎችን ወስድዋል? \_\_\_\_\_

29 በዚህ ስራ ላይ ከተጠቀሙት ጊዜ ጀምሮ የሚሰበሰቡትን መረጃ ጥራት ለማስተካከል የተወሰዱ እርምጃዎችን አሉ ወይ? አዎን ከሆነ፤ በማን እና ምን አይነት እርምጃዎችን? \_\_\_\_\_

30 የሚኒስትር መስሪያ ቤቱ ስልጠና እና ልሎች የስራ ዕድሎችን ለመፍጠር ምን አይነት ዕድሎችን ያመቻቻል? \_\_\_\_\_