Integration of Flexible Water Infrastructure with Local Building Systems for Emerging Small Towns of Ethiopia.

The Case of DannisaGoroTown, Ginchi.

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Architectural Engineering.

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Date: June 2020

Declaration

I declare that the research entitled as “Integration of Flexible Water Infrastructure with Local Building Systems for Emerging Small Towns of Ethiopia, The Case of Dannisa Goro Town, Ginchi.” is my own original work that is not presented anywhere for a degree award and all the sources of material in this thesis have been acknowledged appropriately.

Student name: **Bilisaf Teferri Taressa**

Signature: ______________________

Confirmation

This is to certify that the research entitled “Integration of Flexible Water Infrastructure with Local Building Systems for Emerging Small Towns of Ethiopia, The Case of Dannisa GoroTown, Ginchi” has been submitted for examination with my approval as institute advisor.

Advisor name: Tesfaye Hailu : _______________________

Dedicated to:

Teferri Taressa and Marge Bayissa, beloved and role models in Life.

Table of Contents

List of Figures

List **of Tables**

List of Acronyms

Acknowledgement

I believe good things in life happen by dedication and hard work. Dedication and hard work as thought by my Lord and Savior Jesus Christ, the role model for success during my stay on this world.

I would like to acknowledge my advisors Tesfaye Hailu, Dr. Alazar Assefa and Dr. Zegeye Cherenet for the professional guidance and academic input. Secondly, I would like to thank ECL-AA Staff.

Two years of master's in architectural engineering course was an important stage in my life. I gained in life experience, academic development and social connection with fellow researchers, academicians, work colleagues and other great human beings.

The unexpected reality of the global pandemic of Covid-19(Corona Virus) impacted my research work. Changes and complication on routine way of life has pushed me to be a better person and adapt to extreme scenarios in life, it will be one to remember for a long time. The best is yet to come!

Abstract

The recent rapid urbanization and boom of building construction in Ethiopia has outpaced provision of water and sanitation infrastructure creating unsuitable working and living conditions in buildings. The general objective of the study is integration of flexible water infrastructure in local building systems to improve the standard of buildings and the livability in the emerging small towns of Ethiopia by taking Danissa Goro town as a case study area to design and demonstrate. The study area is located in Eastern Showa Zone, Oromia regional state, 125km from the city of Addis Ababa. The study investigates the negative impact of absence of water and sanitation infrastructure on housing developments, identify methods of integrating flexible water and sanitation infrastructure with local building system and assess feasibility of integrating flexible water harvesting and utilization infrastructure to the local building systems.

Primary and secondary data collection methods are applied to collect quantitative and qualitative data and applied stratified interviews with 45 participants.

The result of the study shows that underutilization of water sources, the absence of water infrastructure and sanitation infrastructure has a direct correlation to low quality of life, and degradation of buildings systems. Decentralized and flexible water systems are not technically complicated to integrate in local building system.

Finally, the research concludes that integrating of rainwater harvesting, water conservation and wastewater disposal systems into the existing local buildings will improve the quality of life of dwellers in the emerging small towns of Ethiopia. Besides, planning and design regulations have to integrate optional spatial standard for integration of flexible water infrastructure systems as a precondition for the future development of small towns in Ethiopia.

Keywords: Rapid urbanization, water harvesting, sanitation, decentralization & urban water system

1. INTRODUCTION

1.1. Background

The urban population in Ethiopia is increasing at a rapid pace. According to the Ethiopian statistics agency the urban population is estimated to be about 15 percent of the total population. This equals to 1.5 people out of 10 persons living in Ethiopia. According to the WDI report, over the past 30 years, Ethiopia's annual urban population growth rate has been higher than the average in Sub-Saharan Africa, which itself is among the fastest urbanizing regions in the world, but still remains to be one of the lowest in sub Saharan Africa and the world (UN report). For the past 10 years, the rate of urbanization in Ethiopia has been growing at 4.1 percent annually (ERUTR, 2014).

The ongoing uncontrolled urbanization process is a problem for the country. The hope for a better standard of life drives people from the rural areas to cities. Thus, highly contributing to the shortage dwelling units and increase in poor living conditions (Ann-Charlotte and Raffi , 2008).

The major housing challenges facing urban households in Ethiopia are poor quality dwelling units and overcrowded living conditions. According to MDG, in Ethiopia 70-80 percent of the urban population lives in slums. These dwelling units lack durability, adequate living space, access to safe water and sanitation and security of tenure (MDG, 2012).

In Ethiopia, despite progress over the last two decades in infrastructure and services across all urban sectors, there is still much to do, even at today's level of urbanization. Coverage for sanitation services is low, even by Sub-Saharan Africa standards, with a municipal sewerage system only in Addis Ababa, serving only 10 percent of the city's population. As in many towns and cities in the developing world, Ethiopian cities struggle to manage solid waste, which is often dumped into open areas, endangering public health (EUR, 2015).

In the case of Ethiopia, access to safe water supply and sanitation services are among the lowest in sub-Saharan Africa. National water supply coverage in 2004 was estimated at 36.7% with urban water supply coverage estimated at 82.5% and rural water supply at only 24.2%. In the year 2000, Sanitation coverage was among the lowest in the world at 18% with urban sanitation coverage at 71.6% but rural sanitation coverage at only 8%. While urban water supply coverage estimated at 83% is reasonable by developing country standards, however access close to home is low with only 4% of the urban population having access to in-house supplies and another 23% having access to water in their own yard, while the rest depend on communal supplies (ERWSSPAR, 2005)

Like other small Ethiopian towns and urban centers, housing developments in Dannisa Goro town do not supplement water, sanitation and drainage infrastructure. The rapid urbanization and construction of buildings for various functions is overwhelming the capacity of stakeholders to provide water infrastructure and related services at a unit, neighborhood, and town scales. Thus, the shortage of clean drinking water, lack of drainage systems and sanitary infrastructure categorized under water infrastructure for the main concern of this research is persistent. It is the situation of dwellings in the emerging small towns of the country: specifically the situation is an observed fact in the case study town of Dannisa Goro.

The delayed provision of water infrastructure has created unsuitable working and living conditions in buildings due to absence of basic necessities like clean water and waste water management systems, looking into ways of providing flexible water harvesting and utilization infrastructure as an integral part of local building systems is the focus of this research paper.

1.2. Statement of the Problem

The pull factors contributing for the nationwide rapid urbanization are mass migrations for better opportunities, population increase, competition for resource etc. Consequentially this process is giving birth to spur of new small towns. The process of growth and transformation of towns like DannisaGoro is not planned and ignores architectural and urban planning standards that are required to provide water and sanitation infrastructure. Thus, the disintegration of water infrastructure from building systems is exasperated by rapid growth and expansion of building construction in urban areas. As a result the lack of water and sanitation infrastructure in the town of Dannisa Goro is affecting the wellbeing of dwellers and polluting the natural environment.

The delayed provision of water infrastructure in the town of Dannisa Goro is forcing buildings to develop without integration of water infrastructure and building systems. Consequently, the buildings develop without provision of basic necessities of clean water and wastewater management systems, creating unsuitable working and living conditions after completion of construction and during the period of use.

1.3. Research Questions

1. What is status of the existing water and sanitation infrastructure in Dannisa Goro town?

2. What is the impact of delayed water and sanitation infrastructure on dwelling units in DannisaGoro?

3. What are ways of integrating water and sanitation infrastructure with local building system?

4. What are Flexible water harvesting and utilization mechanisms for residential buildings in Dannisa Goro town?

1.4. Objectives of the Research

1.4.1. General Objective

The general objective of the study is integration of flexible water infrastructure in local building systems to improve the standard of building and the livability in the emerging small towns of Ethiopia by taking Danissa town as a case study area to design and demonstrate the resulting building envelope and structure.

1.4.2. Specific Objectives

1. To examine the existing situation of water and sanitation infrastructure provision in the case study area.
2. To examine the impact by inadequate /absence of water and drainage infrastructure on quality of housing developments and living condition.
3. To characterize the existing local building system for integrating flexible water and sanitation infrastructure.
4. To develop a design prototype for flexible water harvesting and utilization mechanisms for residential buildings in 'Dannisa'.

1.5. Significance of the study

Due to shortcomings in the existing practice of water delivery system in the emerging small towns, exploring new unconventional water delivery methods is important. Flexible water infrastructure systems that integrate within local building systems as a solution may solve the water problem in Dannisa Goro town and beyond. The flexible water harvesting and sanitation systems can be replicated for application to other small towns and rural settlements in Ethiopia. Furthermore, the relevance of the solution for design and planning practice at local level can increase the capacity of towns to develop resilience, for policy integration at macro level and contribution for further research in the academia.

1.6. Scope and Limitations of the study

1.6.1 Scope of the Study

The research will focus on residential buildings in the town of Dannisa Goro. The town has a population of 1100 with most buildings inhabited, but do not have any type of integrated water infrastructure. The town is experiencing rapid housing construction and surface area expansion without integration of water (clean water and sanitary system) and other related infrastructure systems both at a unit and neighborhood scales.

The spatial Scope of the research is within 3 km2 area that is administered under local Dannisa Goro kebelle in Eastern Showa Zone, Ejersa Lafo Woreda in Oromia regional state and has a geographical location of 9.101459, 38.236549.

The thematic scope of the study are building design, water supply, sanitary and decentralized urban water system.

1.6.2 Limitations of the study

Due to the current political tension and widespread misinformation on land and property issue around Dannisa Goro, some of the dwellers selected for sampling were initially hesitant to participate for interviews and discussions, but through further explanation all participated accordingly. The confining feeling to describe household conditions that are perceived to be kept personal created some uncomfortable exchanges between the researcher and sampled participants. Due to the corona virus pandemic declared locals/samples were taking shorter time to participate during interviews and conditional surveys.

2. METHODS

2.1. Study Area

Dannisa Goro is a small town with a population of 1100, located 125 km from city of Addis Ababa and 15 km from Ginchi town. The town is found in Eastern Showa Zone, Ejersa Lafo Woreda in Oromia regional state and has a geographical location of 9.101459, 38.236549. The town is situated 2800 meters above sea level.

Ownership status other than Schools and health center is private owned by farmers and dwellers. Annual crop production varies from wheat, barely, potato, beans, sunflower and other livelihood productions including animal farming. Dannisa Goro has a market active once a week and a larger market in the nearby town of Ginchi.

Dannisa Goro town is characterized by buildings constructed from mud and eucalyptus wood frames with corrugated metal sheet roof cover, and small number of traditional tukul houses. Basic services such as health care center, piped water, electric power do not exist. The town is connected to the main highway by a 15 km gravel road.

The town of Ambo and the case study area Dannisa goro town lie on 2106m above sea level, the climate in Ambo is warm and temperate. In winter, there is much less rainfall than in summer. The Köppen-Geiger climate classification is Cwb. The average annual temperature is 18.0 °C in Ambo. The rainfall here is around 1012 mm per year.

-The driest month is December, with 8 mm of rain. Most precipitation falls in July, with an average of 218 mm.

-March is the warmest month of the year. The temperature in March averages 19.5 °C.

-In July, the average temperature is 16.7 °C. It is the lowest average temperature of the whole year.

-There is a difference of 210 mm of precipitation between the driest and wettest months. The average temperatures vary during the year by 2.8 °C.

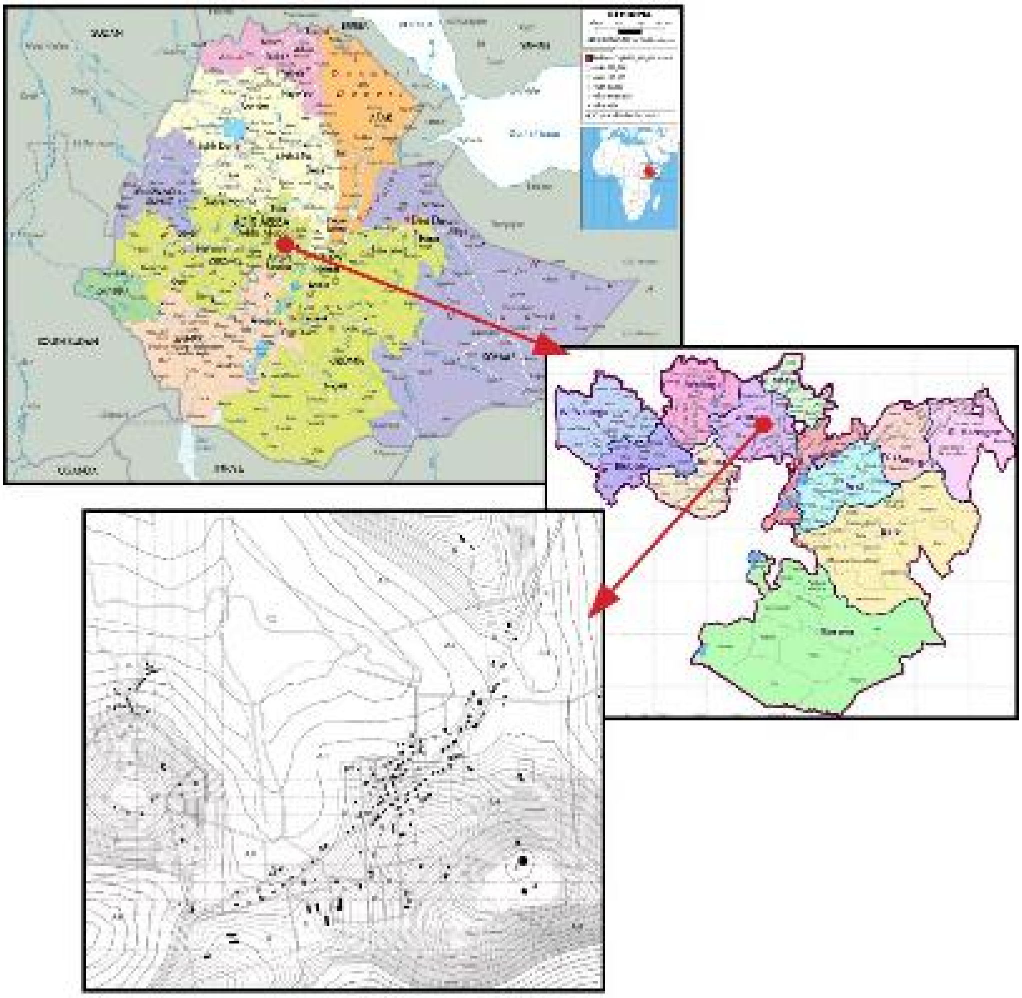


Figure 2- 1: Map of Ethiopia, Oromia Regional state and DannisaGoro town

Figure 2- 2: Dannisa Town, residential buildings and town center, Photograph by author, March 2020.

2.2. Sampling sites

The small town of DannisaGoro represents small economic centers that are spurring all over the country. The town is experiencing rapid expansion in construction of buildings but lags behind in provision of infrastructure services including water infrastructure. There is no proper or traditional water delivery system (municipal water line) in the town. Infrastructure planning and provision is not integrated with buildings (Local building systems). The town has one (1) functioning water well.

Buildings used for sample survey are randomly selected from residential sections of the town. Buildings are constructed from local building materials using local building construction systems. The total number of residential building is Dannisa Goro counted by the researcher is 250.

Figure 2- 3: Location map of study area(maps.google.com)

2.3. Materials used

The researcher used materials to conduct the research:

-Google earth, Google earth generated topography maps to analyze the topography of the study area and to count and identify buildings.

-Revit Architecture is used to generate 2D and 3D modeling of digital illustrations, modeling existing and proposed housing typologies, generate topographic models for sampled sites.

-Nikon 3300 and iPhone cameras are used to take pictures, sketches, and description notes are used to document household conditions, local building material use, surrounding environmental conditions.

-Tape meter was used to measure outdoor building dimensions (wall thickness, room height, building element dimensions) and digital measuring tool was used to measure interior building elements.

2.4. Data sources

For this research, the researcher used primary and secondary data sources. Primary data collection included questionnaires, formal and informal discussions, pictures, sketches, video recordings and physical observation by the researcher. Secondary data was collected from journals, books, written documents, reliable online sources and Google earth maps. In addition, Oromia regional state and zone offices reports, geographic, physical, social and economic status reports, journals, internet, published and unpublished documents are used as a secondary data source by the researcher.

The sampling frame which incorporates the elements of the study and identified population is used to draw the sample. A sample is number of selected individuals' cases that participate on a survey of questionnaire.

The sampling populations for questionnaire are selected based on the following three principles. Variability of characteristics being observed, population size and considering sampling and estimation methods. Qualification criteria for sampling populations is to live in buildings with Within one of the 250 residential buildings in Dannisa town. Construction of building has to be fully completed. Buildings should not have any type of water infrastructure integrated.

Forty five (45) respondents were selected for questioning from residents living in the residential buildings.

$$n = \frac{\left(\dfrac{P[1-P]}{\dfrac{A^2}{Z^2} + \dfrac{P[1-P]}{N}} \right)}{R}$$

n= Number of samples taken, N= Population size, e = sampling error /level of precision.

Based on this the following formula was used for the calculation of the sample size since it was relevant to studies where a probability sampling method was used (Watson, 2001:5).

n = sample size required

N = number of populations

P = estimated variance in the population 50%

A = margin of error = 5%

Z = confidence level = 1.96 for 95% confidence 5

R = estimated response rate = 96% 6

the simplified formula provided by Yemane (1967).

$$n = \frac{N}{1 + N(e)^2}$$

2.5. Feasibility Assessment

The Feasibility studies will be analyzed in combination with the questionnaires. It includes physical assessment, social assessment and technical assessment from primary and secondary source. The feasibility study enquires if the community really needs it? Does the community want such system? and can it be realized in relation to technical requirements. Thus, the physical, social and technical environments are studied in the following steps. The table below shows the details of the feasibility assessment:

Table 2- 1: Feasibility Assessment, Milagros J. 2007

1.	Physical Assessment	Climate
		Current Infrastructure Supply
2.	Social Assessment	Cultural Perceptions
		Gender Roles and community dynamics
3.	Technical Assessment	Available Resources
		Water demand and supply analysis

2.5.1. Physical Assessment

The physical assessment studies and gathers information on current status of the study area. The physical assessment will identify source water, level of quality of water sources, conditions of water sources, availability, reliability and accessibility of water sources. Collect climate data, types of surfaces that exist for catching rain, identify surface materials that are suitable for rain water harvesting and storage.

2.5.2. Social Assessment

The social assessment identifies population size, acceptance of alternative water harvesting options, acceptance of an alternative water harvesting system, maintenance capacity of a water harvesting system, awareness and academic level of the community. The assessment also identifies cultural perceptions on the use of water and traditional preferences.

2.5.3. Technical Assessment

The technical assessment identifies the resources required for the implementation of the new water harvesting system such as available construction materials, financial status of the community, human resources, local skills, training, management abilities and location of water storage, catchment, and water supply systems. In addition the assessment will determine expected demand and supply.

2.6 Demand and Supply

To calculate the amount of rainwater that can be harvested, multiply rainfall (mm) by the roof surface area (m^2) being used to catch rainwater. The resulting number represents how many liters of water you can expect to collect.

Roof Area (m2) X Precipitation Amount (mm) = Amount Collected (liters)

To calculate demand, it is important to consider all the watering needs of the community. This varies from place to place, which demands a contextual approach to find out specific water demand.

The approach by the researcher is to use Ethiopian water demand standards to calculate the overall demand of a household.

2.7. Data presentation and interpretation

To analyzing numerical data, the researcher will use statistical methods. These generally require applications such as Excel and SPSS. These platforms will be used to analyze averages, frequencies, patterns, and correlations between variables in systematic way. The researcher will use questionnaires, occupational and conditional surveys and interviews to conduct data collection.

The values to be derived are included in the questionnaire attached. The analyzed data is presented using statistical tools including tables, charts, and figures. In some case, where need arises for further description, the statistical data are explained by using text descriptions.

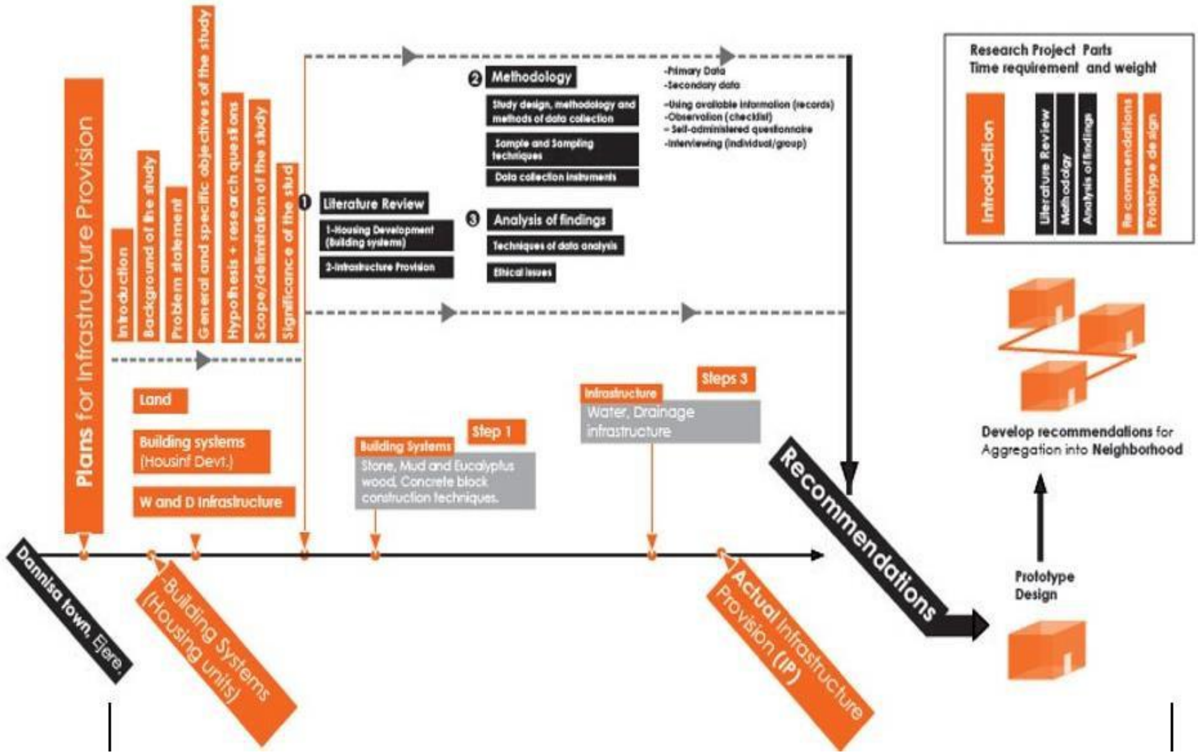


Figure 2- 4: Research structure diagram

3. LITERATURE REVIEW AND THEORITICAL FRAMEWORK

3.1. Global Perspective on Transition to Water Sensitive Cities

(Review on "Moving toward Water Sensitive Cities", Rebekah et al. 2016)

Water Sensitive City Vision

Water sensitive city vision is based on holistic management of an integrated water cycle. It advocates fit for purpose water use and delivery of water through both centralized and decentralized infrastructure and integrates water and urban planning to facilitate better livability outcomes. Transitions imply a shift towards more sustainable modes of production and consumption and can take place over 25-50 years within the domains of technology, economy, institutions, behavior and culture.

3.1.1. The Case of Water Sensitive city transitions

The urban population has exceeded the rural putting pressure on water resources and its availability. This process is exasperated by climate change, resource constraint and stressed ecosystem, unpredictability of weather effects and the society's expectation for urban livability demand and adaptive water management. While linear evolution of water supply systems work, the concept of "leap-frogging" provides better alternative for poorly developed water management systems by skipping parts of transition pathway and proceed directly to a more sustainable infrastructure provision. However, water sensitive city vision is context specific and depends on individual city's water management standards, biophysical environment, ecology, climate, geography and demography.

3.1.2. The Urban water Transition Framework

According to Brown (2016), the framework identifies six developmental states that cities pass through on their path towards increased water sensitivity assesses its supply, sanitation, and drainage infrastructure that reveal current conditions and opportunities to move forward.

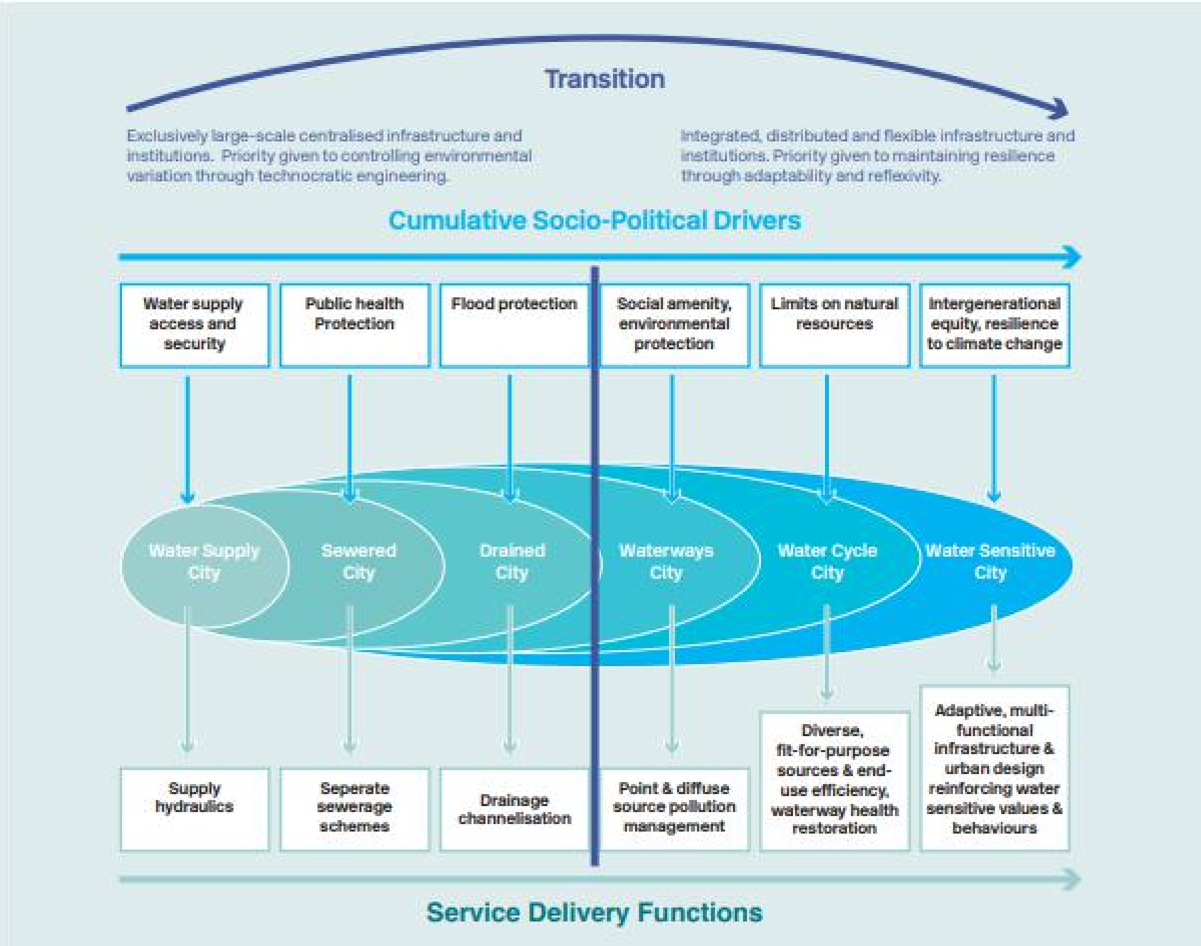


Figure 3- 1: Urban Water Transitions Framework and challenges, Source Brown et al. 2016

The first three stages show utilitarian expectation of supplying water, protecting public health, and mitigation impacts of floods. The following three stages show a significant transition to beyond survival needs, towards a more sophisticated water self sufficiency and reduced environmental impact.

3.1.3. Goals of water sensitive cities

1. **Cities as water supply catchments:** Cities should not only relay exclusively on their natural water sources but develop diverse range of water sources like urban storm water, run-off water, recycled waste water, desalinated water, and groundwater.

2. **Cities providing ecosystem services:** Innovative use of public and green spaces by incorporating sustainable water management, carbon sinks, food production and improved microclimate.
3. **Cities compromise water sensitive communities:** Responsible local institutions should fully support technological solutions.

Transition requires cities to fundamentally change and redirect existing infrastructure, institutions and approaches to water management. Through the process of stabilization and transition, lock in, back lash and system break down may occur during period of development.

3.1.4. Melbourne's transition to improved storm water management

The city of Melbourne in Australia has transited from traditional drainage system towards a sustainable urban water management classified under typology of six distinct phases following an extensive qualitative and quantitative data collection spanning over five decades. Each phase identifies a unique challenge and opportunity for strategic intervention to improve water management policy and practice. The phases of transitional dynamics include:

1. **Issue emergence-** from the mid 1960s the public, media, social groups and the release of scientific freshwater studies exerted pressure on the government to reduce water way pollution and led to the environmental protection to be enshrined into law.
2. **Issue definition-** from 1990-1995 the creation of networks from diverse sectors of engineering, academia, state and local governments led to the creation of research centers to produce reliable scientific papers for a better water management and development of new technologies.

3. **Shared understanding and issue agreement**- from 1996-1999 the network of industry and science expanded to include land developers, planners and government representatives to establish a strong formal policy committee to develop best practice guidelines and storm water quality run off targets.
4. **Knowledge dissemination-** from 2000-2004 the international conferences on water sensitive urban design led international stakeholders to exchange insights from their experience. Besides, the urban storm water quality management of catchment hydrology created a computer based decision support tools was developed and political lobbying diverted fund to develop storm water management plans and fund capacity of storm water professionals.
5. **Policy and practice diffusion-** from 2005-2010 formal policy documents, regulatory change and institutional actors were formalized through agreements. Storm water offset scheme was introduced which required developers to meet storm water quality objectives by implementing best practice measure onsite or by making offset payments for works undertaken elsewhere.
6. **Embedding new practice-** from 2011 to now senior sustainable water management officials came to power and convened on an independent ministerial advisory council and a cooperative research center for water sensitive cities with specific focus on storm water harvesting and treatment was formed In addition city councils are amending more comprehensive requirements in relation to storm water management.

Earlier transition phases are crucial for overall success of a transition journey while on ground result occur late in last stages. In addition, actors, bridging organizations, knowledge, projects and tools are the domains of change used to reveal transitional phase of a city. Successful transition involves community engagement in creating a political mandate for action and providing momentum.

3.1.5. Case study of knowledge and dissemination: Lodz, Poland

The city of Lodz, Poland has typical urban landscape problems like prolonged urban landscape, heavy rain incidents, storm water flooding and urban heat island effects. Over the last two decades an awareness creation on benefits of decentralized systems and storm water retention has been achieved. Directives from European Union's water framework directives and European commission green infrastructure in support of green growth and nature is an important direction for the future which has required Poland to harmonize its national legislation to be consistent with the EU. The implementation includes familiarizing decision makers and industry practitioners with water sensitive urban design, technical knowhow, design, installation and maintenance of infrastructure. To facilitate this up skilling of industry, the city of Lodz is in the early stages of developing technical guidelines and management tools to assist decision-making processes and the operation.

3.1.6. Case study of Policy and Practice Diffusion: The Netherlands

The command and control approach has resulted in the construction of extensive network of dykes and engineering works to protect cities and communities from flood waters but the flooding disasters that occurred on the Rhine and Meuse rivers prompted a new approach to flood protection.

The approach is to make room for the river which preferences spatial rather than infrastructural flood protection measures by the integration of spatial planning and water to widen flood plains to increase the discharge capacity of the rivers. As a result, Netherlands has shifted from total reliance on large scale engineered infrastructure towards both large and small scale spatial and ecological solutions.

3.1.7. Benchmarking procedure

Primarily, identifying the stages that characterize a city or town in terms of both current practice and its aspired future is essential. Secondly, secondary and primary data sources, interviews and questionnaires are conducted to make a comprehensive assessment. Multiple data from multiple sources is triangulated and data analysis and data validation is done in accordance. A comparative assessment is done on the basis of existing water supply, sanitation, and drainage services.

3.2 Regional perspective towards Climate Change Resilient Cities in Africa (Review on "Towards Climate Change Resilient Cities in Africa – Initiating Adaptation in Dar es Salaam and Addis Ababa")

Climate change presents a serious challenge for cities around the world including Dar es Salaam and Addis Ababa. In order to address this a strategy towards making resilient cities has to be an interactive and collaborative process of identifying the most important issues for a broad range of actors in cities, a process that builds both in local, context specific and expert knowledge.

The approach to making cities resilient with a particular focus on adaptation towards urban flooding needs to explore possibilities and barriers for integrating climate change adaptation into urban development and planning by means of initiating a strategy making process to create action in practice. In Dar es Salaam and Addis Ababa massive yearly population increase, demand for services and land have set a rapid pace of urbanization resulting in 70% of informal settlements with no or low service provision. The approach involves spatial urban strategy-making which relates to adaptation planning.

3.2.1. Strategic Planning relevant to African context

According to Halley (2009) for a plan to be transformative there are four contextual dimensions that need special attention: mobilizing attention, scoping the situation, enlarging intelligence, creating frames and selecting actions. The traditional rational planning approach that failed in Europe is a tradition in African cities following colonial planning experiences and this has resulted in the process of preparing master plans by minister officials and foreign experts without involving stakeholders and residents.

Improved land use and higher building standards directly reduce vulnerability of settlements away from flood prone areas, better handling of storm water and urban drainage, sustainable drainage practice which encourage landscape based natural drainage arrangement methods are essential to adaptation.

The two case study cities have similar challenge but are different both in terms of geographical features and governance systems and were undergoing master plan revisions. The methods included case studies, workshops at city and local level which were held on site to gain local perspectives. In Dar es Salaam solid waste management was considered the main contributor to flooding. In Addis Ababa interviews were more related to institutional anchor-age as this has been identified as being the key for implementation. The situation in the two cities will identify the current efforts and barriers to adaptation measures needed, and detected entry points that could hold potential as a starting point for a wider adaptation effort in cities.

Dar es Salaam

In Tanzania the national adaptation policy was prepared in 2007 by the Environmental Ministry that has the mandate to request other government departments to include action on climate change adaptation. In Dar es Salaam there are three municipalities and are responsible for waste water management, drainage, detailed land use planning, and enforcement of land use and building regulations. Services like drainage and solid waste are not offered in the informal areas, waste collection is not formalized and only 10-20 % of waste produced in informal areas ends up in the landfills.

In the informal areas of Dar es salaam flooding is affecting the livelihoods of people by destroying houses, livelihoods and affecting mobility as communities have low quality services, poverty, lack of assets and poor physical infrastructure. However, it is only the local community and individual that have taken up action to clean the area, organize excavation and dig out waste.

The adaptation measures taken are better land use management, improved urban services and better disaster management (resettlement), helping people in vulnerable areas, participatory rehabilitation systems and improved solid waste collection systems.

Addis Ababa

In Ethiopia the structure plan from 2002 addressed a number of issues of resilience to climate change, protection and rehabilitation of green infrastructure, provision of services and waste management. However, most of these intentions were never implemented because of insufficient resources, lack of coordination, legal frameworks and lack of stakeholder involvement.

Benefits from an integrated water management would likely improve the resilience of Addis Ababa to climate change. An integrated water management plan was thus considered a useful frame by pointing to concrete actions. The case study shows that the challenges of climate change adaptation for developing cities are many and severe. As the cities grow quickly, large urban service and management deficits arise. Insufficient solid waste management, drainage and sanitation combined with limited land use management and enforcement make up much of the present problem with flooding, drought and pollution. Thus, weather it is the effect of climate change or it is climate variability, the cities are not resilient.

To make the two cities more resilient to climate change must include short term integrated projects and long term efforts to integrated climate change adaptation into plans, policies and practices. Short term integrated projects including continuation of plans addressing pressing and multiple problems that are currently identified in cities that should commence such as upgrading efforts, housing developments, waste management and green area development should be focus of stakeholders.

In Addis Ababa an integrated water management plan has to be developed to address flooding, drought and pollution by water shade protection, designation and management of buffer zones, waste management, drainage solutions and social issues. In Dar es Salaam imitation of integrated local projects in most vulnerable areas that combine urban service upgrading, livelihood projects and local land use management and regulation is essential.

Middle and long term adaptation measures addressing flooding and drought must be dealt with in the main city plans and integrated into policies and practices in the core fields of land use planning, management and mapping, urban drainage, waste and storm water, and environmental planning. Focus should be placed on involving stakeholders across all levels, local people, municipalities and national bodies, NGOs and utility companies, should be involved in the integration and strategy making of adaptation. Network building among relevant stakeholders, incremental approaches should be applied towards more city wide adaptation.

The two cases in Dar es Salaam and Addis Ababa illustrate that there are no one-size-fits-all solutions, when it comes to adaptation. The important measures to take, according to literature and guidelines prepared by development organizations for climate change adaptation, are numerous. This can be overwhelming for a developing city struggling with a multitude of urban problems. Efforts to make a city resilient have to be explicitly and closely connected to the problems the city already faces in order to be relevant for stakeholders and citizens. A developing city is unable to address all the issues which are important to create resilience, but it might be able to address some: those that can mobilize a range of stakeholders and their resources, which can create synergy effects, and which resonate with the experienced problems in the cities.

3.3 Impact of inadequate water and sanitation infrastructure in cities

Lateral expansion of urban areas, surrounding rural settlements in addition with an extended time of growth in population contribute to the widening the geographical extent of an area that can be defined as urban (Ransford , 2018). Ransford (2018) defines urbanization as the growth process of settlements in relative to other regions or geographical location in terms of population size and physical extent.

Urban areas of the developing world are facing fast expanding slums and growth in squatter of informal housing due to challenges of rapid urbanization. The past 50 years have recorded the fastest increase of urban population in the world, which will be the same case for other 30 years to come. This will be further driven by the increasing number of people leaving rural areas supported and increase in the number of people born in cities (CSGRHS, 2003).

Water management at city level started during the Indus valley civilization, Harappan (2600 BC). Trenches were constructed along streets to convey sewage and waste from houses that are watered by the systems (Pantoleon, 2014). Pantoleon (2014) states Knossos was one of the first places in the world where architecture was influenced by the necessity of water Knossos had a sophisticated drainage systems built with gutters and toilet stations.

In 2010, the UNGAHRC declared that access to water and sanitation is a human right. The challenge of urban centers to provide proper water infrastructure to citizens and urgent urbanization presents a continuous and unpredictable change to planners and governments responsible with providing infrastructure services (U.N., 2010).

Exploring unconventional water delivery methods and integration with building systems, climate and consider sustainable design parameters can solve the shortcomings in the traditional water delivery methods. It is widely accepted that, for the urban water sector to transition to sustainable urban water management, a shift from the traditional, linear approach to an adaptive, participatory and integrated approach is required (Brown and Farrelly, 2009).

Investing on innovative methods of harvesting and utilizing water sources for urban centers will build resilience and adaptive capacity into the water sector. Besides, exploratory modeling of optional futures, searching for robust strategies that work have to be flexible enough to anticipate diverse climatic conditions, develop adaptation strategies and monitor the change (Lempert et al, 2003).

The lifetime of water infrastructure systems have to prove to be flexible and adoptable in order to satisfy water demand and wastewater discharge. This may change as a result of faster economic and urban development, water use habits, technological progress, climate change and change in construction technology. In this regards, integrated urban water management minimizes the impact of urban water systems on the natural environment by maximizing the social, economic vitality and increases overall community wellbeing (Shiroma et all., 2010).

The urban population in Ethiopia is increasing at a rapid pace. According to the ESA, the urban population increase is estimated to be about 15 percent of the total population and is also reconcilable to 1.5 persons out of 10 persons living in Ethiopia. As a result for the past 10 years, the rate of urbanization in Ethiopia has been growing at 4.1 percent annually overstretching the bearing capacity of large and secondary cities and catalyzing the creation of small new towns in rural areas (ERUTR, 2014).

In Ethiopia urban households are characterized by challenges such as poor quality and often overcrowded living conditions. Besides, a study conducted to design the implementation strategies of the Millennium Development Goals (MDG) states, about 70-80 percent of the urban population lives in a slum. According to the international definition, housing units classified as slums lack durability, adequate living space, access to safe water and sanitation or security of tenure (MDGs, 2005).

There are factors that contribute for the expansion of slum housing in urban areas. The use of building materials for building systems by using locally available, cheap and poor quality materials contributes to the degradation of the dwelling units in urban centers. In Ethiopia, nearly 80 percent of building units in urban areas are made from tradition construction method, using construction materials like wood and mud. While two thirds of all urban housing units have only earthen floors, another indication of very low-quality housing (CSA, 2007).

Factors supplementing to identify a building as substandard are earth floors, mud walls or straw roofs are substandard building materials. This violates building regulations in most countries. Thus, slums are associated with large number of residential structures that are substandard, often built with non-permanent construction materials that do not respond to the given specific location and climatic requirement (UN-Habitat, 2003).

The UN habitat, 2002 the United Nations Statistics Division and the Cities Alliance report agreed on an operational definition to classify buildings as slums by the extent to inhabitants suffer one or more of the ‘household deprivations. The definitions are listed below,

1) **Access to improved water-** 20 liters/person/day drinking water per household at affordable price, available at less than 10% of the total household income, easily accessed, the process should take less than one hour a day for women and children. Protected from external contamination and sewerage line. Clean water has to be provided into housing units, plot or yards. Springs should be protected and rain water collection need to be treated. Such possible option can be integrated with a building system to provide proper amount of water to users.

2) **Access to improved sanitation** – Households need to have an excreta disposal system, either in private or public forms shared with reasonable number of people. Human waste must be separated from human contact. Improved systems, latrines must relate to a sewer line, septic tank or pit. The systems need to properly ventilate. Pit latrine must be constructed from lab or platform, which is covered entirely, which has to be the same case for composting toilets/latrines.
3) **Sufficient living area –** Prevent overcrowding.
4) **Structural quality/durability of dwellings–** buildings must be durable, permanent, and adequate structure to withstand extreme weather and climatic conditions.

3.4 Integration of water and sanitation infrastructure in different contexts

3.4.1. Integration

In architecture the process of integration serves the purpose of combining several sub systems to form a properly functioning building. The process of integration is an important step towards achieving a required performance criterion expected from a building (Gulser, 2002).

Understanding how a construction work is assembled helps to understand how systems work and the structure behaves in response to various kinds of loads but mainly towards the ones it faces through all the times and its integration with different service systems. Even for which previous provisions were made at its inception meaning it has to be adoptable if there needs to be change. The evolution of a construction system over the centuries is the result of a process of adaptation to climate, to geographical location and soil conditions, but is also influenced by past and present cultural background, economic considerations, taste and fashion (Alice et all., 2014).

Households are the essential and flexible units to adopt technology to know the variability in households and improve the status of water scarcity by using water conservation technology supported by conservation behavior and awareness. Thus, water saving technologies has to be developed and implemented into different households of different demographics, households and external factors (Brianne, 2016).

Rainwater has to be collected before it reaches the ground to prevent the collected water from getting polluted. Big urban areas in developed world and small poor villages in the developing world can get clean water source from a properly treated storm water source (Forssberg et all., 2015). Forssberg et all., (2015) states that Conventional technical measures like infiltration, vegetation, swales can contribute to retaining storm water and reduce pollution of water in cities and urban centers.

As cited in Pantoleon, (2014) states recycling water for urban is very crucial as it is estimated that only 15% of all water used is potable.

3.4.2. Building Systems

A building incorporates other sub-systems that serve different diverse functional tasks in a building. A building, consisting of space or spaces, cannot be realized if the building system is not defined in concrete terminologies and functional properties (Gulser, 2002). (Gulser, 2002) states the basic sub-systems that can be analyzed depending on their functions and tasks within the building: Structural System, building envelope system, services Systems, space separating systems, circulation systems and finishing systems.

Table 3- 1 : Building systems, Gulser, 2002

	Types	Description
1.	Structural systems	-Includes foundations, columns, beams, and slabs designed to hold the dynamic and static loads. Can be classified into Non-load bearing and Load bearing systems.

2.	Envelop systems	-Separating the internal from external environment that have different environmental conditions. Creates the physical ambiance in consistency with the function and external environment of the building.
3.	Service system	-Includes water system, heating system, ventilation system, climate responsive System, lighting system and electrical system.
4.	Space separating systems	-Determine qualities of visual and audile insulation, color and form) and quantities of the space.
5.	Circulation systems	- Corridors, entrance hall, stairs, elevators, mobile bands or movable bands.
6.	Finishing systems	-Claddings/coatings, suspended ceilings, flooring etc.

In the late twentieth century the production of construction was focused on delivery of crafts with the building site, apprenticeship and oral communication. The control of quality and standard relied on sub standards and informal agreements. Thus, the production process was conditioned by diverse social structures and cultural background Alice et all., 2014).

The advantages of implementing sustainable principles on building projects is gaining appreciation and acceptance worldwide by the building construction practitioners (Peter et all., 2016).

The design development stage of a building project provides architects, Designers, engineers and other involved professional a unique opportunity to implement sustainability objectives to reduce environmental impacts (Peter et all., 2016).

Sustainability initiatives are relatively weak in addressing small scale projects at a unit scale project level(micro-level). This is because in the current trend sustainability initiatives, strategies and processes focus wider on global aspirations and strategic objectives (Ugwu et all., 2006).

Figure 3- 2: Framework for implementing sustainability in building construction, Peter et al., 2012

Guidelines for choice of flexible design alternatives for engineers and planners, it is crucial to know when to apply which flexible design alternative, particularly in the early design and planning stage, since later changes are difficult and costly to implement. The proper guidelines proposed to select different designs depending on the character of environmental change, the ability to incorporate technological progress, the speed of change and the location of the implementation within the urban area considering different parameters.

The use of gray water is now widespread. Incorporated into household building systems all over the world. The application of gray water recycling is practiced from small to large scale residential and multi-function buildings all over the world. This has been tested and proved to be a sustainable way of utilizing resource in urban areas (Pantoleon, 2014).

3.4.3. Local Building Systems

Ethiopia construction industry is mainly classified in to modern and traditional building material based types of buildings. The common traditional building material-based buildings are local mud building systems that use sustainable building materials and do not harm the environment. But this varies all over the country and several types of building types can be found depending on a diverse building culture, typologies, wide range of climatic zones, topography, and diverse societal structures (Petra, 2015).

Modern systems can integrate with local building systems to produce sustainable design and the integration can be applied into local building types like ‘Chika-Bet’ or mud block house, Stone house and brick house. Besides, in terms of energy consumption, material availability, cost, labor, environmental adaptability, and local construction techniques traditional building material based are more sustainable (Ann-Charlotte and Raffi, 2008).

The traditional local construction method in Ethiopia consists use of wood frame (eucalyptus wood) placed inside the wall element and wooden posts are cut into proper length and put in the ground as a structure. Because eucalyptus is a fast-growing type of tree, mostly found in the highlands, often with poor durability and quality ‘Thid’ and ‘Kosso’ wood types reconstitute eucalyptus. The frames are laid out with a spacing of 1m and later covered with clay mixed with straw (Bengt and Kristian, 2015).

The traditional building system does not require a ground or foundation work and the wall structure is founded on wooden panels covered with clay. The wood is used as a frame, used as a supporting pole and covering purposes. The wooden poles are stabilized by burying into the ground and supported by adjacent stones. The main wood panels used as a grid and structural elements and connected by less strong wood. The less strong wood elements are also to fill open halls between the wood frames to make a suitable platform to apply layer of clay. When need arises additional layer of limestone plastering is used as a protection against water and moisture (Emma and Hanna, 2013).

Local and traditional technology has advantages. Local technologies are well known and can be applied locally. Local construction materials with durability can be technologically advanced to create buildings which are climate responsive and provide good indoor environment. Buildings provided with proper foundation, ceiling, sufficiently long overhangs with areas experiencing high rainfall and use of roof gutter are necessary (Bengt and Kristian, 2015).

Most common roofing material in Ethiopia is corrugated iron sheet. Majority of residential units/houses do not have ceilings and the main flooring material is stamped earth. The most common way of building walls uses eucalyptus wood (timber) covered on both sides by clay mud mixed with straw. In 50 percent of all case used for study, walls are not supported by foundations. In addition, the condition of many houses is very poor, requiring urgent need for repair (Beng and Teferri, 2007).

3.4.4. Flexible water harvesting and utilization Cases

Thailand

In Thailand storing rainwater from rooftop run-off in jars is an appropriate and inexpensive means of obtaining high quality drinking water. Prior to the introduction of jars for rainwater storage many communities had no means of protecting drinking water from waste and mosquito infestation and store sufficient rainwater during the dry season lasting up to six months.

Two approaches are used for the acquisition of water jars. The first approach involves technical assistance and training villagers on water jar fabrication. The two approaches encourages the villagers to work cooperatively to use environmentally appropriate technology, learn, and fabricate water jars for sale at local markets.

The second approach involves access to loan fund to assist these villages in purchasing the jars and develop skills for self-maintenance of the water. Villagers are also trained to ensure a safe supply of water and how to extend the life of the jars.

Figure 3- 3: Example of the rainwater jar used in Thailand

Africa

In some countries in Africa, rainwater collection is becoming widespread with more projects currently in Botswana, Togo, Mali, Malawi, South Africa, Namibia, Zimbabwe, Mozambique, Sierra Leone and Tanzania among others. Since the late 1970s, many projects have emerged in different parts of Kenya, each with their own designs and implementation strategies.

The water harvesting projects in combination with the efforts of local builders operating privately and using their own local designs have been responsible for the construction of many tens of thousands of rainwater tanks throughout the country. Where cheap, abundant, locally available building materials and appropriate construction skills and experience are absent ferro-cement tanks are used for both the surface and sub-surface catchment.

Figure 3- 4 : (a) (b) Rainwater tanks constructed by local builders

Singapore

Singapore has limited land resources and a rising demand for water, is on the lookout for alternative sources and innovative methods of harvesting water. Almost 86% of Singapore's population lives in high-rise buildings. A light roofing is placed on roofs to act as catchment. To collected roof water and hold water in a separate cisterns on the roofs for non-potable uses.

The approach has demonstrated an effective saving of 4% of the water used, the volume of which did not have to be pumped from the ground floor. A marginally larger rainwater harvesting and utilization system exists in the Chang Airport. Rainfall from the runways and the surrounding green areas is diverted to two impounding reservoirs. One of the reservoirs is designed to balance the flows during the coincident high runoffs and incoming tides, and the other reservoir is used to collect the runoff. The water is used primarily for non-potable functions such fire-fighting drills and toilet flushing.

Germany

In Berlin rainwater falling on the rooftops (32,000 m2) of 19 buildings is collected and stored in a 3500 m3 rainwater basement tank. It is then used for toilet flushing, watering of green areas (including roofs with vegetative cover) and the replenishment of an artificial pond. In another project at Belss-Luedecke-Strasse building estate in Berlin, rainwater from all roof areas (with an approximate area of 7,000 m2) is discharged into a separate public rainwater sewer and transferred into a cistern with a capacity of 160 m3 , together with the runoff from streets, parking spaces and pathways (representing an area of 4,200 m2). The water is treated in several stages and used for toilet flushing as well as for garden watering.

The system design ensures that the majority of the pollutants in the initial flow are flushed out of the rainwater sewer into the sanitary sewer for proper treatment in a sewage plant. It is estimated that 58% of the rainwater can be retained locally through the use of this system. Based on a 10- year simulation, the savings of potable water through the utilization of rainwater are estimated to be about 2,430 m3 per year, thus preserving the groundwater reservoirs of Berlin by a similar estimated amount.

Both of these systems not only conserve city water, but also reduce the potential for pollutant discharges from sewerage systems into surface waters that might result from storm water overflows. This approach to the control of non point sources of pollution is an important part of a broader strategy for the protection of surface water quality in urban areas.

3.4.5. Building Water resilience in Addis Ababa (Liku Workalemaw) Add CASE

4. RESULTS AND DISCUSSIONS

4.1. Status of the existing water and sanitation infrastructure in the case study town Dannisa Goro.

4.1.1. Water sources

The town of Dannisa Goro has no water delivery systems. The town has three water holes of only which one gives service the whole year and the remaining two water holes work during the rainy season. Two water holes are sponsored by the government and one sponsored by a Korean NGO. The source of drinking water for people living in the city and surrounding small villages is the water holes. The scarcity of clean drinking water during dry seasons has created a big problem for dwellers as springs are rapidly drying up in the surrounding areas due to overuse.

The lack of water infrastructure has impacted the construction, design and use of buildings and street infrastructure. The buildings constructed in the town do not integrated clean water and wastewater infrastructure of any kind. In addition, buildings do not have drainage system at building scale, plot/property scale, neighborhood scale and town scale. This lack of integration between water infrastructure and building systems is impacting building and the surrounding environment conditions and affecting wellbeing of users. The impacts range from inappropriate use of building spaces and building elements, rapid degradation of durability of buildings and unhealthy and unattractive living and working area for users.

4.1.1. Water delivery system

Drinking water in the town of Dannisa Goro is not delivered to the house via a standardized method. The dwellers have to move outside the building and property boundary to access the water sources. This requires mechanisms to transport the water from the source point to the building and property location. The common method of transporting water is by using 20 liter plastic containers on the back of people and donkey. Most of the time it is the women who fetch water. Dwellers with stable financial capacity use or rent donkey to transport water from the source.

Water is transferred into separate pots and plastic containers for storage. Thus, creating water spills on the mud floor and deteriorates the durability the floor finish material (mud). During the process of cooking water is fetched into smaller containers and transported to the kitchen space. Depending on the house typology, buildings have either integrated or detached kitchen space from the main building. Washing of kitchen appliances is done outside the main building. The wastewater from washing kitchen appliances is disposed on the mud floor finish to let the soil floor finish to absorb the water. The animals used to transport water are kept inside the compound.

4.2. Impact of delayed water and sanitation infrastructure on buildings in Dannisa Goro.

4.2.1. Spatial arrangement

A common residential building in Dannisa Goro town has a wide and large overlapped living and dining space on the front side. The Living room is characterized by a wooden two loaf door extending from a veranda. The Veranda is characterizing buildings as a common styling design tool. The veranda space is used for social gathering and traditional informal functions. The ground floor is stumped soil finish without waterproofing material, making it susceptible to dust, irregular slop and dirt.

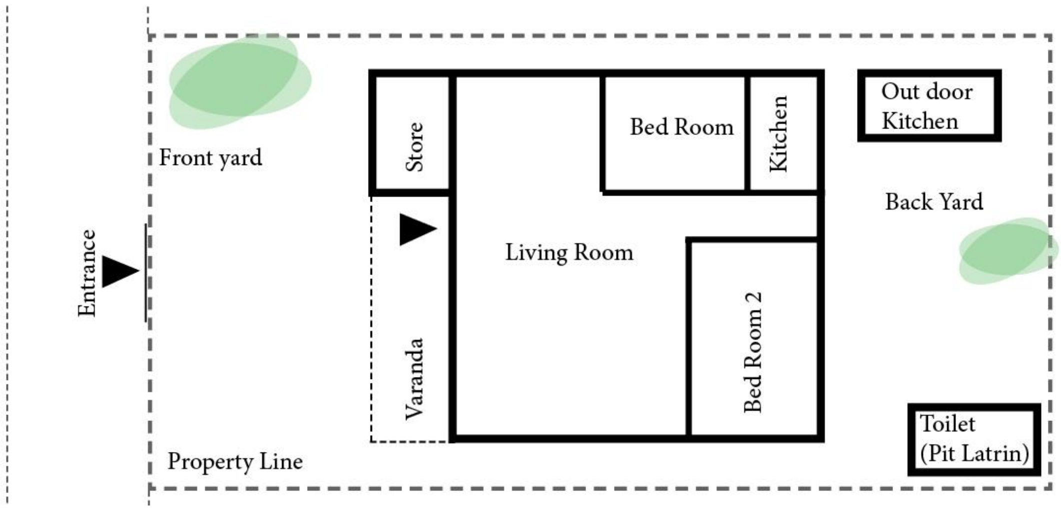


Figure 4- 1: Typical Ground floor typology

Living spaces is commonly 5m x 4m or 5m or 6m wide. This space has overlapping functions. Additional functions as food storage, material storage and semi-cooking function are practiced. During making coffee and cooking water is spilled on the ground on purpose to keep the stumped soil floor finish slightly wet. This is to prevent dust and cracking up of floor finish. Aesthetically not appealing and reduces visual appearance. The side space from the living room are mostly designed as storage room and bedrooms. Most residential buildings integrate 2 bedrooms and 1 storage room which can either be accessed from the outside or inside. There is no visible consideration for integration of any kind of water infrastructure in the living room spaces.

Figure 4- 2: Building condition analysis, Photograph by author, March 2020.

Storage rooms are located on sides of living rooms. In most buildings' storage rooms are accessed from the outside and in rare cases from the inside the space is used to store produces from farmers and farming tools sensitive to store outside.

Kitchen space is located on the back side of buildings. In most cases the kitchen is accessed through the living room by a door. Secondary access and window openings are visible from the back-yard space in almost all the observed buildings. The type of cooking practiced in the main building is relatively requires minor cooking fire energy. The local method of cooking requires large quantities of firewood to be used resulting in heavy smoke penetrating into the other rooms in the house. This has forced the construction of detached kitchen space into the back yard of the compound in most of the observed buildings. The cooking process goes back and forth in both spaces. The other functions include storage space for water collected from different sources for various uses. Spilling of water is common while use and transport, and proper conditions for storage of clean water is missing. The floor finish is stamped mud. This has resulted in wet floor finish and slightly muddy and slippery surface.

Figure 4- 3: Household conditions (a), (b), Photograph by author, March 2020.

The toilet and shower space are built in a separate structure to prevent smell and relatively ease of managing waste. Most observed toilets are pit latrine toilets. Toilet pits are dug and replaced when needed. The pit slab is covered with placed eucalyptus wood sticks. The wood sticks are placed in two directions for stability and nailed. Smaller wooden sticks are then fitted into openings. The walls and ceiling are covered by re used plastic and fiber stretched around eucalyptus wood panels. In rare cases corrugated metal sheet is used as a roof cover. The toilets use minimum quantity of water, as the toilets do not require flushing and water is required for personal cleaning and sanitation. Water is placed next to toilet entrance in small plastic tankers and traditional the proximity of the toilet to the main building has created unpleasant and unwanted smell as location of toilets is constructed very close the buildings due to lack of space.

Shower units are located next to toilet spaces and can basically be characterized as shades. Water is carried to the shower room in water tankers from storage area. The floor finish is mud and with stone pieces laid at proximity as a standing platform. Water is led to drain directly into the ground and in most times diverted as a surface drain.

4.2.2. Building System

The external wall bases are eroded by rainwater and surface drainage as it lacks ditches and retainers. In addition, the base of the walls is not elevated from the external ground level failing to maintain proper elevation and divert surface drainage.

Roof systems on buildings selected for observation do not integrate water conveying systems such as gutters and down pipes. Rainwater collected on the roof runs down on the sides of roofs and erodes wall bases and infiltrates wall finish materials. Surface drainage inside building compound is not designed and constructed properly. Signs of erosion and cracks are seen on the ground surface.

Interior spaces of the kitchen, wall finishes, and base is eroded by contact with water, objects and lacks hygiene and aesthetic values due to continuous spill of water on the mud floor finish. Generally, the lack of proper water infrastructure harms and degrades the durability, aesthetics, and functionality of building systems.

4.2.3. Water Use

Spilling of water on the inside and outside floor of rooms has created unwanted smell and attracts insects. The Transport and use of water for use of domestic purposes such as cleaning materials and building elements, washing cloths and domestic appliance requires mechanisms to transport from the source point to the building. During the dry season water is collected from various water sources. Several types of water transport methods are used depending on the proximity of buildings from the water source. Mid-size plastic containers, jars, traditional water pots and other materials are filled with water and carried by people and donkeys. Residents with proximity to the water holes use carry water by themselves or pay daily laborer to transport water.

The water needed for domestic use stored in kitchen and living rooms. As most of the activities related to it take place outside the main building. Space for washing cloth is allocated outside the building on a back yard. The wastewater from this activity is disposed outside the building on the plain ground, and vegetation.

4.2.4. Results of questionnaire

Results from the socio economic study shows a balanced gender proportion among the population with 55% men and 45% women. The employed status is diverse with 65% involved in farming, 15% trade and 18% daily laborers and construction works. 43% of the population is below 20 years of age and 30% are between 21-40 years of age. The monthly income of the population shows 30% earn about ETB 30004000 per month and 30% earn more than ETB 4000 per month. The average family number is 5.3 persons per household. The socio economic study concludes a young population and skilled personnel for construction work and related tasks is available. The financial status of the population will determine cost and finance for integration of flexible water harvesting system.

The identification of building age helps to identify feasibility of modification for buildings by addressing the aspects of structural integrity, durability and age of construction materials used. In the Pie displays the results of the building age survey. The respondents were asked to identify the date for the completion date for the buildings they own. According to this survey 5% percent of the buildings are five (5) years old, 35% percent of buildings are three (3) years old and 60% percent of buildings are four (4) years old. The results show all buildings are at a very early age of use.

The status of financial capital of the residents will determine affordability range of any kind of infrastructure design and its implementation process. Thus, the possible amount of investment towards realizing and the afterward process of maintaining the new water infrastructure can be determined. The results show the monthly total income of the families. 10% of respondent families earn less than 500 ETB per month, 5% earn between 500-1001 ETB, 10% earn between 1001-2000 ETB, 15% earn between 2001-3000 ETB, 30% earn between 3001-4000 ETB, 30% earn more than 4000 ETB. In total, 75% percent of respondents earn more than ETB 2000 per month.

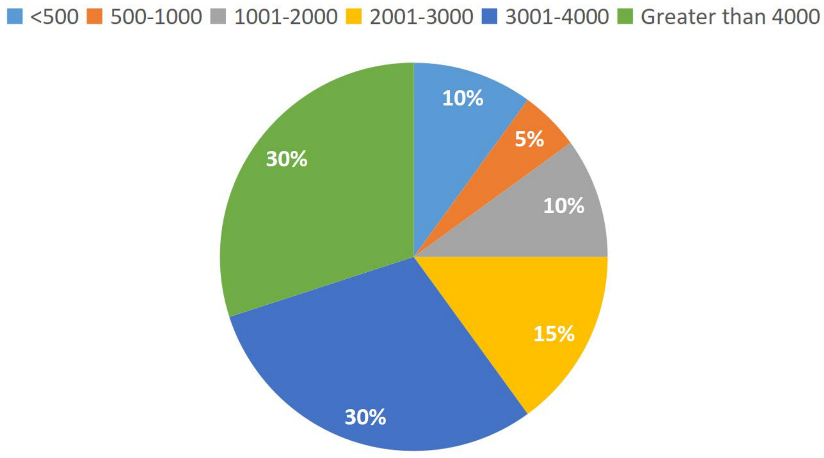


Figure 4- 4: Household Income per month (ETB)

There are various sources of water in the town of Dannisa Goro town. The responders identified the sources of water according to frequent level of use. The respondents choose between the bore well/hand pump, Community well and spring water that are available in and around the town. The results will help suggest a better alternative. According to the survey 100% or respondents use the bore well/hand pump for water source, only 35% use community well and only 25% use spring water.

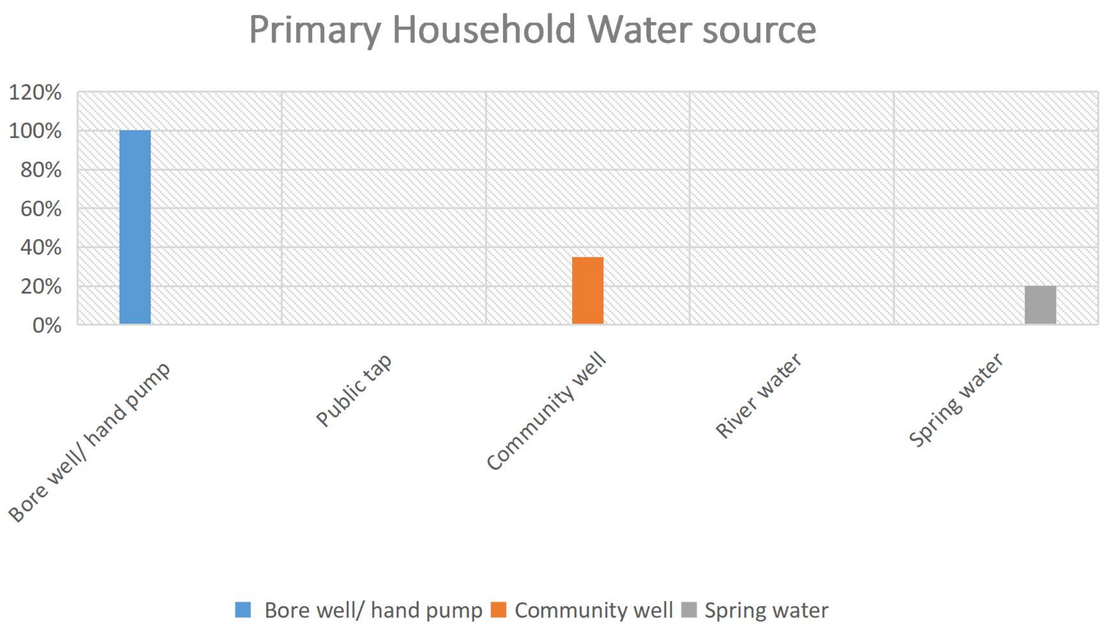


Figure 4- 5: Primary Household Water Source

Based on the above result the bore well/hand pump is the primary source of water. Average distance and proximity from respondent's residential location is calculated to be 1.89 kilometers. And the average time required traveling to the source of water and back to the building is 95 minutes. Access to water is subjected to extreme effort specifically to women and children and is quantified into taking more than 1 hour a day.

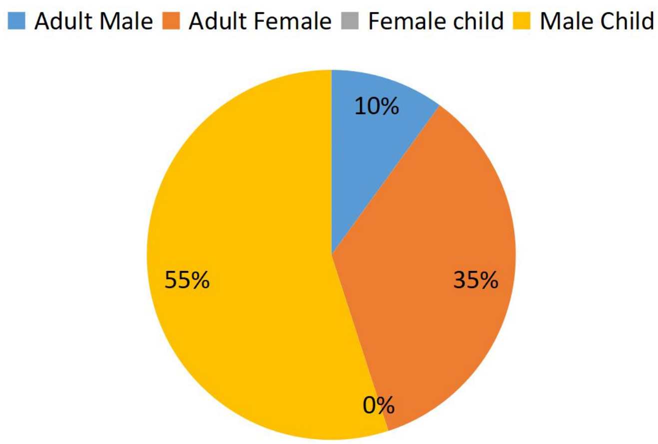


Figure 4- 6: Frequency of water transportation

Water is transported into the buildings is carried by the dwellers. The frequency of fetching water from the water bore wheel/hand pump to the buildings is undertaken by varying age groups and social gender. The researcher classified social groups into four: adult male, adult female, male child and female child. 55% of households told male children fetch water most of the time, followed by 35% adult male followed by 10% Adult female and 0% by female child. The reason given for this is the water well demands extreme physical effort to use the mechanical apparatus to pull water up. In addition, the Water Wheel has broken down Several times at a frequency of at least once every six (6) months. All respondents told the water Wheel has never been fixed on time when it broke down and is not reliable source of water.

Public tab is the second source of water. The average distance from the water source to the building is 1.8 kilometers. This distance includes both cycles of going to the water source and coming back to the building. The average time required to travel the given distance and back is 90 minutes. Access to water is subjected to extreme effort specifically to women and children and is quantified into taking more than 1 hour a day.

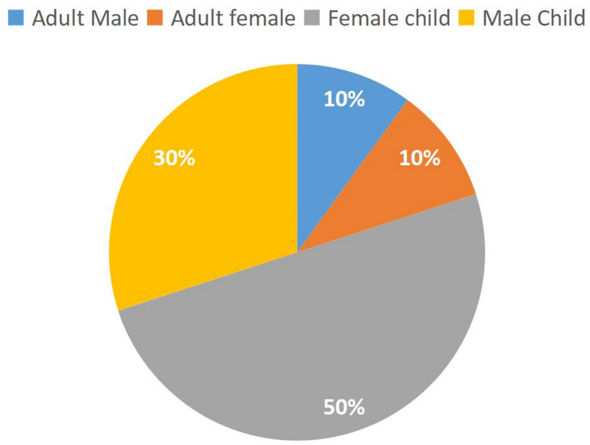


Figure 4- 7: Frequency of fetching water

In comparison to the primary water source discussed above, the frequency of fetching water from the public tab has a significant difference. Based on the result 50% responded female children fetch water, followed by 30% male children, 10% adult males and 10% adult females. In addition, the respondents told the Water Wheel has broken down Several times at a frequency of every three (3) months. All respondents told the water wheel is not fixed on time when it breaks down is not a reliable source of water.

The spring water is a group of seasonal springs surrounding Dannisa Goro town and serves as source water. The average distance from the building to the water source and back to the building is 2.8 Kilometers and takes an average time of 175 minutes (Includes distance travelled fetching water and distance travelled back). The respondents suggested the Water source does not give service half the year because it dries out and is not reliable source of water.

Water use varies in different regions due to its use for specific activities. The household water use study has identified common task performed according to the local context. All households use water for drinking, cooking, bathing, toilet and washing. 35%of households use water for vegetation and 20% of households use water for other tasks. Water use has significant similarity to the water use in other parts of Ethiopia and a new water infrastructure system has to address demand of water for the uses.

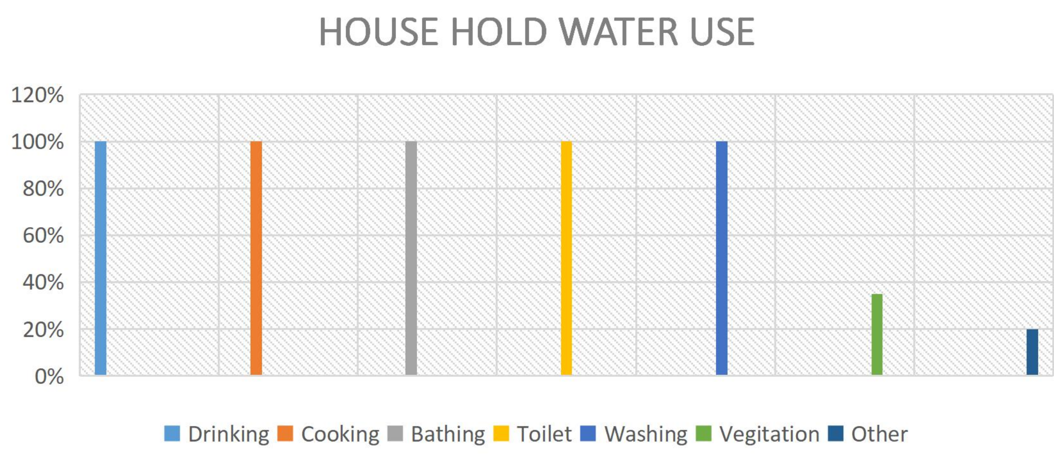


Figure 4- 8: House hold water use

The specific amount of water used by dwellers for specific tasks purposes is required to determine the quality and quantity of water for a new water infrastructure system. The chart below shows 5% of water is used for drinking, 10% percent of water us used for cooking, 25% of water for bathing, 15% of water toilet, 30% of water washing, 5% of water vegetation and 10% of water for other duties.

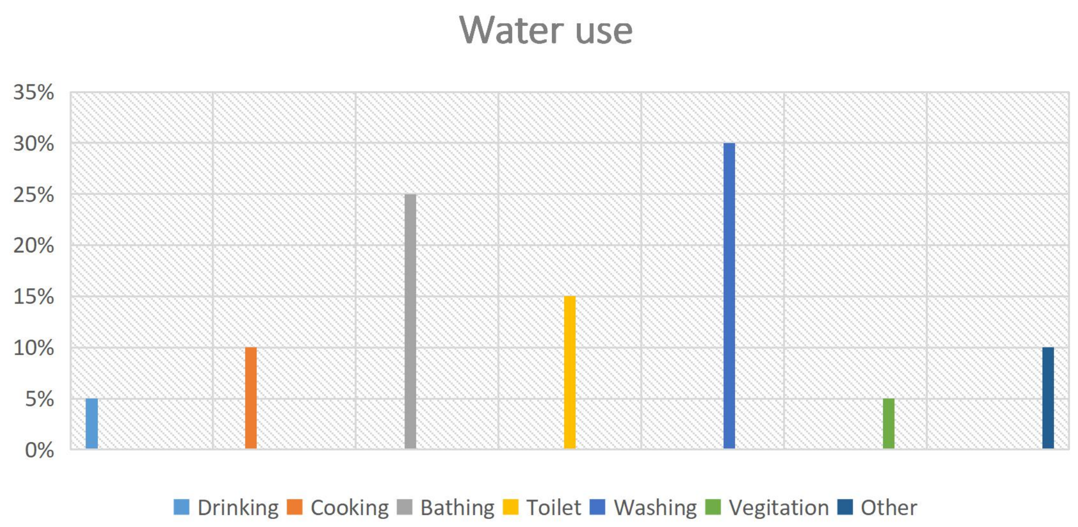


Figure 4- 9: Household water use

Water storage is an essential tool for proper water use and utilization. The different water storage mechanisms have positive and negative impacts. The respondents were asked to list kind of water storage mechanism is used. 47% of respondents use 20 liters plastic container to store water, 33% use tradition pot and 19% sue buckets. There is a culture of storing water for further use is common among the dwellers. It is those very traditions and social roles that will determine the successful implementation and use of a rainwater harvesting system.

95% percent of the sampled population say the only the three local source of water mentioned above. For the rest 5% of the population approve of buying bottled water from nearby town of Ginchi when the need arises.

The literacy level of the local community is essential for the construction, application and maintenance of a new water infrastructure. The researcher asks if there is a knowhow of a rainwater water harvesting technique practiced. The result from the respondents shows 85% of respondents have information about water harvesting systems and 15% of respondent have no information about water harvesting systems.

Water use satisfaction studies the perception of residents towards the current water supply systems. The respondents were asked to describe the water supply in four options, excellent, very good, bad and very bad. 75% of respondents stated the water supply systems are in a very bad condition and 25% stated it as bad. The current water supply methods need improvement or a new water system.

Access to water is surveyed by asking respondents to explain the process to access water sources and then selected graded the process in one of the four sets of choices: Very demanding, demanding, convenient and very convenient. 86% respondents described the process very demanding and 14% demanding. The current water supply methods need improvement or a new water system.

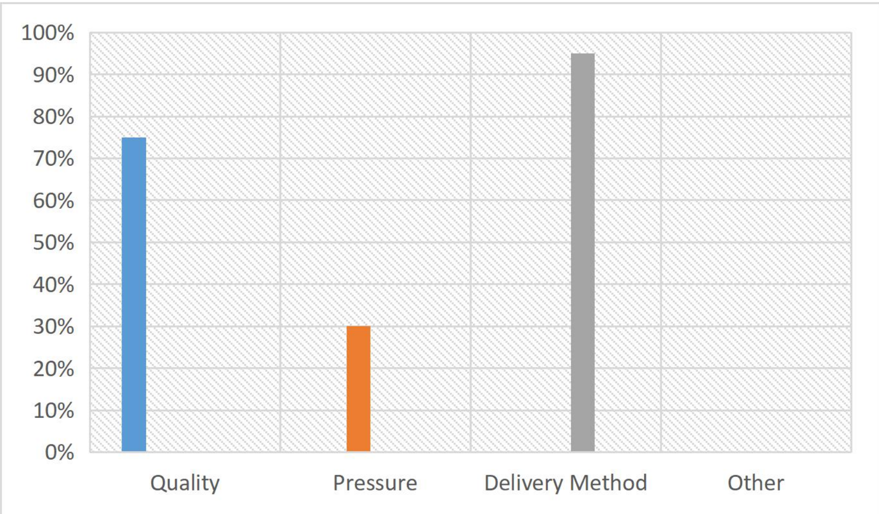


Figure 4- 10: Improvement aspects of water supply

The implementation of a water infrastructure system requires addressing the financial capacity of users and their willingness to financially contribute. The survey for the willingness to contribute financially for the new water infrastructure shows 95% of respondents agree to financial contribution while 5% of respondents are unwilling.

As continuation of the above result, the respondents were asked the maximum amount of financial support dwellers are willing to contribute for the new water infrastructure system and the result shows minimum financial contribution is ETB 5000 and maximum ETB 25000. The average range of contribution by all is ETB 12500.

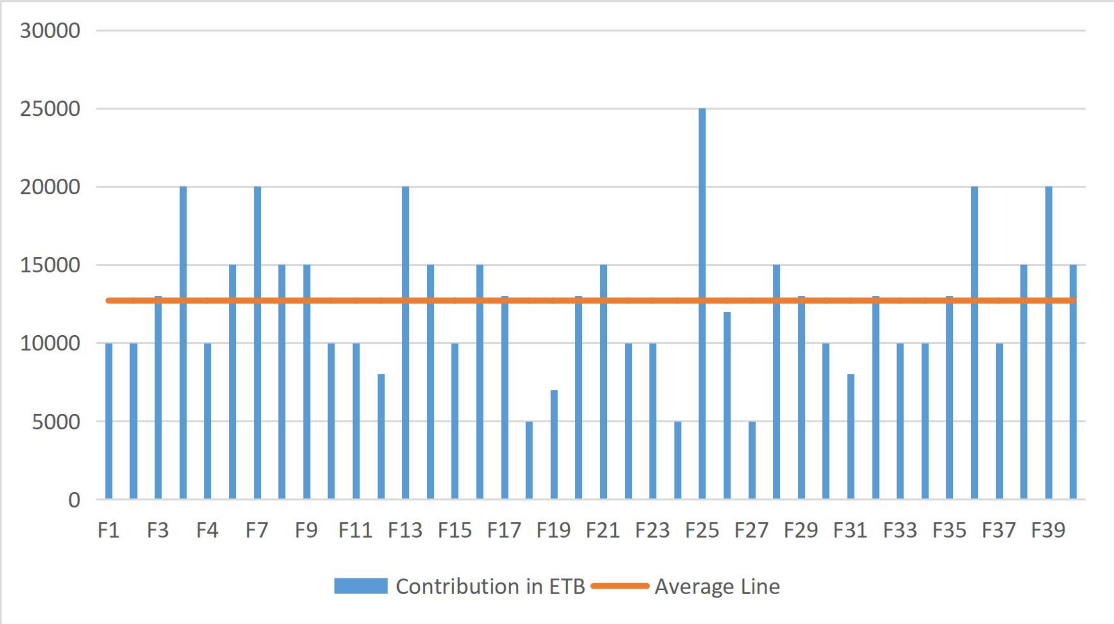


Figure 4- 11: Average range for financial contribution

The willingness of dwellers to allow their buildings to be modified for the purpose of integrating new water infrastructure systems into buildings is studied. After the explanation about the importance of water infrastructure integration into the building systems, the researcher asks if dwellers approve and modification. The result shows 95% percent approval and 5% disproval for the modification of buildings.

Base on the above result the researcher has surveyed the extent of modification the dwellers will allow on their building systems. The result shows the allowable level of modification that will be undertaken on the building for the purpose of integrating a new water infrastructure system. The result from the questionnaire shows 90% of respondents are willing to allow 25% modification to their buildings while 10% will allow 50% modification.

Willing to share several types of water infrastructure was part of the questionnaires. Willingness to share new clean water infrastructure with neighboring buildings resulted in 10% disapproval and 90% approval.

The survey to study the acceptance to share the clean water for domestic use and shower units shows 15% approval and 85% disapproval.

The survey to study the acceptance to share to share toilet and waste management infrastructure shows 92% percent disapproval and 8% approval.

4.3. Integration of water and sanitation infrastructure with a local building system.

4.3.1. Available Resources

Eucalyptus wood forest is found in the surrounding area with already existing skills to use for it building construction. Stone, mud and clay soil is abundant for various uses including building construction. Corrugated metal sheet panels are widely used and easily available for use from nearby market areas and Addis Ababa. Related construction materials and appliances can be easily found at nearby markets.

Figure 4- 12: Dannisa Town, residential building typologies and local building system, Photograph by author, March 2020.

Figure 4- 13: (a)Incomplete buildings (b)Eucalyptus tree forest, Photograph by author, March 2020.

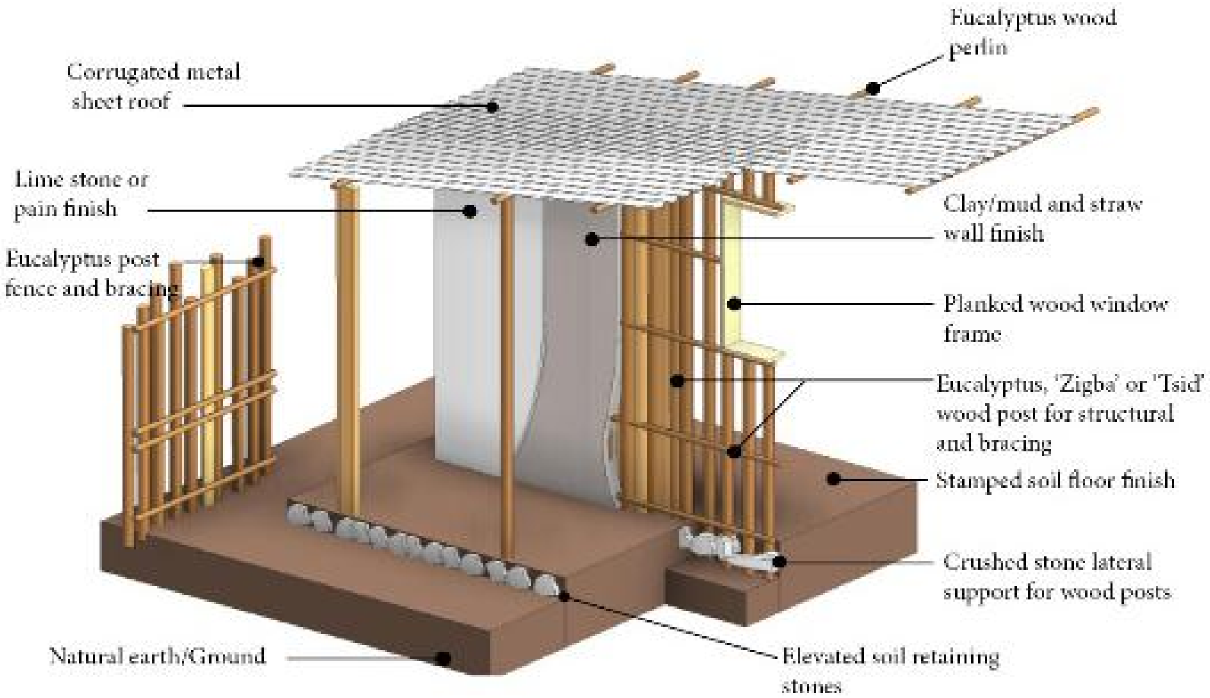


Figure 4- 14: Local building system in Dannisa town

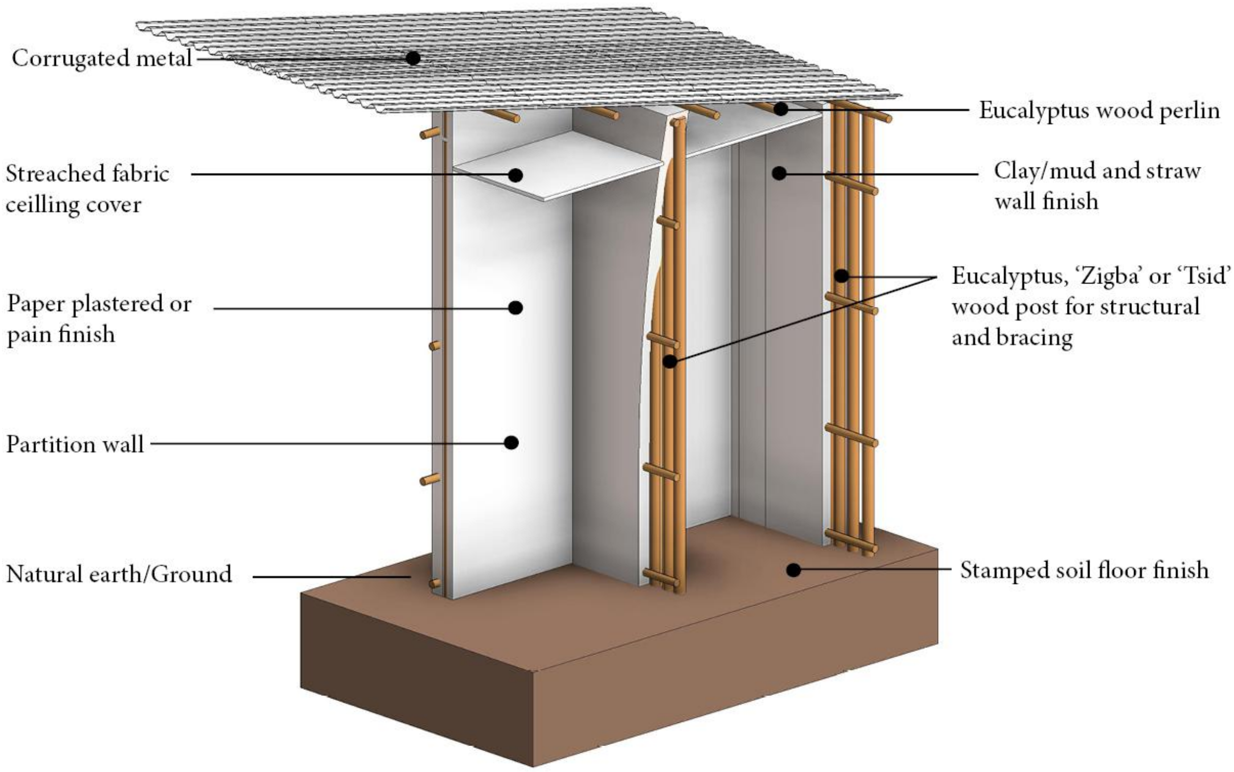


Figure 4- 15: Local building system in Dannisa town

Local and less clean water supplies can be used to match the water demands by enhancing the quality using treatment and variety of processes and can be used for several purposes like drinking, hygiene, vegetation, sanitation services. The quality of all supplied water has to be dictated by the most stringent requirements, specifically for potable water (Hermanowicz, 2005). Hermanowicz, (2005) states the process of achieving advanced and more complex technical solutions is realized through integrating water withdrawal, conveyance, treatment, and waste disposal is through progressive sustainability.

4.3.2. Flexible Water harvesting systems

Rainwater harvesting technology is used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques. Rainwater harvesting has been practiced for more than 4,000 years, owing to the temporal and spatial variability of rainfall. It is an important water source in many areas with significant rainfall but lacking any kind of conventional, centralized supply system. The application of appropriate rainwater harvesting technology is important for the utilization of rainwater as a water resource (Milagros, 2007).

4.3.3. Components of Water Harvesting Systems

There are three common systems used to collect water for domestic use: roof catchments, ground catchments, and rock catchments (Sharafaddin et al., 2017).

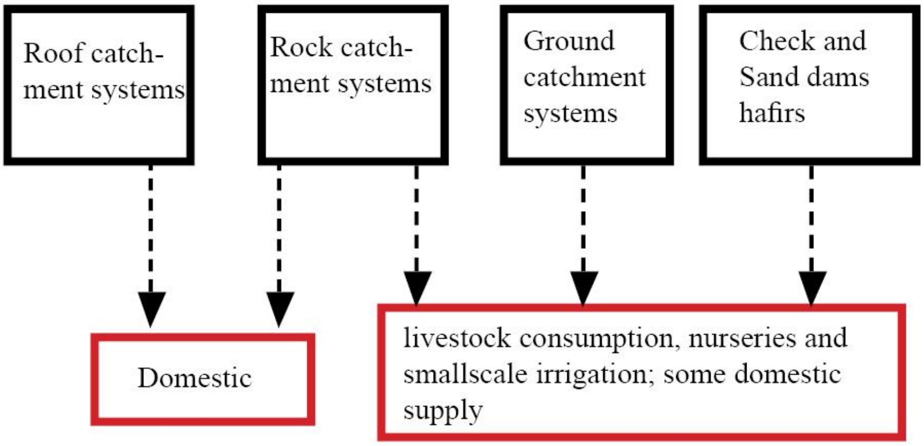
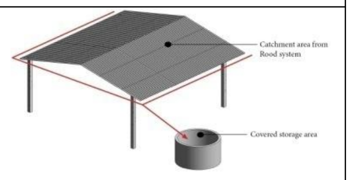
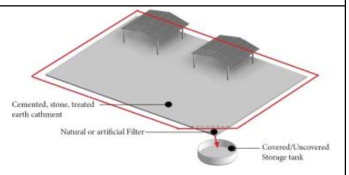


Figure 4- 16: Water harvesting systems and their use, Sharafaddin A. et al, 2017

According to Sharafaddin A. et al. (2017) rainwater harvesting systems are classified as follows:

Table 4- 1: Rain water Harvesting Systems, Sharafaddin et al. 2017

No.	**Types**	**Description**	**Diagram**
1.	Roof Catchments	- The roof of a building or a house is a choice for a catchment installation. -Water quality is related to the roof material, climatic conditions, and the surrounding.	
2.	Rock and Ground Catchments	-Where water quality is of less -Approach promotes the use of runoff water. Can be stored in ponds or underground tanks.	

4.3.4. Water Delivery System

Different types of delivery system are used to transport water from catchments to storage reservoirs, including gutters (drainpipes), glides, downpipes, and surface drains or channels. Care must be taken to ensure they are appropriately sized and installed around the entire roof catchment area and the building system. Filters should only be used if they can be easily cleaned, as they might otherwise become clogged, preventing water from being collected.

Table 4- 2: Water Delivery Systems, Sharafaddin et al. 2017

No.	**Types**	**Description**
1.	Gutters and Downspouts	-capture rainwater running from the eaves of a building, half-round PVC, vinyl, pipe, seamless aluminum, and galvanized steel can be used
2.	Leaf screens	-keep debris out of a rainwater harvesting system. Include leaf screens, funnel-type downspout filter, strainer baskets, cylinders of rolled screen, gravel, sand and mesh filters.
3.	First flush system	-Separate first flush water from the systems to dispose contaminated water to prevent it from entering the storage tank.
4.	Filtration systems and settling tanks	-To treat water before, during, and after storage. Simple trash racks, Sand filters, settling tanks and partitions are used to remove silt and other suspended solids.
5.	Storage tank sitting	-Storage tanks should be located as close to supply and demand point, protected from direct sunlight. -Tank has to be elevated to reduce the load on the pump, tank inlet is lower than the lowest catchment downspout.
6.	Storage tanks	-Painted white to keep the water inside cool, preventing bacteria growth, white-washed annually. Tank must remain permanently covered and sealed.
7.	Overflow pipe	-Allow the safe disposal of excess rainwater and to prevent flooding. Overflow water should be drained away to a pit, plant, or storm water drain.

4.3.5. Conclusion

1. The impact of delayed water and sanitary infrastructure on buildings in Dannisa Goro has negative implication on social, economic and. well being of the community. The lack of basic services and the unavailability of water infrastructure is the main characteristics of buildings in Dannisa Goro and has resulted in misuse of interior and exterior spaces during use, caused early degradation of building parts and construction materials, reduced architectural value and pollution of the external environment around buildings. Besides, according to the UN habitat criteria all buildings in Dannisa Goro are identified as slums. Existing and future buildings should be integrated with flexible water and sanitation infrastructure systems to create a livable urban area and natural environment. Thus, planning of water infrastructure has to be a basis to plan future small towns or urban centers.

The process fetching water is time consuming and physically tiring. and the results from the questionnaires show 85% of respondents claim accessing water is very demanding and 15% claim as demanding. In addition, the average distance to travel from the building to the water source and back to the buildings is 1.89km, 1.8km and 2.8km respectively for the bore well/hand pump, community well and spring water. Also, the process of transporting water has created disproportional responsibility on children and women in particular, hampering them from education, health or development. In addition the results from the three separate surveys on frequency of fetching water for each of the three types of water sources shows similar results.

2. The integrating water and sanitation infrastructure in local building systems requires modification to the existing building system. The maximum extent of demolition for the purpose of modification to the existing building systems should not exceed 25% and modification should not alter structural stability of the building system. Measures should be taken to avoid demolition of columns, structural walls, post and foundations, internal partitions can be modified when required and the structural material (eucalyptus post) can be reused for the redesigned partition walls. The back yard spaces can be converted into a location for water storage tankers and waste water drain fields.

Transition to a flexible water and sanitation infrastructure is context specific and requires holistic management of an integrated water cycle. Water use should be strictly fit for purpose only and delivery of water infrastructure has to be through decentralized infrastructure, and the integration of water with urban planning needs to be implemented at initial stages to facilitate a faster transition. The shift towards more sustainable modes of production and consumption of water can take place over multiple years within the domains of technology, economy, institutions, behavior and culture.

3. A flexible water harvesting and utilization system identified to integrate in local buildings is a rainwater harvesting system. Roof catchment systems are not technically complicated to construct by using the local construction skills and materials at the case study location and the cost is minimal. A group of households can also construct communal large-scale catchments in phasing and incremental steps. Nevertheless, the system is flexible, has low running cost, constructed from locally available building materials and requires minimal space can meet the demands of most small Ethiopian towns. Thus, rainwater harvesting technology is suitable for use in all areas as a means of augmenting the amount of water available. This presents a maximum setting to integrating the system to existing buildings, neighborhoods and future planning of new towns.

4.3.6. Recommendation

Systematic Approach

Flexible Rainwater utilization, together with water conservation and wastewater disposal, should be incorporated into planning regulations for future application in small towns of Ethiopia. In addition, it is appropriate to standardize the design of integrated rainwater utilization system with building system designs as a pre-condition. This will increase the resilience of towns towards climate change and environmental degradation.

Implementation strategy

As small emerging towns in Ethiopia are financially incapable of single handedly covering the cost of new flexible water infrastructures, implementation policies should be established to make rainwater utilization and other measures a part of the social system. Academic institutions, local governments and non-governmental organizations must take the initiative to promote the concept of rain water utilization and promote the system. Consideration should be given to subsidizing facilities for rainwater utilization. In addition, for poor countries like Ethiopia decentralized systems like this can replace high cost of municipal water lines and divert resource to other infrastructure projects.

Technology Development and local training

Supporting local technology and utilizing human resources to support rainwater utilization is very important. The local unemployed youth can be skilled to grasp the technology and devices to construct and maintenance. It is also important to promote the development of efficient and affordable devices to conserve water. While allowing local skills to master the new technology, use of locally available construction materials should also be explored.

4.3.7. Integration Approach

The integration process of building systems and water infrastructure is proposed to be implemented at various scales. The scales for integration include town scale, neighborhood scale and building-unit scales. These scales integrate specific types water infrastructure mechanisms with built environment. The diagram below illustrates the systematic approach and plan.

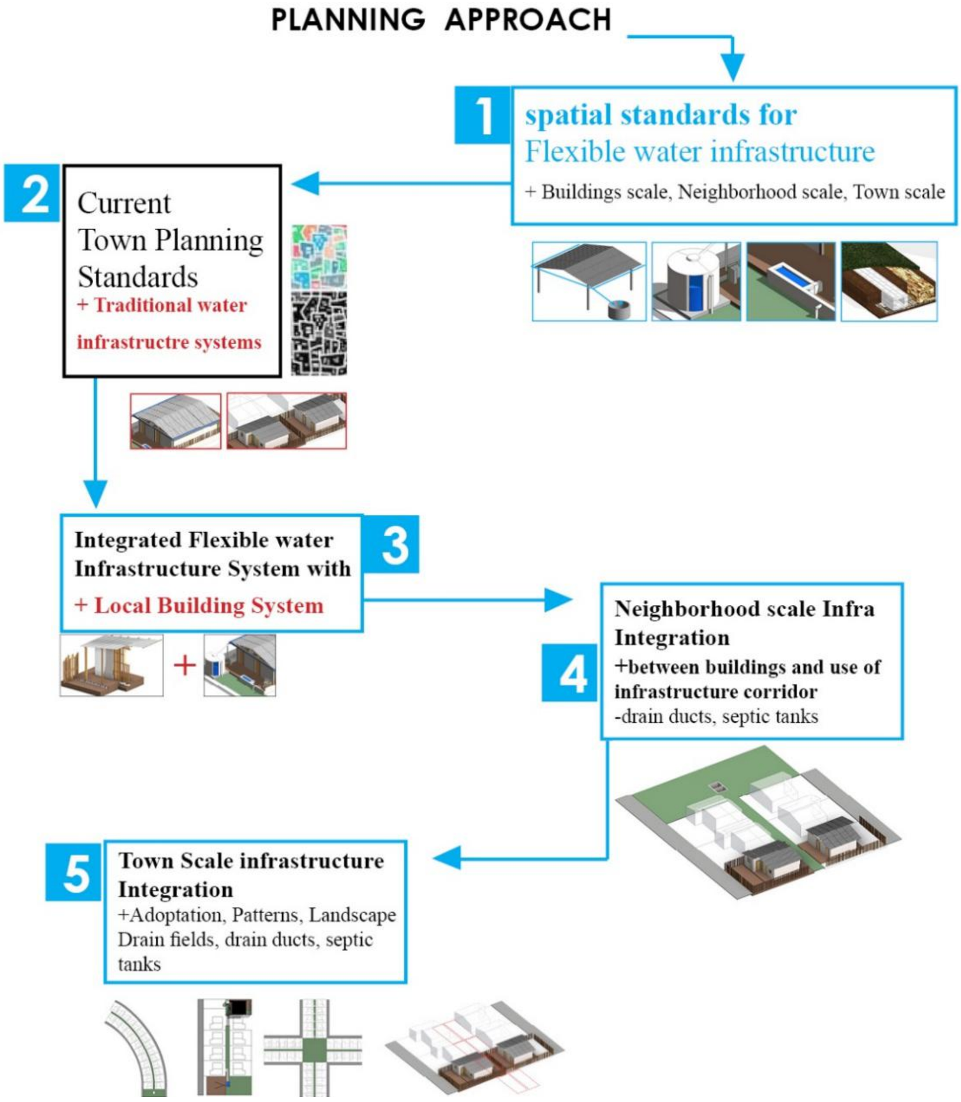


Figure 4- 17: Planning Approach

4.3.7. Physical integration Approach

1-Buildings and properties in the town of Dannisa Goro incorporate an open space at the back buildings. The buildings are fenced off by eucalyptus post from rear adjacent property. This rear side space is used for various flexible functions such as washing clothes, storage and animal staples. This space extends from the real wall of buildings up to the property line fenced by eucalyptus wood post.

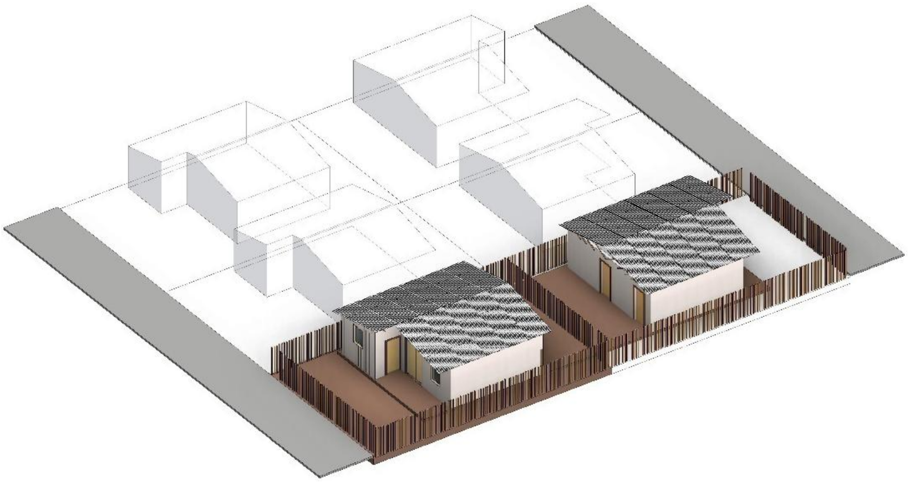


Figure 4- 18: Building arrangement

2-The infrastructure integration proposes the rear open space of buildings to be as water mitigation and storage spaces. Open space in separate properties (marked in red broken lines) is proposed to be converted into a system accommodating water storage tanks and water conveyance system. This space will accommodate water storage tanks and water and waste conveying duct systems.

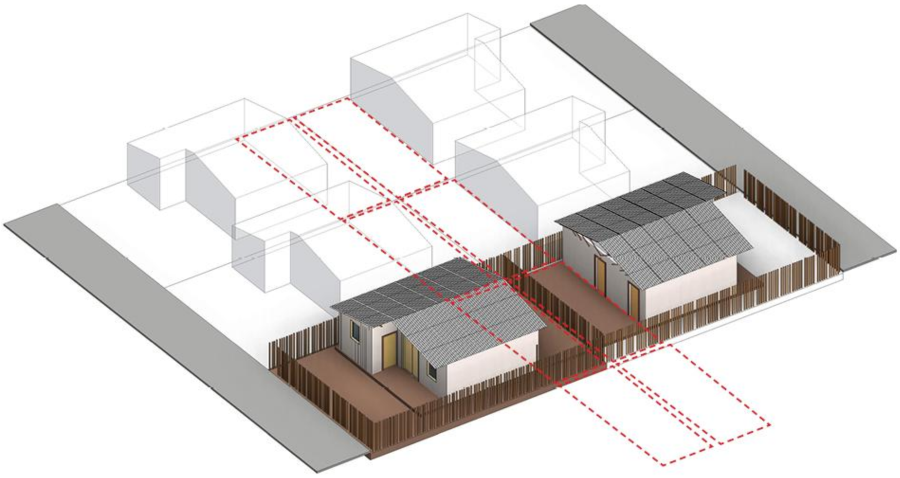


Figure 4- 19: Individual backyard open space

3-The connected back yard open spaces are converted into one elongated infrastructure line Incorporates ground catchment drain field, Septic tank, Discharge sections and distribution boxes. The waste water conveyance ducts system will stay underground disguised by greenery and vegetation on top, keeping the green and enhancing the ecosystem.

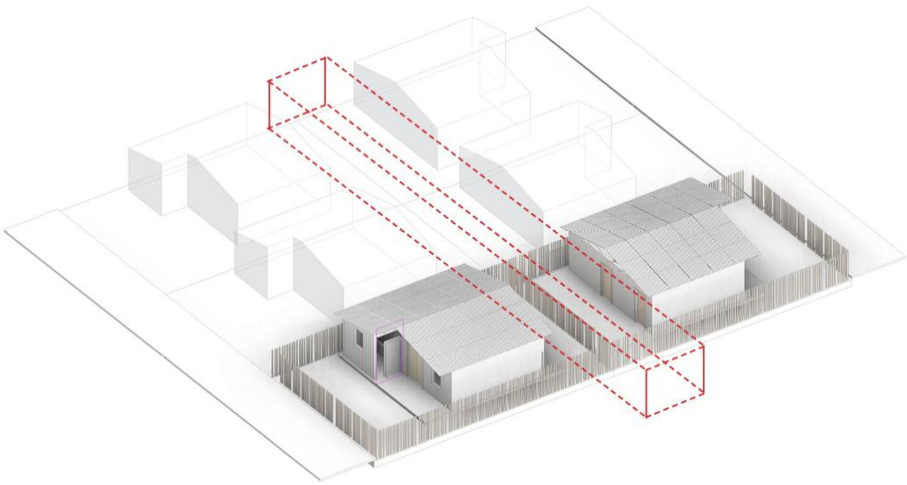


Figure 4- 20: Connected backyard open space

4-At a town scale there will be distributed and decentralized drain fields. The drain fields are allocated as discharging stations with the intention of in taking waste water from the septic tanks of neighborhoods. The green corridor will convey wastewater directly from buildings into septic tanks via underground sewage line constructed from stone and concrete. The drain charge is an underground system constructed from perforated tubes designed to discharge grey water into the underground. The drain charge area will keep the ecosystem intact can accommodate entertainment functions.

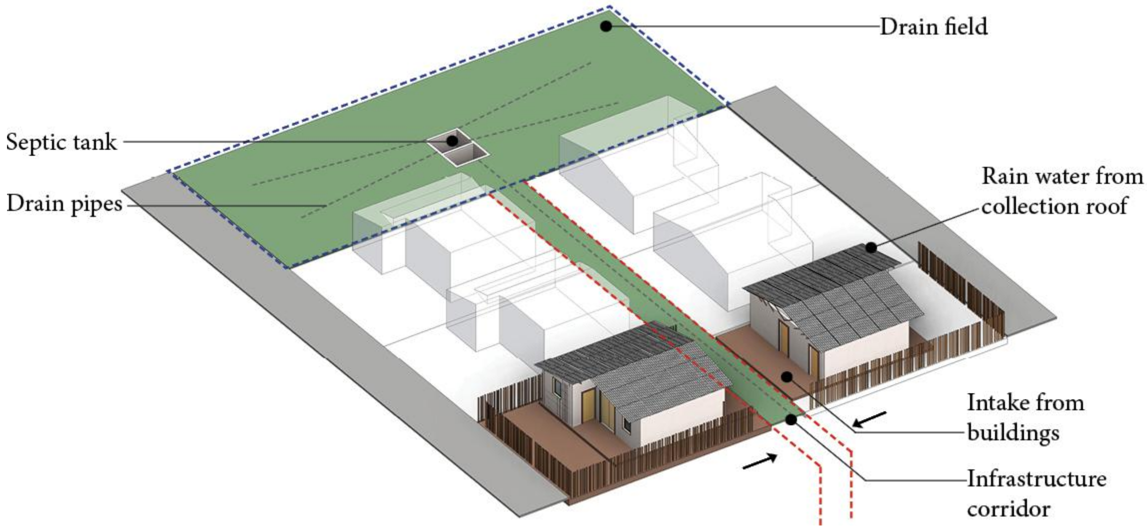


Figure 4- 21: Water infrastructure and Building integration at different scales

4.4. Flexible water harvesting and utilization for residential buildings in Dannisa Goro town.

4.4.1. Design Guidelines

Modification of existing building systems for the purpose of integrating flexible water harvesting systems must be in the range of 25%. The modification should not alter structural stability of the building system. Measures should be taken to avoiding demolition of columns, structural walls, post and foundations. Internal partitions can be modified according to need. The structural material (eucalyptus post) can be reused for the redesigned wall. Back yard spaces can be used to store water tankers and waste drain fields.

Future planning should integrate flexible spatial standards to accommodate flexible water infrastructure integration. Spatial standards at unit scale, neighborhood scale and town scale should be mandatory in small town of Ethiopia.

All systems need to have a guttering/conveyance system (galvanized metal sheet or half PVC pipe) that drains rooftop runoff to a fine filter (to filters out contaminants) before the water reaches the storage tank. The water can be stored compound site, above or below ground levels. It is recommended not to place the water tank below ground level to avoid use of pressure pumps. To make use of gravity the water tank should be placed above at a higher elevation than the building.

Make a proper site study and analysis to determine whether an above or below ground tank is the best option. To determine the tank size, prepare a correct data for rainfall and roof area as shown on the next chapter. There should be a frequent water quality check to determine the water treatment system that is most appropriate for the home's potable needs.

The back-yard Space in buildings is ideal location to integrate rainwater harvesting systems. Water storage tanks require a stable foundation. The foundations can be constructed from locally available stone. Several options for water storage tanks are available. The researcher recommends plastic tankers or ferro cement due to ease of access of construction materials and availability in local markets.

There needs to be consideration for phasing and incremental growth strategies to apply flexible water infrastructure technologies on different scales. A flexible water infrastructure for Building units can integrate with surrounding buildings as the system demand grows. This will facilitate cost effective and efficient physical infrastructure provision by sharing some facilities

4.4.2. Prototype Design

4.4.2.1. Calculation of water requirement per day per household size

The concept of providing water of a specific quantity needed for a specific use, rather than simply providing adequate quantities of water for all uses is the most important aspect of a sustainable water supply system.

-Average family number of a selected neighborhood in Dannisa Goro town is 5 people, each family member is estimated to use 15 liters of water per day (MoH, 2001; Ali and Terfa, 2012).

-Amount of water required daily = 5people x 15 liters.

-Amount required for the six (4) months (October, November, December January) = 5people x 15liters x 120 days=9000 liters

-The volume of water storage(tank)should be 10% larger to provide allowance. This is to compensate for the dead storage at the bottom where heavier particles collect and a top space for air circulation.

Additional storage capacity is = 10% x 9000 liters = 900 liters

=900litetrs + 9000 liters = 9900 liters = approx. 10000 Liters

4.4.2.2. Roof Catchment Area

Residential units in the selected site of Dannisa Goro have an average of 56 m2 area.

Roof catchment area is =56 m2

1mm of rainfall on a hard roof (corrugated metal sheet roof), the total volume of runoff = 1 Liter

Therefore, for an average annual rainfall of 1018mm (Dannisa Goro). The amount of water that can collected from 56 m2 area of rood in one year would be = 56 m2 x 1018 mm

=57008 Liters

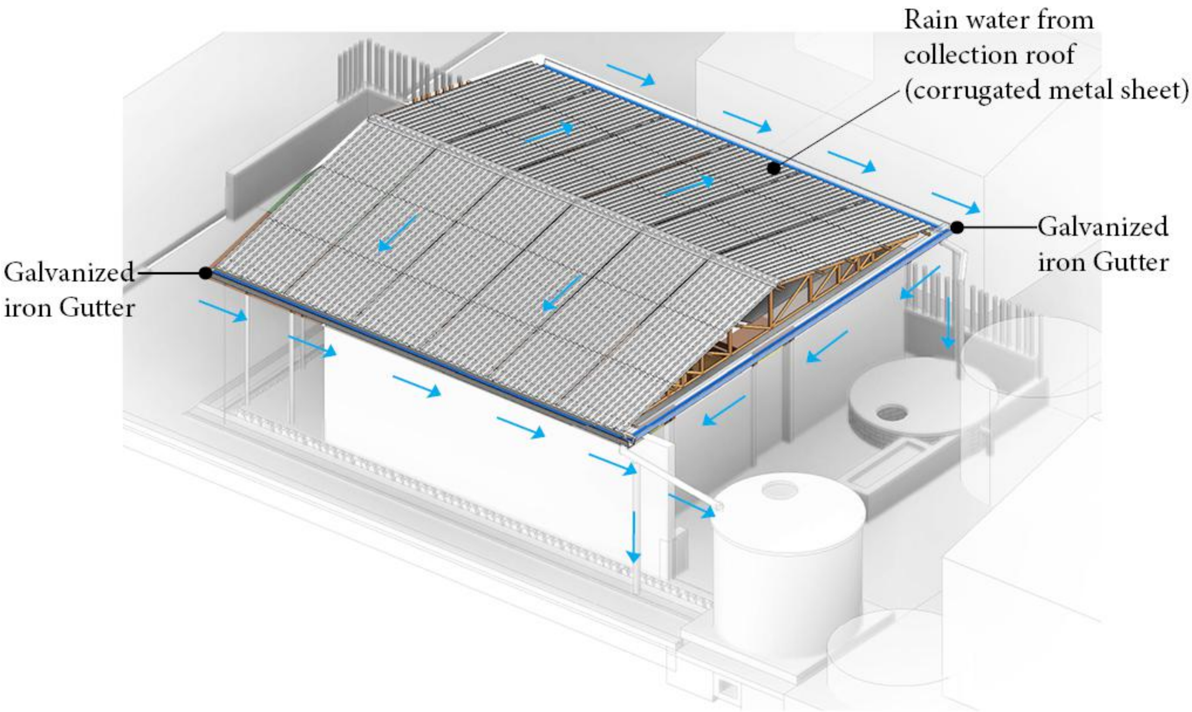


Figure 4- 22: Roof catchment area

4.4.2.3. Guttering

1-Gutters can be constructed from galvanized iron sheet metal.

2-The slop of the gutter towards the water tanks should be such that there is a drop of about 10 cm for every 10 m run.

3-The end of the gutters towards the tank should be provided with a down pipe and a purpose made first flush system.

4-The ends of the gutter should be blocked with stoppers to reduce water loss.

5-Gutter support bracket, gutter downpipe clips accessories are used.

4.4.2.4. First flush system

First flash diverters require draining first flush water (dirty water of rain) volume following each rainstorm.

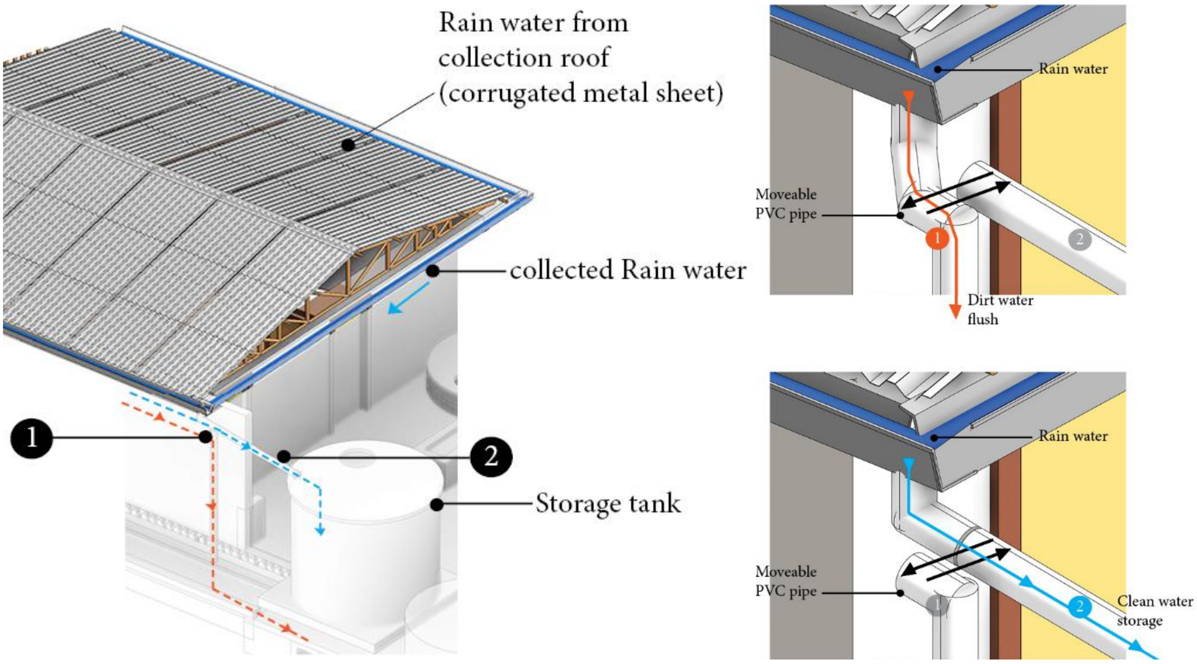


Figure 4- 23: First flush system(a) and details(b)

4.4.2.5. Water quality management

The process of water quality management includes use of filtration screens to prevent debris, leaves, insects, and rodents from getting into the water storage tank, regular cleaning of conveying system and water storage tanks (every start of rainy season), minimize light penetration to avoid growth of algae and other organisms. Disinfect water with chlorine to make safe for drinking.

4.4.2.6. Water storage tanks

There are different types of water storage tanks available. Ferro cement tanks, Reinforced concrete and masonry tanks and plastic tanks can be viable in the local context. Selection for the types of tanks considers cost, feasibility by local construction skills, availability, complexity of construction methods, use of heavy equipment and durability. Based on this plastic and ferro cement water tanks are proposed by the researcher.

Advantages of Plastic water tanks

A plastic water storage tank has many advantages. There are no joint leakages, does not rust, ease of maintains water quality, ease of cleaning and installation, available in required sizes, readily available in the market, water taste and color does not change and can last for more than 30 years if well maintained.

Advantages of ferro cement water tanks

Tanks made of ferro cement are crack-resistant, light weight, can fit into smaller spaces, low technology, less complex construction methods and less skilled labor and cheaper than reinforced concrete and masonry water tanks.

Additional storage capacity is = 10% x 9000 liters = 900 liters

=900litetrs + 9000 liters = 9900 liters = approx. 10000 Liters

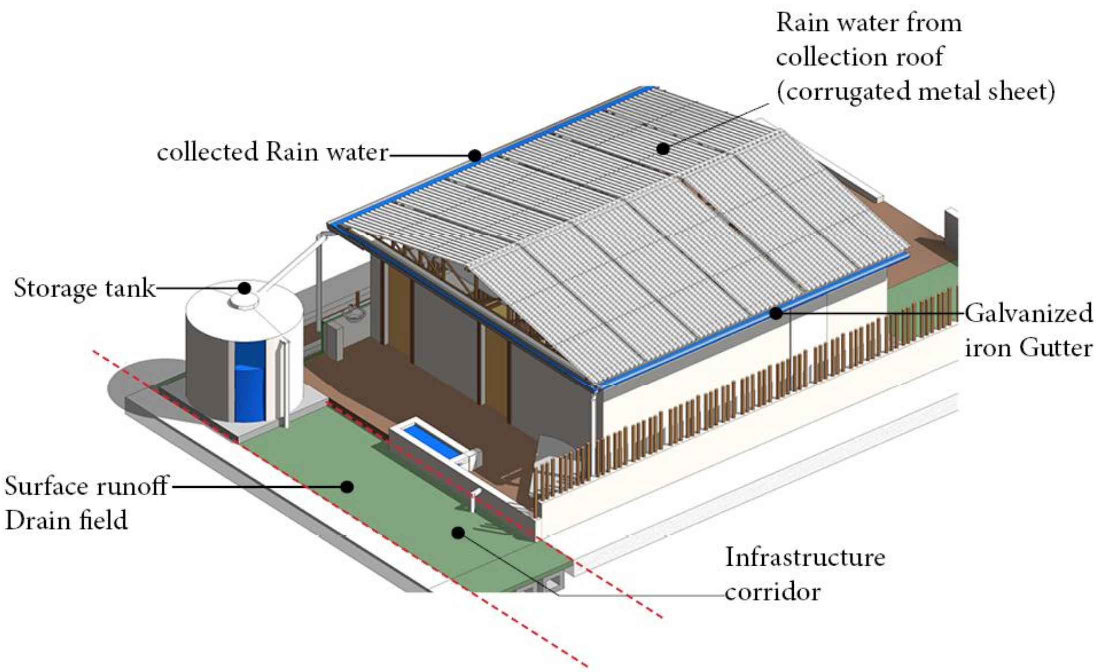


Figure 4- 24: Water infrastructure and building integration at unit and neighborhood scales

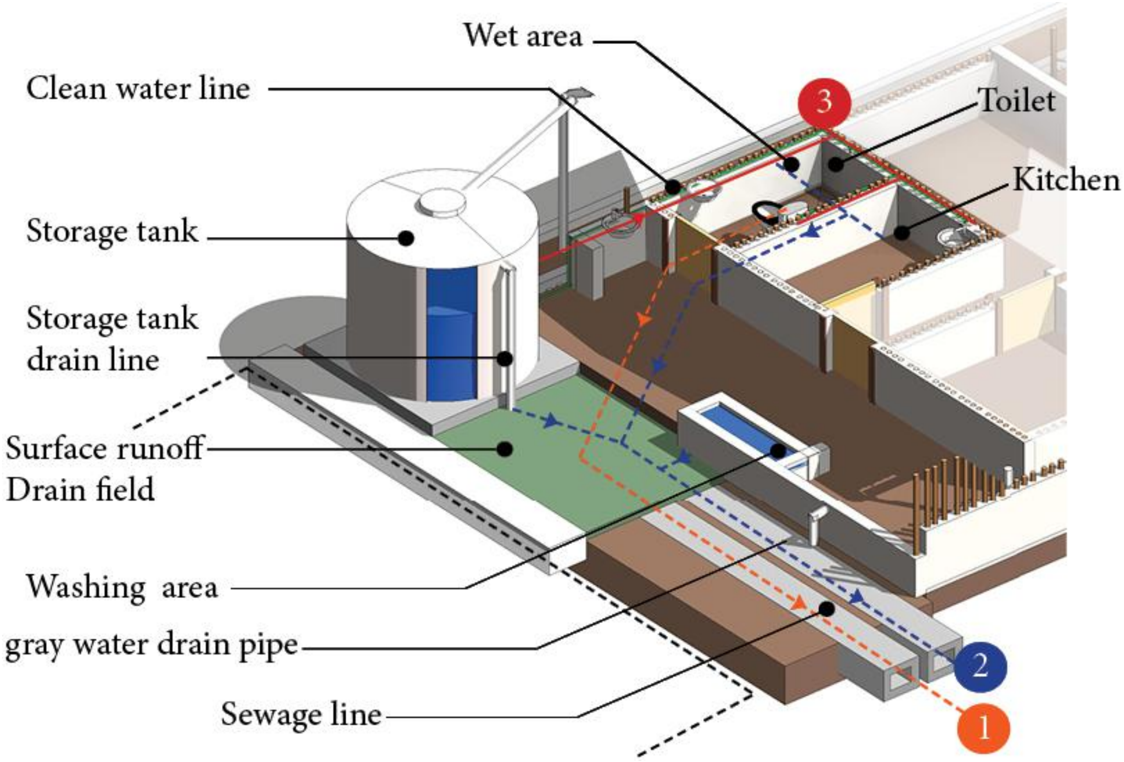


Figure 4- 25: Water infrastructure details

4.4.2.7. Sanitary Infrastructure

A. Option 1

The toilet is integrated with building system. The individual septic tank is partially dug into the building perimeter removing some portion of non-structural part of the wall. The septic tank structure is constructed from burned brick and plastered with cement. For maintenance purposes septic tank is accessed from the outside. The draining pipe uses perforated PVC pipes placed on gravel screed and extended into the drain field (Infrastructure corridor) underground.

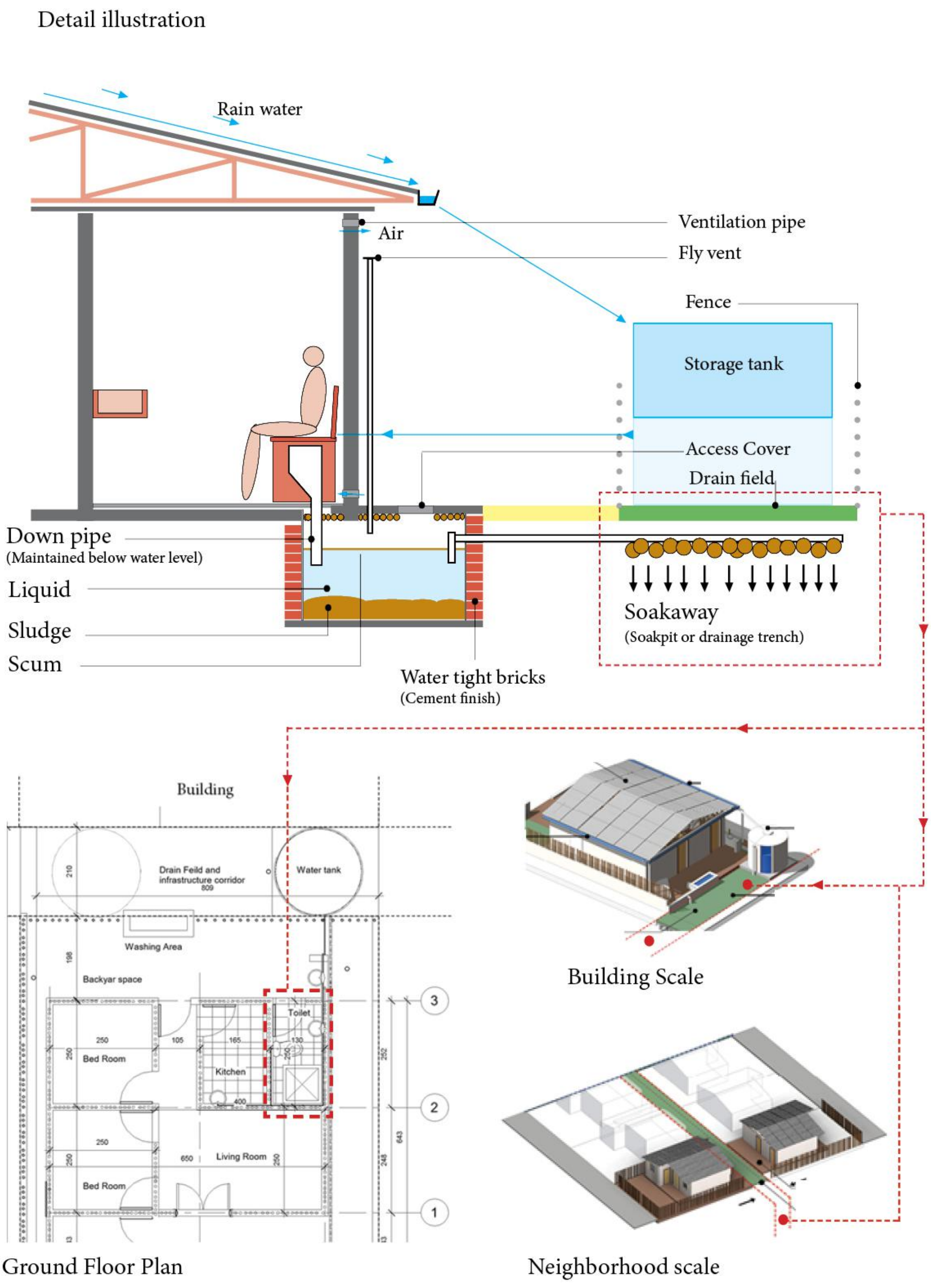


Figure 4- 26: Integrated toilet system

B. Option 2

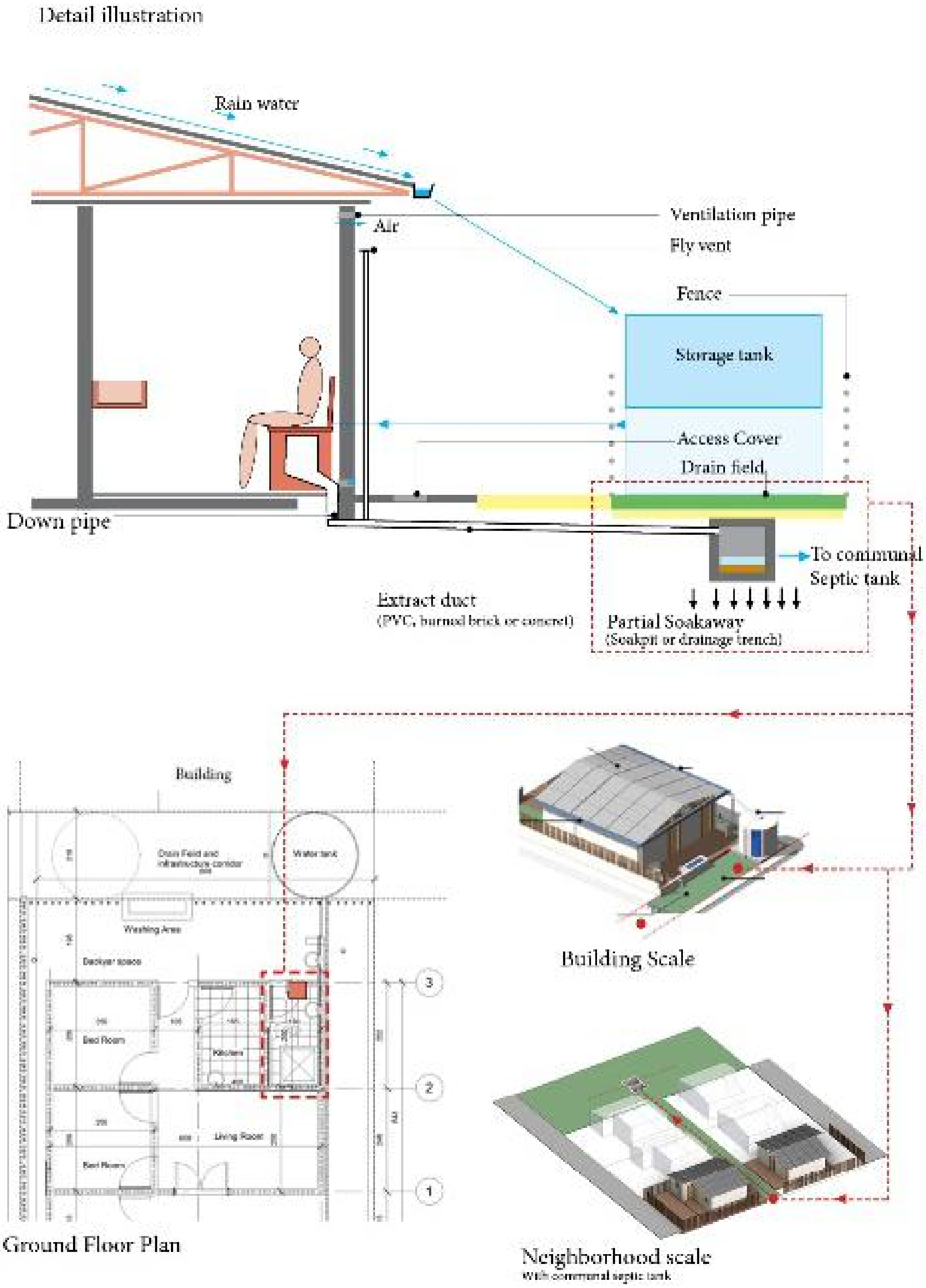


Figure 4- 27: Toilet Option 2

4.4.2.8. Infrastructure Corridor

(1) Sewage waste from toilets is diverted into a communal duct that runs across the infrastructure corridor. The duct intakes sewage from individual building units and connects into a communal septic tank. The duct is constructed from small pieces of stone that are locally available and mortared and joined with cement.

(2) A perforated masonry ditch is used to guide surface drain and gray water through the infrastructure corridor. The perforated duct acts as a draining felid.

(3) Water tank is connected to the wet area to direct water into the building. The toilet and kitchen are directly provided with water from the water tanker.

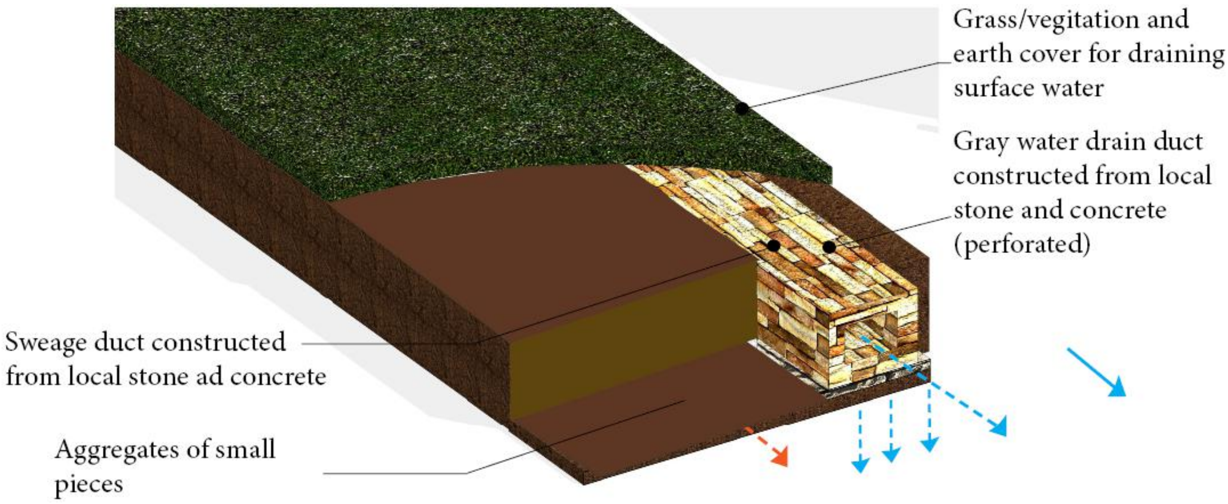


Figure 4- 28: Sewage and drainage line details

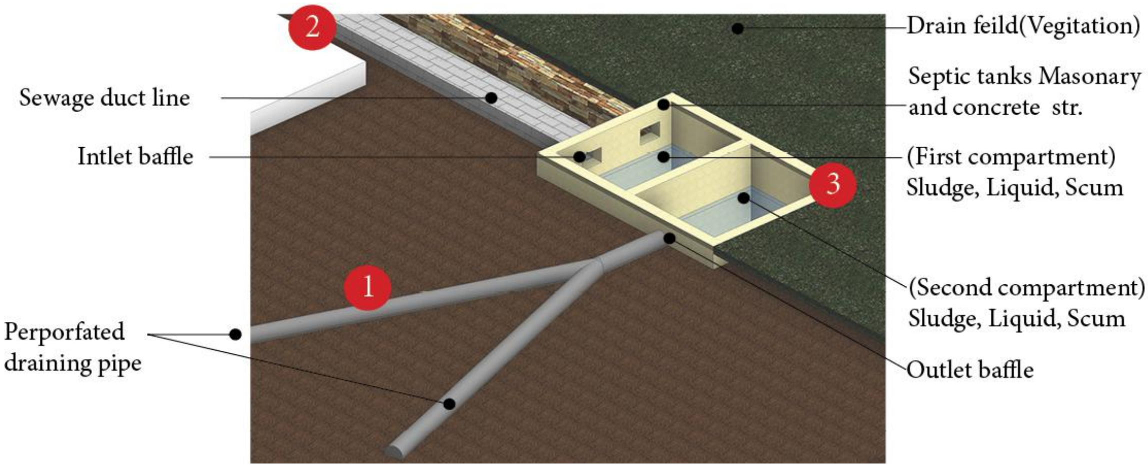


Figure 4- 29: Septic tank details

Building Site Plan and Perspective

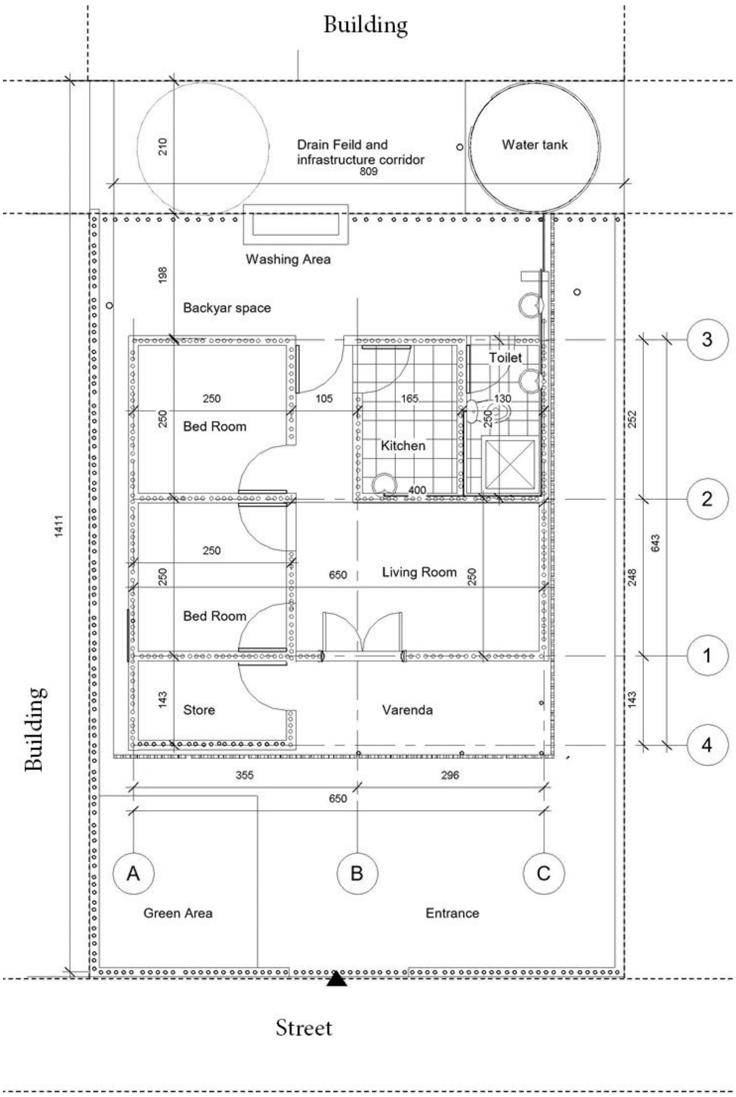


Figure 4- 30: Ground Floor Plan

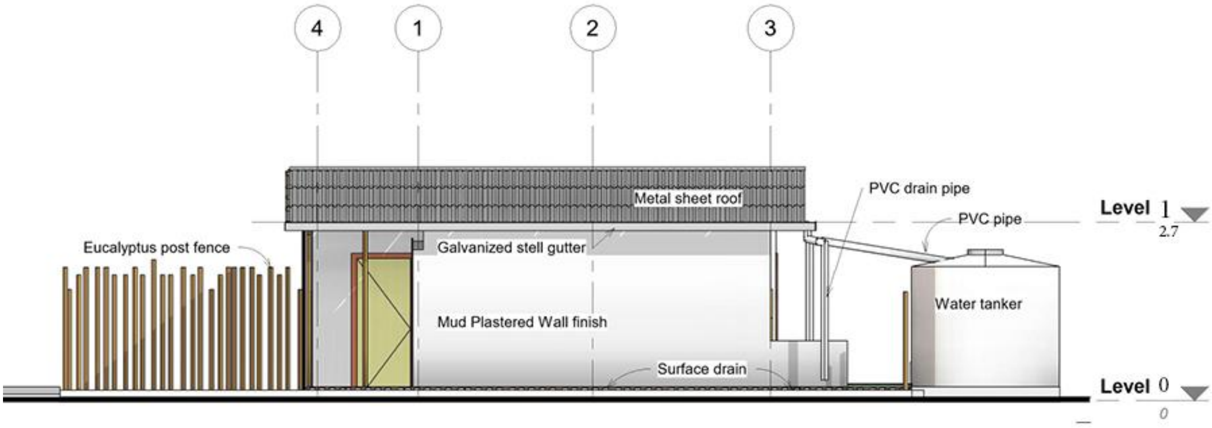


Figure 4- 31: Elevation

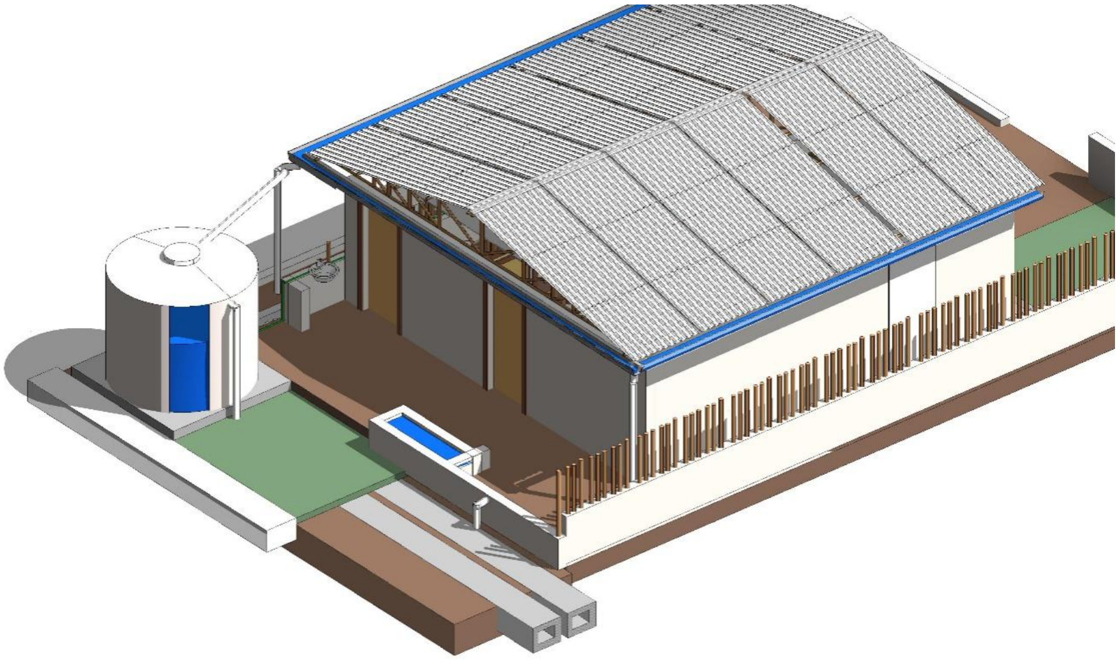


Figure 4- 32: Rear side perspective

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8. Appendix

8.1. Appendix I: Questionnaires

8.1.1. English Version

Addis Ababa University

Ethiopian Institute of Architecture, Building construction and City development School of graduatestudies

Research site: Region - **Oromia** Zone- **Ejere** Woreda- **Dannisa**

Village- **Dannisa**

Questionnaire survey for conduction of MSc. Thesisresearch

Target Groups: This questionnaire will be provided to residents who have lived inside "Dannisa" town for at least five years and above. The residents should are selected from Households.
-The residents should be aware of the change on the households and surrounding environment throughout a minimum of five and maximum of ten years.
-The housing units should built with local building materials that are available at a regional level.

Investigator Introduction: Hello, my name is BilisafTeferri , and I am a Masters student at the Ethiopian institute of Architecture, Building Construction, and City Development(EiABC) , I and other data collector named _________________ are collecting some information for my research on the town of "Dannisa" regarding the integration of water infrastructure and buildings in the town. May I speak to the head or an adult member of your household? (Modify the introduction to sound as friendly as possible, in this case use Afaan Oromo.)

Instruction to Investigation: please use pencils and circle the code where applicable and write the answers in legible handwriting in the spaces provided for responses.
Part I. Demographic Questions

1 What is your name?

2 Gender of respondent 1- Male 2- Female
3 What is your age? _______ years
4 Location/ Address:

5

a. Number of adult males in the household ______________ ________ .

b. Number of adult females in the household _____________________.

c. Number of male children _____________________.

d. Number of female children _____________________.

6. How many members in the household are employed?

7. What is the monthly household income?
1- <500 birr.
2- 500-1000 birr
3- 1001-2000 birr
4- 2001-3000 birr
5- 3001-4000 birr
6- If above please state _____________________ birr.
7.When was the building built? _______________.

Part II.
Drinking Water

8. Which of the following sources of drinking water are available in your neighborhood? **(Multiple responses are possible)**
1- Bore well/ hand pump
2- Public tap
3- Community well
4- River water
5- Spring water
6- Other,
____.

9. Which of the following sources of drinking water does your household use? **(Multiple responses are possible)**
1- Bore well/ hand pump
2- Public tap
3- Open well
4- River water
5- Spring water
6- Other
____.

10. What is your main source of water? **Single response**
1- Bore well/ hand pump (skip to q. 12)
2- Public tap (skip to q.18)
3- Open well (skip to q.28)
4- River water
5- Spring water
6- Other, ____ (skip to

Q36)

Bore well/ Hand Pump

11. How far (in meters) is the bore well/ hand pump that you use?

12. How long (in minutes) does it take to fetch water and return home? ______

13. Who fetches water most often?

1- Adult male
2- Adult female
3- Male child
4- Female child

14. Has the bore well / hand pump broken down in the past one year?
1- Yes
2- No (skip to q. 36)

15. How frequently has the bore well/ hand pump broken down during the past years?
1. Once a week
2. Once a fortnight
3. Once a quarter
4. Once in six months
5. Once a year

16. Is the bore well/ hand pump fixed promptly when it breaks down? 1- Yes 2- No

Public Tap

17. How far (in meters) is the public tap that you use?

18. How long (in minutes) does it take to fetch water and return home?
-
19. Who fetches water most often?
1- Adult male
2- Adult female
3- Male child
4- Female child
-If others, please list____

20. What is the frequency of water supply?
1- More than once a day
2- Once a day
3- Once in two days
4- Once in three days

5- Once a week
6- If other, please specify____

24. On the days that you get water, how many hours do you usually get water for?
____

25 Has the public tap broken down in the past one year?
1- Yes 2- No (skip to q. 36)

26. How frequently has it broken down? 1- Once a week 2- Once a fortnight 3- Once a quarter 4- Once in six months 5- Once a year
27. Is the public tap fixed promptly when it breaks down? 1- Yes 2- No

Open wheel

28. How far (in meters) is the open well from which you get water?

29. How long (in minutes) does it take to fetch water and return home?

30. Who fetches water most often?
1- Adult male
2- Adult female
3- Male child
4- Female child

31. What is the frequency of cleaning the well?
1. Once in a quarter
2. Once in six months
3. Once a year
4. Not cleaned in the last year
5. If not, please specify the date____.

Final Part: Similar for all types of water sources
Household Water Use Behavior and Perception Data

F1. Does your household use water for?
Drinking, Cooking, Bathing, Toilet washing, Laundering, Flower watering Donkey cart washing, Others

F2. What is the percentage of each use? (Estimation)
1. Drinking
2. Cooking
3. Bathing
4. Toilet washing
5. Laundering
6. Flower watering
7. Car washing
8. Others____.

F3. What do you use for storing water during the water shortage season?
Jar Tank Bucket Basin Kettle
Others__________________________

F4. Is there any other source of supply except for the stored water?
-
-
-
F5. How long did the latest water shortage last?
Several Weeks______ Several Moths_______ Several years_______
Do not know specific time_______________________________________.
F6. Are there any water-saving measures practiced in the household?
Yes_______ No_________ Do not know______
If has, please explain:
____
____
____
F7. How would you rate the existing water supply methods?
Excellent________ Very good________ Good________ Bad________
Why?
____
_____

F8. Do you know how much do you pay for each Litter of water?
Yes_____________ No____________ If yes, How much?____________________

F9. What do you think about the cost of water ?
Too high_______ Normal_______ Too low___________
Others____________________

F10. Which of the following aspects of your water supply method need improvement in the future?
-Quality
-Pressure
-Rate
-Others
F11. Which one of the above aspects do you think should be improved right away?
-
-
-
F12. If the water company/Governmental/ Non-Governmental, further provides new services, for example by providing better quality water that you could drink directly from the site/ Neighborhood with new water infrastructure, would you be willing to pay more for your new water infrastructure?

Yes___________ No__________
Others____
______
F13. What is the maximum price you are willing to pay for each cubic meter of water?

What is your price range, from ______birr to _____birr.

F15. Have you ever noticed any methods/systems on water conservation before?
Yes_____________ No____________.
If yes, please mention some____
____
____________________.

F16. If you are willing to take part in the new infrastructure provision, what is the maximum expense would you be willing to assume/contribute?
-__________________________________ birr.

F17. Are you willing if the new infrastructure system can be integrated with the existing building system?

F18. Will you allow modifications and demolition to your building and compound for the new infrastructure system?
Yes___________No____________
Why_____
_________.

F19. To what extent will you allow modifications?
____
_________.

F20. Will you share the cost for the modification?
____
_________.

F21. -Are you will to share the new water infrastructure with your neighbors housing units?
-Clean water source/Drinking/cooking Yes_____________ No___________
-Water for domestic use/Washing cloth/Shower Yes_____________ No___________
-Water for sanitary purposes/Toilets Yes_____________ No___________
-Are you willing to share Toilets Yes_____________ No___________

Physical Status Survey

32. Which Space do you use for cooking? Is it an interior or exterior space?

1. How did it affect the condition of the house?
-
-
-
-
2. How did it affect condition of the external environment?
-
-
-
-

33. Which space do you use for sanitary purposes? Is it an interior or exterior space?
-

-

1. How did it affect the condition of the house?

-
-
-

2. How did it affect condition of the external environment?

-
-
-

34. Which space do you use for washing and cleaning purposes? Is it an interior or exterior space?

-
-
-

1. How did it affect the condition of the house?

-
-
-

2. How did it affect condition of the external environment?

-

3.5 Building construction style and material description

-
-

8.1.2. Afaan Oromo Version

Addis Ababa University

Ethiopian Institute of Architecture, Building construction and City development School of graduatestudies

Research site: Region - **Oromia** Zone- **Ejere** Woreda- **Dannisa**

Village- **Dannisa**

1. **Unkagaaffifdeebiiqo'annaadigirilammaffaafqopha'ee**

Gare Xiyyeeffannoo:
UnkigaaffifdeebiikunijiraattootamagaalaaDaannisakeessajiraatanifraabsama. JiraattonnigaaffifdeebiikanaaffilatamanmagaalaDaannisaakessa mana jireenyaaqabaachuqabu. Jiraattonojijirama nano issaniff, gamo mana jirengaessani era ta'uqubaqabachuuqabu.
-Gamoonyokinmannijireenyaaisaankeessajiraatankanijarameemeeshaleeijarsaabiyyakeessatti argamurrata'uqaba.

Seensa: Nagaanisinifhaata'u, ani Bilisaaf Tafari jedhama, barataadigiriilammaffa (Masters degree) ti. Kan ani baradhuyunivarsitiFinfinnedha. Aniifqoratoti ana walinjiranmaqaanisaanikan __________________________ ta'eodeeffannoogaragaraaqorannaafsasabna.
-Qorannonkunhaalabu'uraaleemisoomaabishaanii aka bishaandhugaatiifikan kana fakkaatangamoo mana jireenyaakeessanwalinhalaittiisinitifayadamudandeessanirrattixiyyeffata.
-NamniqorannokanaafdhihaatuHadhawarraayokinAbbaawarraayokinnamaunumrinwaggaa 18 olta'efigamoo mana jireenyamagaalaDannisakeessajiraatuta'uuqaba.
Tarsiimoqoranno:
Deebiikeessanisasirriiyokindeebikeessanqalamaanmarsaayokinjalasararaa.
Deebiikeessanidoosararaduwaqabuirrattibareessa
Part I:

1. Maqaankeessanenyu?______________________
2. Saala/korinyaa ______________________
3. Umurikeessanmeeqa______________________
4. Iddoo/Teesso ______________________________
5. A. Lakkobsiga'eessaDhira mana kessajiranmeeqa?_______________
   B. Lakkobsiga'eettidubaraa mana kessajiranmeeqa?_____________________
   C. LakkobsiIjolleedhiraa mana keessajiranmeeqa?_______________________
   D. Lakkobsiijolleedubaraa mana keessajiranmeeqa?_____________________

6. Lakkobsamiseensa mana tokkokeessajiraatankeessaakanhojittiboba'ee (employed) namameeqa?

____

7. Galliinmaatiikanaameeqa(Ji'atookoti(1))?

7- <500 birr.
8- 500-1000 birr
9- 1001-2000 birr
10- 2001-3000 birr
11- 3001-4000 birr
12- Yooknanarradarbata’emeeqata’a? ________________________________
13- Gamonmannijireengaakeessan bara kamijaarame? ______________________

Kutaa II

Bishan dhugaatii
8. Maddi bishandhugatiiQe’ekeessaniiisa kami?
(Deebitokkocaalaakeennunidandeessu)

1. Paampiharkaa (Bore well/ hand pump) _______
2. Bishaanboonoo (public tap) _______
3. Bishaanwalokanhawaasaa (Community well) _________
4. Bishaanlagaawaraabamu _______
5. Bishaanburqaadhawarabamu _______
6. Maddi bishaanikanbiranyoojiraate____

9. Madi bishaandhugaatiigamo mana jireengaakessan kami?
(Debbi tokocaalaakeennunidandeessu)

1. Paampiharkaa (Bore well/ hand pump) _______
2. Bishaanboonoo (public tap) _______
3. Bishaanwalokanhawaasaa (Community well) _________
4. Bishaanlagaawaraabamu _______
5. Bishaanburqaadhawarabamu _______
6. Maddi bishaanikanbiranyoojiraate____

10. Maddiiijonbishaankeessanisa kami (tokkoduwwaafiladhaa)

1. Pumpiharka (Bore well/ hand pump) _______ (garagaffilakkobsa 12ti darbaa)
2. Bishaanboonoo (public tap) _________ (garagaffilakkobsa 18ti darbaa)
3. Bishaanwalokanhawaasaa (Community well) _______ (garagaffilakkobsa 36 tidarbaa)
4. Bishaanlagaawaraabamu ____________
5. Maddi bishaanikanbiranyoojiraate ____________
6. Madi bishankanbiranyoojiratee ____

<u>Paampiharkaa (Bore well/ hand pump)</u>

11. Bishaanpaampiharkaaisinfayyadmtanisinirra hammam fagaata?
Meetiraanhamaamfagaata?______________________
12. Bishaanwaraabuyodeemtanifyero mana jireenyakeessanittideebitanwalindaqiqaameqaisinittifudhata? _______________
13. Yeroirraaneessaenyutubishaanwaraaba?
1. Ga’eessa______
2. Ga’eetti ______

3. Mucaadhiraa ______
4. Mucaadubaraa ______

14. Pampiinharkaawaggaadarbeekeessacabeebeekaa?
1. Eeyyen
2. Lakki(Garagaffilakobsa 36ti darbaa)

15. Yeroohammamikeessapampiinharkaakessancaba?
1. Torbanittisi'atokko_______________
2. Ji'a 1tti si'atokko_______________
3. Jia 4ti si'atokko ______________
4. Jia 6 kessattisi'atokko_____________
5. Waggaattisi'atokoo_____________
16. Maddi bishaanikun(Pampiharkaa) (Bore well/ hand pump) yoohojidhaa ala ta'eyeroodhannisuphamaa?
1. Eeyyeen ________
2. Lakki ________

Bishaanboonoo (public tap)
17. Bishaanpaampiharkaaisinfayyadmtanisinirra hammam fagaata? Meetiranhamaamfagaata?

____
18. Bishaanwaraabuyoodeemtanifyerogamo mana jireenyattideebitanwalindaqiqaameqaisinittifudhata?
19. Yeroirraaneessaenyutubishaanwaraaba?
1. Ga'eessa______
2. Ga'eetti ______
3. Mucaadhiraa ______
4. Mucaadubaraa ______
20. Pampiinharkaawaggaadarbeekessacabeebeekaa?
1. Eeyyen
2. Lakki(Garagaffilakobsa 36ti darbaa)

21. Yeroohammamikeessapampiinharkaakessancaba?
1. Torbanittisi'atokko
2. Ji'a 1tti si'atokko
3. Jia 4ti si'atokko
4. Jia 6 kessattisi'atokko
5. Waggaattisi'atokoo

24. Yeroyokinguyameeqaafbishaanargattu?_________________
25. Bishan boonoo (public tap) waggaadarbeekeessacabeebeekaa?
1. Eeyen
2. Lakki(GaraGaffilakobsa 36ti darbbaa)
26. Yerroohammamikessabishaanboonoo (public tap) cabayokinhoji ala ta'a?
1. Torbanittisi'atokko
2. Ji'a 1tti si'atokko
3. Jia 4ti si'atokko
4. Jia 6 kessattisi'atokko

5. Waggaattisi'atokoo

27. Maddi bishaanikunbishaanboonoo (public tap) yoohojidhaa ala ta'eyeroodhannisuphama?

1. Eeyyee ________
2. Lakki ________

Bishan walokanhawasumma (Community well)

28. Bishaanwaloisinfayyadmtankunisiniraa hammam fagaata? Metiraan hammam fagaata?

____

29. Bishaanwaraabuyodeemtanifyerogamoo mana jireenyattideebitanwalindaqiiqaameeqaisinittifudhata? __________________

30. Yerooirraansaenyutubishaanwaraaba?

1. Ga'eessa______
2. Ga'eetti ______
3. Mucaadhiraa ______
4. Mucaadubaraa ______

31.Bishan walonkunwaggaadarbeekeessacabeebeekaa?

1. Eeyyee ________
2. Lakki _______(GaraGaffilakobsa 36ti darbaa)

32. Yeroohammamiikeessabishaanwalonkuncaba?

1. Torbanittisi'atokko
2. Ji'a 1tti si'atokko
3. Jia 4ti si'atokko
4. Jia 6 kessattisi'atokko
5. Waggaattisi'atokoo

<u>KutaaXumuraa: Bu'uralemisoomabishaanihundafkanta'u Haalailaalchaafifayyadamummabu'uralemisomaabishaanigaragaraahawaasakessajiran qorata</u>

F1. Gamoo mana jireenyakessankessattibishaanwantaakamifffayadamtu?
Dhugatidhaf, Bilcheessuf, dhiqanaadhaf, Mana finchaniitif, Wayya(hucu) micuf, Abaaboobaasuf, Meesha garagaraaittinmicuf, kan kana fakkaatan

F2. Dhibbentameeqatutajaajilaarmangadifoola? (tilmaamaa)

1. Dhugatidhaf______
2. Bilcheessuf ______
3. Dhiqanaadhaf ______
4. Mana finchanitif ______
5. Wayyamichuuf ______
6. Abaaboobaasuf ______
7. Meesha garagaraaittinmicuf ______
8. Kanbiroo ______

F3. Hanqinabishaaniyerojiraatubishan mal kessatikuustu?
Jarikani, Tankerii, Baaldii, Lafaaqotamekessatti, qabebishani, kanbiro

____

F4. Bishaankuusamemaleemaddaabishaaniikanbiraqabduu?

-____________________________________

-______________________________________

-______________________________________

F5. Bishaanyeroobaduyerohamamta'uf bade dhufa?

Guyyootaaf_____________Torbanootaaf ________, Ji'otaaf_________, Wagotaaf________ Yerosahinyadadhu_____

F6. Bishaanqusachufhaalaittinisinfayyadmtanjiraa?

1. Eeyee_________
2. Lakkii_________

Jirrayota'eibsaa

-____

-____

F7. Bu'urabishaaniiammaittifayyadamaajirtanakkamittiilaaltu?

1. Bayyeegariidha _______
2. Gariidha ________
3. Ga'adha_______
4. Haalahamaakeessajira_________

Maalif?- ____

F8. Bishaanargachudhafgatiikaffaltimeeqaakkabaastanbeektuu(wagatokoti)?

1. Eeyee_________
2. Lakkii_________

Yobeektanmeeqaata'a?______

F9. Wa'ekaffaltibishaani mal yadduu?

1. Bayemi'aadha ______
2. Gaariidha ______
3. Xiqqaadha ______
4. Kanbira ______

F10. Gama bishaanitingarafuldurattiakkafoya'ukanbarabaddanmaali?

1.
2. Humnabishaaniiittidhangala'u
3. Gatiikaffaltti
4. Kanbira

F11. Wantotafoyya'uqabankeessaahatattamanakkasirra'ukanbarbadanisa kami?

-____

-____

-____

F12. Warshaanbishaani, Kan mootummaayokinkanmitimootummaa, tajaajilabishaaniyooisiniifmijeessaninihayamtuu? Yoobishaanqulqulinniisaeegameegaragamoo mana jirernyakessaan, yookingandakessan, yookinimomagaalakeessaniittifiduisinifhojjechubarbaadeenihayyamtuu?

1. Eeyee_________
2. Lakkii_________

Kanbira____

F13. Gatiikaffalttiibishaaniihumnikeessanhayyamuhammameeqaatti?

Qarshii__________ hama __________ giddutti.

F15. Siistemiiyokintoftaaleeittinbishaanqusatanargitaniibeektuu?

1. Eeyee_________
2. Lakkii_________
3. Yooeyeeta’eekanakkamii________________________________

____

F16. Bu’uraleemisoomaahojjechuuirra +ttiqodaaakaamifudhachubarbaduu? Fudhachuffyofee’fhiqabataanhammameqatiigumachuubarabaduu?

_________________________Birr.

F17. Sistamnibu’uraaleebishaanifmisoomaakkahojjeetamuf mana yokinmoraankeessanakkafoyyeessamuyokinakkadiigamunihayamtuu?

1. Eeyee_______
2. Lakkii_______

F18. Siistaminbu’uraaleebishaanifmisoomaaakkahojjetamufmanaafimooraakeessankessattiij arsiyoogodhamenihayamtuu?

1. Eeyee_______
2. Lakkii_______

F19. Gamoo mana jireenyakeessanyoofoyyeessitan (modification) amameyyamtu?

-
-
-

F20. Gatii/Baasiigamoo mana jireenyakeessanfoyyessufba’uwalinqodachuuf/hirmachuhindandessu(Fedhiqabdu)?

1. Eeyee_______
2. Lakkii_______

F21. Bu’urabishaanihaarayerooijaaramu olla keessanwalinittifayyadamuunifetu/nihayamtu?

1. -Bishaanquluqullukandhugaatii- Eeyee_______Lakkii_________
2. -Bishan dhiqannafmeeshagaragaraaittiinmicanEeyee_______Lakkii______

-Bishaanqulqullinaafkanoolu(Shower)?, Eeyee_______Lakkii_______

-Mana qulqullinaaollaakeessanwaliinfayyadamufnihayamtu? Eeyee_______Lakkii_______

<u>Qoranoohaalagamoo mana jireenyaa (Physical status Survey)</u>

32. Baka kamittiibilcheessitu? Mana kessattimoalattibilcheessitu?

1. Hallikun mana keessanirratimidhaamaaliqaba?

-
-

2. Dhibbaainniqeeyekeessanirrattigeesiseeqabumaali?

-
-
-
-

33. Mana qulqullinaabakkakamittifayadamtu? Mana kessamo, Qe’eekessamo, Qe’eedhaa ala?

-
-

1. Dhibbaainnigamoo mana jireenyaakeessanirrattigeessisemaali?

-
-

-
2. Dhibbaainniqe’eekeessanirrattigeessiseqabumaali?
-
-
-
34.Micuuf qulqulleessufiddo/bakkakamfayyadamtu?
Mana keessamomanaa ala?
-
-
1. Haalamanichaairattidhiibbaakkamiiqaba?
-
-
2. Haalaqe’eeirrattidhiibbaakkamiiqaba?
-

8.2. Appendix

To:
DANNISA, EJERE

EiABC

Ethiopian Institute of Architecture, Building Construction and City Development
Addis Ababa University

Building Ethiopia Since 1954

Subject :
Requesting Co-operation

Addis Ababa, Jan 30/2020
Ref No: EiABC/GPD/842/2020

BILISAF TEFERRI ID.No. GSR/9310/11 is a postgraduate student MSc in the field of Architectural Engineering in EiABC, and AAU, Currently, he/she is conducting research for his/her seminar/project entitled:

Water infrastructure for emmerging new towns, the Case of Dannisa.

Due to limited research budget that the student gets from AAU, the Graduate Program Director Office kindly request and very much appreciate, your cooperation and support in providing him/her with the necessary data/information in the research area mentioned above.

Thank you.

Dr Dangachew Adugna
Director for Graduate Programs

EiABC
Ethiopian Institute of Architecture, Building Construction and City Development
Addis Ababa University
Graduate Program Director

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